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Proceedings

International Workshop on Greenhouse Gas Mitigation Technologies and Measures

Beijing, The People's Republic Of China

November 12-15, 1996

Co-Sponsors

MASTER

U.S. Country Studies Program

Deutsche Gesellschaft für Technische Zusammenarbeit

The People's Republic of China State Science & Technology Commission

Tsinghua University, Beijing

Netherlands Ministry of Foreign Affairs

Environment Canada

This work was supported by the U.S. Country Studies Program. These proceedings were compiled by Ernest Orlando Lawrence Berkeley National Laboratory through the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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PREFACE

More than 150 countries are now Party to the United Nations Framework Convention on Climate Change (FCCC), which seeks to stabilize atmospheric concentrations of greenhouse gases at a level that would prevent dangerous human interference with the global climate system. All FCCC Parties are required to communicate a national inventory of greenhouse gas emissions by sources and removals by sinks. Each country is eventually required to describe the steps and actions it is taking to implement the principles and goals of the FCCC. Climate change country studies are a significant step for developing countries and countries with economies in transition to meet their national reporting commitments to the FCCC. These studies also provide the basis for preparation of National Climate Change Action Plans and implementation of technologies and practices which reduce greenhouse gas emissions or enhance carbon sinks.

The U.S., in support of the FCCC, initiated the U.S. Country Studies Program (U.S. CSP) in 1992 to provide technical and financial resources to complete climate change country studies. The primary objectives of the U.S. CSP are: (1) enhance capabilities of countries and regions to inventory their greenhouse gas emissions, assess their vulnerabilities to climate change, and evaluate response strategies for mitigating emissions and adapting to the potential impacts of climate change; (2) enable countries to establish a process for developing and implementing policies and measures to mitigate and adapt to climate change, and re-examining these policies and measures periodically; and (3) share information that can be used to further regional, national, and international discussions of global climate change science and policy.

To support assessments of the Intergovernmental Panel on Climate Change (IPCC) and the information needs of FCCC Parties and other international/intergovernmental bodies, the U.S. CSP has co-organized and co-financed over 30 international workshops and conferences in cooperation with developing and transition countries as a forum to share and review information flowing from climate change country studies. Prior workshops, organized on five continents, have covered the topics of greenhouse gas emissions inventories from energy and land-use sectors, climate change impacts on natural systems, economic sectors, and human institutions, identification and implementation of options to adapt to a changing global climate, identification and evaluation of technologies and practices to mitigate greenhouse gas emissions in the land-use and energy sectors, development of national climate change action plans, and mitigation project feasibility assessments, finance, and implementation.

In cooperation with other sponsors and organizers, the U.S. CSP implemented prior regional workshops on developing and evaluating greenhouse gas mitigation methods and strategies in Africa, Asia and the Pacific, Europe, and Latin America in 1995. These workshops involved over 500 participants and authors and the technical proceedings were published in special issues of *Ambio, Environmental Management, Environmental Professional,* and *Interciencia.* Copies of the publications are available from the U.S. Country Studies Program, PO-6, 1000 Independence Avenue SW, Washington, DC, 20585 USA.

In an effort to summarize several years of climate change country study mitigation assessments and to help support the technical discussions in preparation for the Third FCCC Conference of the Parties, Kyoto, Japan, December, 1997, the U.S. CSP co-sponsored and co-organized the "International Workshop on Greenhouse Gas Mitigation

Technologies and Measures," November 12-15, 1996, in Beijing, China. The broad goals of the workshop were to: (1) present results of country study mitigation assessments, (2) identify promising "no-regrets" greenhouse gas mitigation options in land-use and energy sectors, (3) share information on development of mitigation technologies and measures which contribute to improved National Climate Change Actions Plans, and (4) begin the process of synthesizing mitigation assessments for use by FCCC subsidiary bodies. The workshop was attended by over 120 scientists, policy analysts, government, and private sector representatives from over 34 countries and intergovernmental bodies. Over 60 presentations on technical and policy topics were offered.

The workshop keynote address was offered by Madame Deng Nan, Vice-Minister, State Science and Technology Commission, People's Republic of China (PRC). Madame Deng emphasized the PRC commitment to the goals of China's Agenda 21 Program which supports sustainable development and the principles of U.N. FCCC. Other senior representatives offering remarks included Professor Gan Shijun, Director General, PRC State Science and Technology Commission, Dr. Richard Hosier, U.N. Development Program, Mr. Holger Liptow, Deutsche Gesellschaft für Technische Zusammenarbeit, and Dr. Robert Dixon, Director, U.S. Country Studies Program.

The workshop was hosted by the PRC State Science and Technology Commission and Tsinghua University, Beijing. In addition to U.S. CSP, the workshop was co-organized and co-financed by Environment Canada, the German Federal Ministry for Economic Cooperation and Development, and the Netherlands Ministry for Foreign Affairs. The U.N. Development Program also participated in the workshop.

In addition to the these Proceedings, a Workshop Summary highlights key results and conclusions of the materials presented by participants. The information presented in these documents has been subject to technical peer-review but does not necessarily reflect the official views of any national government or intergovernmental organization.

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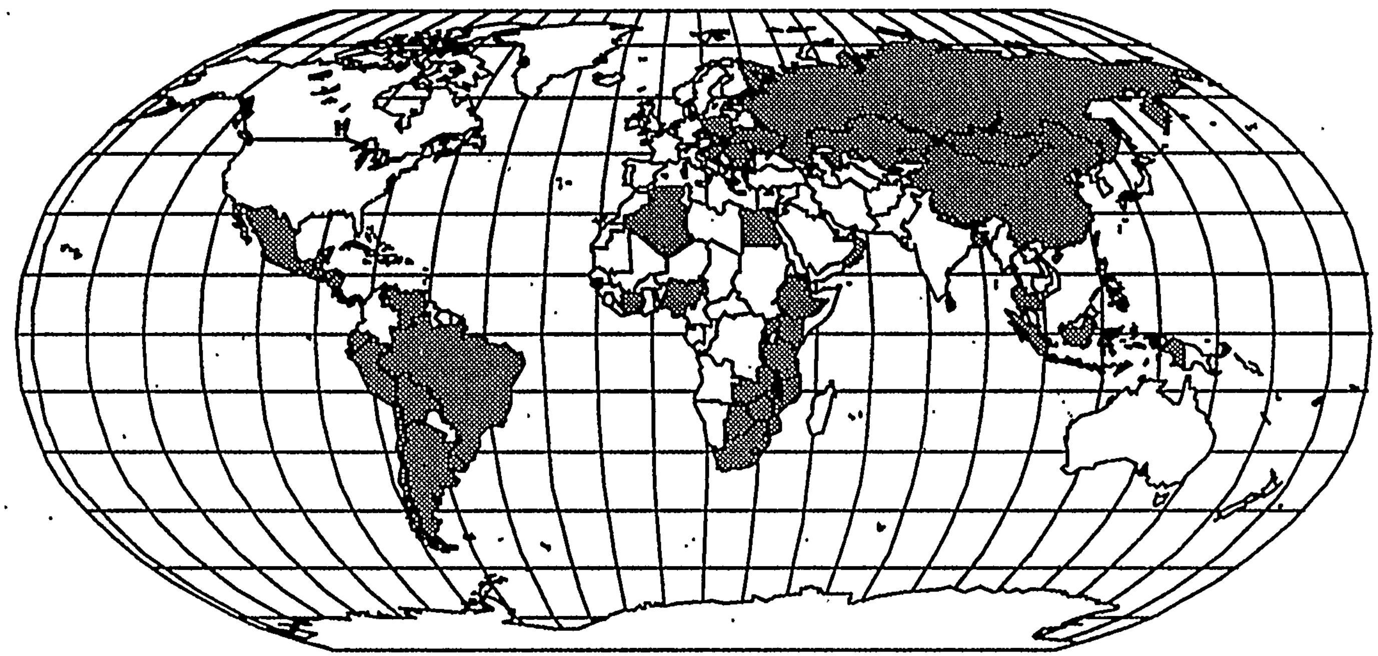
U.S. Country Studies Program:

Results from Mitigation Studies



Technical Support ←→ *Cooperative Agreements*

Supporting the Principles and Objectives of the Framework Convention on Climate Change

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U.S. Country Studies Program Objectives

- Enhance capabilities to conduct climate change assessments, prepare action plans, and implement technology projects

- Help establish a process for developing and implementing national policies and measures

- Support principles and objectives of the Framework Convention on Climate Change

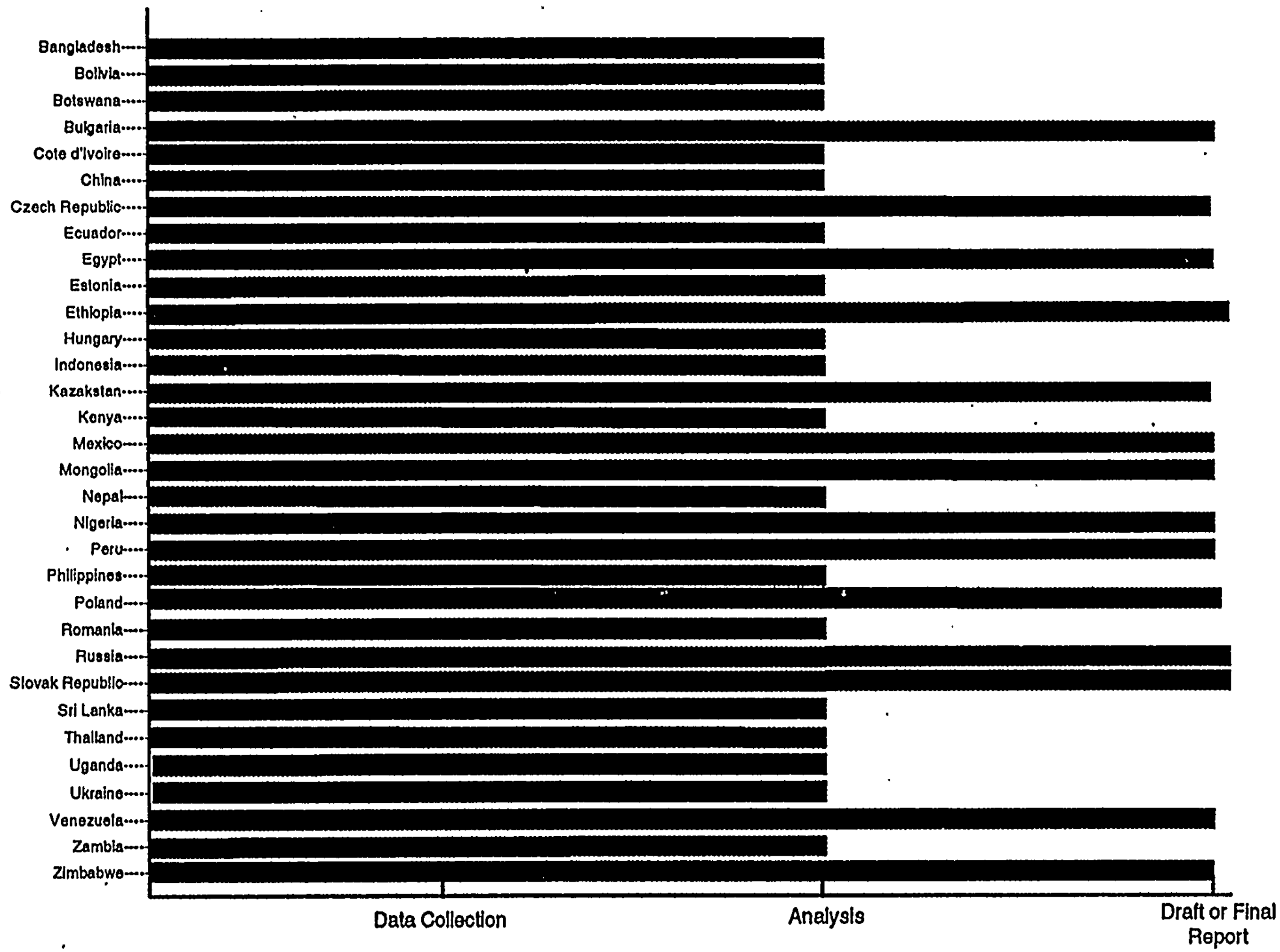
55 Countries are Completing their Studies

- More than 2000 analysts engaged in studies have received training and analytical tools on three major topics
  - Emission inventories
  - Vulnerability and adaptation assessments
  - Mitigation assessment
- Established and strengthened Interagency Climate Change Committees
- Results enhanced understanding and support for climate change issues by developing and transition countries

Study Results Widely Disseminated

- More than 20 conferences and workshops to share methods, results and country strategies
  - Co-sponsored with GEF, UNDP, UNEP, IPCC, OECD, IEA, ADB, Germany, Netherlands, Japan, Canada, Korea, and others
- 3 major synthesis reports on emission inventories, vulnerability and adaptation assessment, and mitigation assessment (in preparation)
- Over 200 publications by the 55 countries

Mitigation Sector Progress



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U.S. CSP Mitigation Assessment Publications

- Greenhouse Gas Mitigation Assessment: A Guidebook (Kluwer Academic Publishers, 1995)
- Journal special issues with papers from 1995 regional workshops
  - Eastern Europe: *Environmental Management* (February 1996)
  - Latin America: *Interciencia* (Nov/Dec 1995)
  - Africa: *The Environmental Professional* (July 1996)
  - Asia: *Ambio* (June1996)
- Mitigation Synthesis Report in preparation (May/June 1997)
  - Submission of country chapters still encouraged

Overview of Studies Completed So Far

- Nature of studies has varied among countries
  - Energy system has received greatest attention
  - Most studies have used bottom-up approach (macroeconomic impacts are uncertain)
  - Costing of options done in most but not all cases

- Mitigation opportunities differ somewhat for economies-in-transition and developing countries
  - Retirement or upgrading of old capital stock offers large potential in EITs
  - Forestry sector can play greater role in developing countries than in EIT countries

Mitigation Assessment of the Energy System

- Energy Supply sector has received greatest attention
  - Data on mitigation potential and costs more reliable than for end-use efficiency options
  - Nuclear energy has considerable mitigation potential in many EIT countries
  - Renewable energy technologies not fully analyzed due to data limitations
  - Improving efficiency of electricity supply and district heat supply is an attractive option

- End-use energy efficiency also offers much opportunity for mitigation
  - Industrial sector most important target; efficient motor systems are a promising option
  - Attractive residential/commercial options include lighting efficiency, electric appliances, space heating, and cookstoves
  - Transportation has received least attention; most challenging to analyze

Some Key Issues

- Definition of baseline greatly shapes mitigation potential and costs
  - Baseline is difficult to choose, especially for economies in transition
  - Some countries have considerable "mitigation" in the baseline scenario, others have less
- Proper balance between assessment of:
  - Long-range options -- potential for major impact
  - Near-term options -- potential for implementation in the near term
- "Joint Benefits" exist for many mitigation options, but their analysis has been limited
  - These benefits are important for implementation to occur

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Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

Results of German Support Programme to Implement the UN FCCC.

Presentation at the
International Workshop on
Greenhouse Gas Mitigation Technologies and Measures

by
Holger Liptow
GTZ, Eschborn, Germany

Beijing, PR China
November 1996

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1. Introduction

Which results of the German support programme may you be interested in?
First of all, no doubt, you may like to hear about important insights which may have come out of the programme and its individual. Particpants from Thailand, the Philippines and Tanzania will tell you more about that in the course of the workshop. You most probably would also like to hear about our general experience with the programme, how it fits into the context of German Technical Co-operation (TC) - which is the general task of GTZ -, and what future activities it may lead to; I myself will be reporting on that. Then, on the last day of the workshop, Mr. Schneider from the German Ministry of Economic Co-operation and Development (BMZ) will inform you about the climate protection programme within the framework of German bilateral Economic Co-operation, emphasing the People's Republic of China.

2. Getting Down to Work After Rio

Back home in Germany after the 1992 Rio Conference, motivated by and committed to the Framework Convention on Climate Change, we - like all other participants, I'm sure - embarked on an intensive search for the best way to breathe life into the convention. Since the non-Annex 1 countries were expecting for assistance in drawing up their national communications, BMZ commissioned GTZ to promote country studies and other enabling activities.

3. Missing Methods

In laying out the substance, we had no time-tested instruments or methods to rely on. The IPCC-Guidelines for National Greenhouse Gas Inventories had not yet been adopted;. the U.S. Country Study Programme had not yet issued any guidelines concerning the Vulnerability and Adaptation Assessment; and the UNEP Greenhouse Gas Abatement Costing Studies were still in their first phase. Not to mention the Guidelines for National Communications for Non-Annex 1 Countries, which the Conference of the Parties - CoP - still has not been able to pass.
Moreover, GTZ together with other donor organizations had just begun work on the Environmental Manual, which was not finished until early 1996. That manual is also available in the form of a computer programme for use in determining the environmental impacts of power generation and distribution, including GHG emissions.

4. The Programme's Key Component

We soon discovered that national specialists in a surprisingly large number of countries were already drawing up initial inventories of greenhouse gas (GHG) emissions, while others had already begun to study their options for reducing such emissions.

This reinforced our inclination to make such options the main thrust of our programme - as a point of departure for rapid assistance in reducing, or at least decelerating the increase of, GHG emissions. (As we all know, no obligatory reductions have yet been stipulated, though we do expect some, at least for the industrialized countries, to come out of the 1997 Kyoto Conference.)

Aiming for rapid progress does not preclude careful planning - on the contrary. I have often observed that actionism for the sake of quick results tends to "kick up a lot of dust". Afterwards, though, when the dust has settled, what we see is less a sturdy structure than a Potemkin Village.

5. Climate Protection: a Long-term Task

But we do need quick results, because the public and the politicians who represent them tend to lose patience when the taxpayers' money is squandered for climate-protection measures that yield no change for the better. This is quite understandable - we feel the same way ourselves. Unfortunately, however, it so happens that climate change has long-term causes that call for long-term remedies. Initially, at least, the only way to obviate the contradiction between a long-term challenge and a rapid change for the better in developing countries is to provide win-win options. This is what we now concentrating on.

6. Climate Protection as a Cross-sectoral Task

Climate protection must be understood and handled as a cross-sectoral task. This is to say that it needs to be integrated into the sectors energy, transportation, industry, waste management, agriculture and forestry. Climate protection is everybody's business, because each and everyone of us, each and every family and private household, does things that affect our climate to a greater or lesser degree.

Like environmental protection and the conservation of resources, practical climate protection often equates to an exercise in self-restraint: like foregoing the fast satisfaction of wants and needs in favor of long-term imperatives; above all else, it means seeking out alternative options (action-pattern variables) that do not consume irretrievable resources.

On the other hand, systematic climate protection does not equate to total inactivity. In my opinion, the only logical consequence is to at least be sparing and efficient in our consumption of irretrievable resources, though it would be better still, of course, to rely more on renewable resources. This would make it easier for the majority to adjust and adapt as necessary, while only a minority would have to radically alter their behavior.

Why? So we can leave our children and grandchildren a world that is fit to live in.

Climate protection is about as broadly based as the rest of what I've told you up to this point. If tangible results are to be achieved, our efforts must be directed either at the major dischargers or the major sinks of greenhouse gases.

7. Polluters at the Source

For the purposes of the German Support Programme to Implement the Convention, we have decided to concentrate our efforts on the polluters at the source, especially the consumers of fossil fuel, including motor vehicles. Germany's relevant technical co-operation includes a number of other programmes and projects devoted to the preservation of sinks, most notably in the form of tropical forests.

8. Project Selection

Which activities have we decided on?
What did we see as the main objective of our planning and implementing activities?
At first, our programme gave rise to certain individual measures, because we were aiming for broad dissemination of information about the assistance Germany has to offer. Thus, those initial measures consisted extensively of inventory studies and country studies on reduction options (Colombia, Pakistan, Zambia, Tanzania). Once the programme achieved a certain "awareness rating", both within the scope of German Technical Co-operation and internationally, we were better able to identify approaches with a more sectoral or regional (country-specific) thrust. In our view, this improves our chances of actually achieving the planned results (pertinent examples including activities in China, India, Indonesia, the Philippines, Thailand and Zimbabwe. *(Annex 1: world map with general overview).*

9. Co-operation within German Technical Co-operation

As a large organization engaged in development co-operation activities in more than 120 countries, we naturally make use of our existing connections to ongoing projects and familiar partners.
In addition to providing approaches for enabling activities, this also yields synergistic effects with ongoing German TC projects in the energy sector.
For example, in close co-operation with our rational-use-of-energy specialists, we derived some concrete, practical options for demand-side management from a since-completed TC project in the Philippines. Similarly, ways of enhancing energy efficiency in industrial facilities and buildings are being pursued via an ongoing TC project in Thailand. In Zimbabwe, we have integrated the "Reduction Options within the Framework of Southern African Power Pooling" measures into the local GTZ-supported energy programme. And in Bangalore, India, we are expanding our co-operation with TERI beyond the present energy conservation and efficiency enhancement scope for the local industry to include a climate protection project. In that project, we will explore the available alternatives for environmentally and climatically correct planning and implementation in the fields of transportation and waste management.

10. Project Formulation as a Technical-assistance Task

Frequently, the final, exact formulation of projects has emerged from intensive dialogue with our partners. In our opinion, such dialogue constitutes the first advisory input on the way to achieving adequate accordance with the Framework Convention on Climate Change. Regrettably, there were some requests that we were unable to support, either because they were not in line with the exigencies of the convention or because they were situated too far away from our programme's focal area.

11. International Co-ordination of Country Measures

In my own view, thanks to the initiative of the Climate Change secretariat, the measures being supported by the various donor organizations have been internationally well co-ordinated. Redundancy was effectively avoided, and the limited funds available to the individual donor organizations precluded all competition concerning the "best" projects. On the contrary, every effort was made to round out one's own approaches, one example being our co-operation with the US Country Study Programme in Thailand, Zambia and South Africa and with the AsDB's AL-GAS project in Pakistan.

We helped achieve good co-ordination by informing CC:INFO about our own activities and by actively participating in the CC:FORUM's meetings. This general exchange of views and information led to concrete agreements with various donors - most intensively with the US CSP, one result of which is this very workshop.

Subsidization of the climate secretariat's information activities has made it possible for each and every country to present their climate-protection activities in a uniform manner on the Internet's World Wide Web. (If you would like to know more about this, please contact either me or the Climate Change Secretariat in Bonn.)

12. Drawing on International Know-how

We have designed our advisory, upgrading and on-the-job training activities around both German expertise and the knowledge of specialists from other countries with intensive experience in the field of climate protection in emerging countries.

United Nations Colaborating Centre on Energy and Environment in Risø/Denmark, for example, helped local specialists in Tanzania and Zambia draft a set of reduction options; in doing so, the team showed a depth of commitment that often far exceeded the contractually binding scope.

We also helped arrange direct South-South co-operation. The team from the Ministry of Energy and Mines in Caracas, Venezuela, was a great help to the team in Bogota in preparing an inventory study for Colombia. Together with UCCEE, the Southern Centre of Energy and Environment in Harare, Zimbabwe, provided general support and their own experience to the same Zambian team we were assisting.

13. Results of Completed Studies

What have we actually achieved?
Let me give some extremely condensed sampling of results from Indonesia, the Philippines, Thailand and Tanzania. My colleagues from the Philippines, Tanzania and Thailand will be offering details in their own reports. Our pamphlet entitled "Measures to Prevent Climate Change" provides information on our programme's results to date and additional data documenting how climate protection is already being built into GTZ's energy projects. And for anyone interested in specific cases, we will be glad to provide copies of studies we have conducted in various partner countries - naturally only to the extent that the measures in question have been completed.

13.1 Indonesia:

Above and beyond the country's already environment-oriented energy planning, there are still other win-win options that could help reduce GHG emissions. In the end-use sector, these would include advanced lighting systems, energy-conserving refrigerating equipment and variable-speed motors. And in the power sector, highly sophisticated options like pressurized fluidised-bed combustion and gas-fueled fuel cells have emerged as additional options for enhancing established technologies.

13.2 The Philippines:

According to the results of the GTZ-assisted study in the Philippines, there are two options for substantially reducing CO_2 emissions in the energy sector: by improving the gross heat rate in power generation and by reducing transmission and distribution losses. The use of natural gas, hydropower and geo-thermal energy can further reduce emissions by significant degrees.
With the aid of the aforementioned Environmental Manual we also conducted a pilot project in which the environmental impacts of the entire power-generating sector were investigated and scenarios developed for engaging in least-cost forms of environmental and climate protection.

13.3 Tanzania:

In Tanzania, the options for reducing GHG emissions are limited more by market and institutional barriers than by any lack of access to appropriate technologies. Indeed, the industry has numerous technological win-win options to offer - like efficient combustion, power-factor correction and efficient motors. The power sector also has some latitude for contributions toward climate protection, one example being the intensified use of hydropower. Conversely, the large number of people who would have to be involved in measures geared to private households and agriculture would make them difficult to implement.

13.4 Thailand:

In most of the surveyed industrial operations and commercial buildings there were identifiable win-win options (that is, options with payback periods of up to 4 years) that would make climate protection attractive and reduce CO_2 emissions by seven to ten percent. Now, the decision makers have to be persuaded to make use of the available opportunities. As already mentioned, the long-term German TC project aims to follow-up and to help achieve that goal.

14. Planning-stage Approaches

We all use energy to heat and light our homes, cook our meals, power our appliances and we are expending more and more energy - trends increasing particularly in emerging countries - to get from one place to another by motorcycle, bus, airplane or private motor vehicle - the latter being characterized by more prestige but less efficiency. And while our mobility is increasing, we note that motorists in Bangkok average about 7 km an hour, whereas a bicycle would get us there twice as fast and help keep our CO_2 balance more in equilibrium. And is it really a sign of progress when private automobiles with built-in toilets have become the "latest thing" in some cities?

For our general country studies, we at GTZ have therefore begun to accentuate energy-sector reduction options in certain sectors and certain regions of large countries. In doing so, we "discovered" the major cities, where people often and increasingly suffer under the intolerable noise levels and exhaust-gas pollution of motorized traffic, ubiquitous garbage heaps, and emissions from uncounted stoves, furnaces, household and commercial chimneys and, of course, industrial smokestacks.

As local pollution worsens, so do the GHG emissions from motor-vehicle tailpipes, and the mountains of refuse continue to grow menacingly. Since the needs of local and global environmental protection once again happen to coincide, we are aiming our initial minor attempts in both directions: in the State of Karnataka, India, and the booming City of Bangalore, with the Asian Energy Institutes for Asian Cities and, outside of the programme, with a TC project entitled "CO_2 Reduction in the Transportation Sector of Surabaya, Indonesia".

Our contributions will remain modest but essential.

15. Climate Protection at GTZ

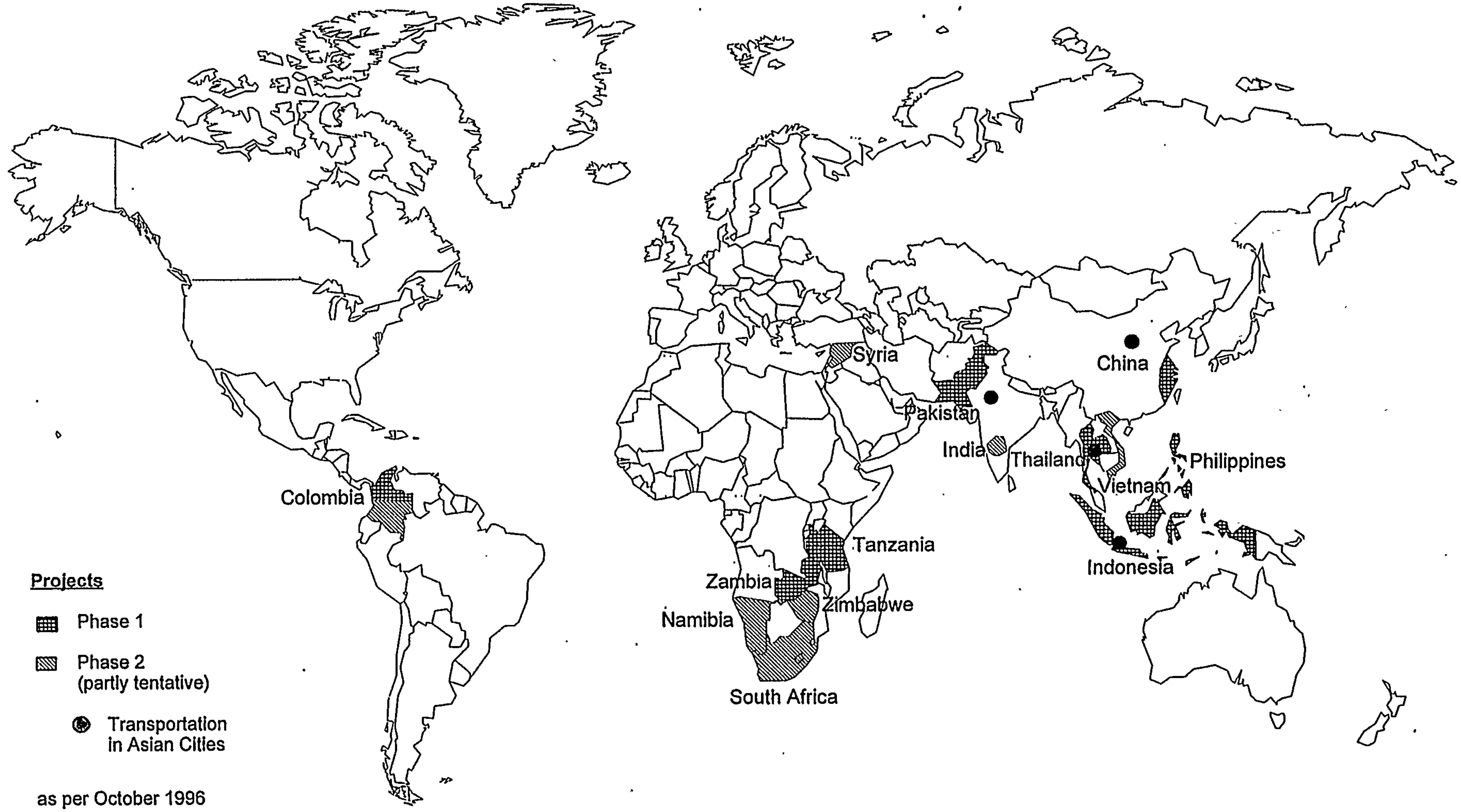
At GTZ, people are well aware of the fact that climate protection begins at home. We try to follow the well known motto: think globally and act locally. Then again, as a TC organization, we have our own way of looking at things: for us, "local" means a co-operative in Central America, a Technical College in Southern Africa or a railroad workshop in Southern Asia. And to this very day, climate protection has avoided becoming a virulent subject on our own premises. We continue to indulge in the luxury of driving our own cars to work. The company has plenty of underground parking slots - but no bus tickets for environmentally aware employees. And the government gives each of us a tax cut for every kilometer we drive to and from work. Well, the more petrol we burn, the more we help our economy grow. All this, of course, makes it rather difficult for us to convince others of the importance of climate protection. It makes it hard to persuade others to get by with less - less private motor vehicle traffic, for example.

Nevertheless, GTZ is trying to be active - if mostly in areas that do not hurt so very much - one example being its participation in a new initiative by climate-conscious European companies who have grouped together under the name of "European Business Council for a Sustainable Energy Future" (e^5) to lobby for implementation of the Framework Convention on Climate Change - as opposed to the kind of foot dragging the coal and oil lobby once again practiced at the second CoP in Geneva.

16. Perspectives

Once our ongoing activities have been brought to conclusion in the course of the next two years, we will be able to pursue new, even more tangible climate-protection activities in connection with TC projects in the energy and transportation sectors, as well as in the preservation of tropical forests and in other areas. As for me, I am anxious to hear what you are planning for your home countries. Though our future contributions will have to remain modest on the whole, I will nonetheless be happy to take home your ideas for new projects.

German Support for the Implementation of the UNFCCC



THE FRAMEWORK CONVENTION ON CLIMATE CHANGE A CONVENTION FOR SUSTAINABLE ENERGY DEVELOPMENT

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presented at:
The International Workshop on Greenhouse Gas Mitigation Technologies and Measures

Beijing, The Peoples Republic of China
13 November 1996

THE FRAMEWORK CONVENTION ON CLIMATE CHANGE: A CONVENTION FOR SUSTAINABLE ENERGY DEVELOPMENT

I. PREMISE

In 1992, over 165 countries signed the United Nations' Framework Convention on Climate Change (FCCC). These countries have implicitly agreed to alter their "anthropogenic activities" that increase the emissions of greenhouse gases (GHGs) into the atmosphere and deplete the natural sinks for these same greenhouse gases. The FCCC states that:

> "the ultimate objective of the Convention and any related legal instruments that the Conference of Parties may adopt is to achieve in accordance with the relevant provisions of the Convention stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (*United Nations Framework Convention on Climate Change, Article 2: Objective, p. 5*).

The energy sector is the major source of the primary anthropogenic GHGs, notably carbon dioxide (CO_2) and methane (CH_4). The OECD countries[1] presently account for the major share of GHG emissions from the energy sector. However, the developing countries are also rapidly increasing their contribution to global GHG emissions as a result of their growing consumption of fossil-based energy. Implementation of this global climate change convention, if seriously undertaken by the signatory countries, will necessitate changes in the energy mix and production processes in both the OECD and developing (non-OECD) countries. **In this sense, the FCCC is the first world-wide convention on energy use and management.** International cooperation and the development of new management, financial and policy instruments for the sector will be critical if all countries are to comply with the Convention.

To date, the primary public agencies in both the OECD and non-OECD countries involved with interpreting and complying with the FCCC have been the environmental ministries. Yet successful, sustainable compliance with the Convention in the future will require far greater commitments, actions and financial resources dedicated to this effort by the ministries of energy and finance. The multilateral development banks and OECD bi-lateral donor agencies can provide critical and needed support to the non-OECD countries to assist and encourage their energy and finance agencies to address the objectives of the FCCC. In making their transition to GHG-neutral development paths, the developing countries will need substantial OECD technical and financial assistance to allow them to diversify and reorganize their energy sectors. Without the commitment of the finance and energy ministries, this process will not move forward.

Additionally, the 1980s and 1990s have been characterized by an increasing reliance on market-based energy planning because markets, despite their known and well-documented imperfections, generally are assumed to work. The energy sector is undergoing global privatization. Within this context, fossil fuel prices have declined in real terms and are, in fact, lower than those of the early

[1] OECD stands for "Organisation for Economic Co-operation and Development".

1960s. However, as demonstrated in this paper, the market has not accurately reflected the social and environmental costs of fossil fuels or the benefits of non-fossil based energy resources. As long as energy prices do not reflect social and environmental costs and benefits, markets will not provide the appropriate signals for sustainable energy development.

Changing from established development patterns, based on fossil fuel dependency, will require the strong commitment of government, active participation of the private sector and a willingness of populations to adapt to new norms of behavior. Governments will need to recognize and admit to the unsustainability of their present economic, and specifically, energy development policies. In addition, governments, primarily those of OECD countries, will have to place greater emphasis on the research, development and implementation of energy technologies and resources that sustain development rather than strain it. Because the private sector, when unconstrained, will react to market signals, governments must strive to ensure that markets reflect the true societal costs and benefits of all energy options and should implement policies and economic instruments to ensure that this is the case. Finally, populations in general must support the basic and fundamental changes in expectations and lifestyles needed for sustainable development.

International actions also will be needed to put the world on a sustainable energy path. By adoption of the FCCC, representatives of the world's populations have indicated their desire to move toward such a path. The Conference of Parties (CoP) to the Convention has just concluded its second meeting, at which the Parties endorsed a U.S. proposal that legally binding and enforceable emissions targets be adopted. Such quotas, when coupled with appropriate financial incentives, an emissions credit trading system, technology transfer mechanisms and the national and regional activities already mentioned, will strengthen the FCCC and accelerate the move toward a sustainable energy future.

II. INTRODUCTION

Risks of Global Climate Change

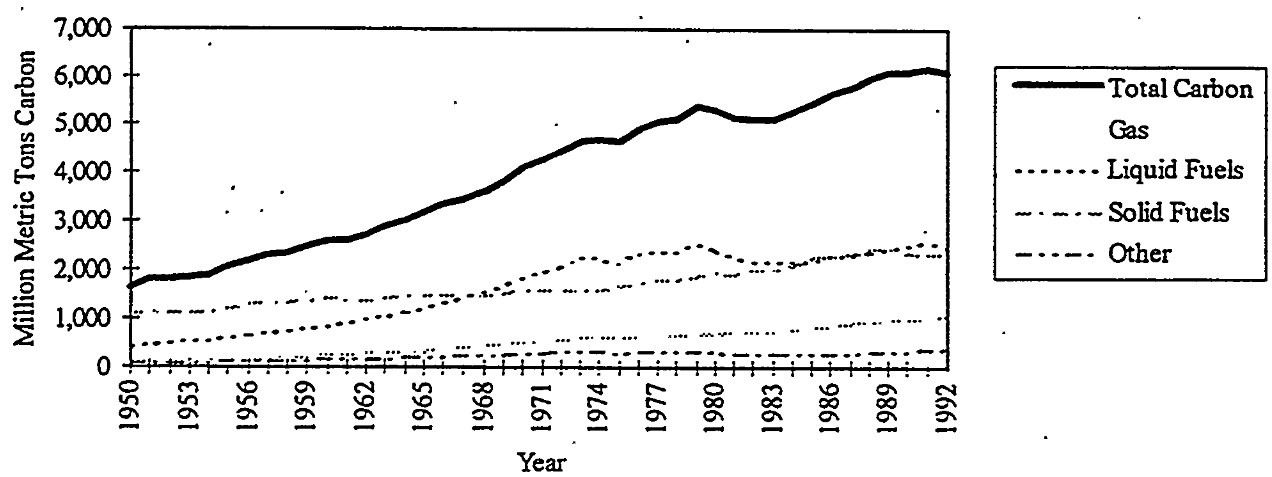
The most recent report of the Intergovernmental Panel on Climate Change (IPCC) presents convincing evidence of the possibility of significant global climate change resulting from anthropogenic (human) activities. The IPCC found that "the balance of evidence suggests a discernible human influence on climate" (IPCC, 1995a). The magnitude and rate of the projected global climate change anticipated is unprecedented within the time frame of human existence on the planet: The IPCC has indicated that an increase in the mean global temperature of 2°C over the next century is likely, resulting in a sea level rise of almost one meter, increased inundation of coastal areas, higher frequency of flooding and more intense storms (Lemonick, 1995). The importance of the IPCC's prognosis is that if present trends of human activity that contribute to climate change persist, the resulting impacts on human economic and social well-being could be extremely serious.

Anthropogenic GHGs and their Link to Global Climate Change

The IPCC has identified the emissions of greenhouse gases (GHGs) from human activities as a primary cause for global climate change. The main GHGs are water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and ozone (O_3). While water vapor has the largest GHG effect, its atmospheric concentrations are not directly affected, on a global scale, by human activities. Although most of the other GHGs also occur naturally (the exceptions are CFCs, HCFCs, HFCs and PFCs), human activities in this century have contributed significantly to increases in their atmospheric concentrations.

The anthropogenic global production of GHGs totaled approximately 32 billion metric tons (of CO_2-equivalent) in 1990 (authors' calculations, based on IPCC, 1992). Figure 1 presents a graphic illustration of the global growth of anthropogenic carbon emissions since 1950 (CDIAC, 1995), while Figure 2 illustrates the relative contributions of the different GHGs to total global warming potential. The two figures show that GHG emissions have been increasing rapidly, and that carbon dioxide, methane and nitrous oxide are the primary anthropogenic GHGs.

Figure 1. Estimates of Global CO_2 Emissions from Fossil Fuels and Cement Production, 1950-1992



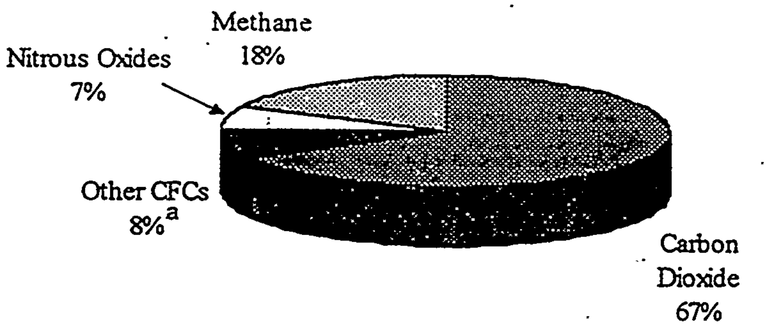
Source: Carbon Dioxide Information Analysis Center, 1995.

Sources of Anthropogenic GHGs: The Dominance of GHGs from Energy Consumption

The primary sources of these anthropogenic GHGs are the consumption of fossil fuels, land use changes (e.g., deforestation), agriculture, and cement manufacturing. Figure 3 illustrates the 1991 emissions of GHGs addressed by the FCCC (i.e., all GHGs except certain CFCs). The data in

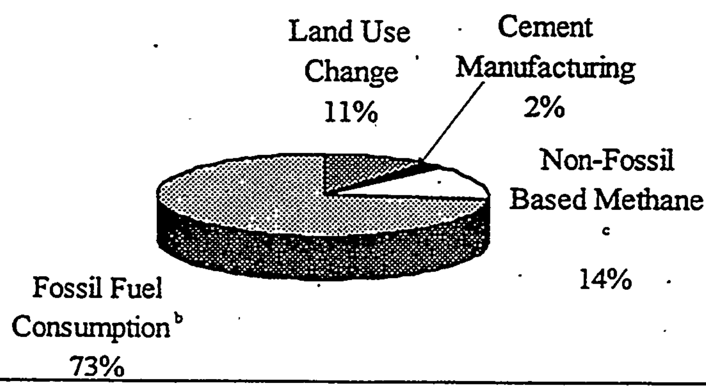
Figure 3 demonstrate that **global fossil fuel consumption dominates the production of anthropogenic GHGs,** accounting for over 73 percent of the global total.

Figure 2. Greenhouse Gas Emissions by Relative Contribution to Climate Change



Source: Global Environment Facility, 1995.
Notes: a. Includes CFCs other than CFCs 11 and 12.

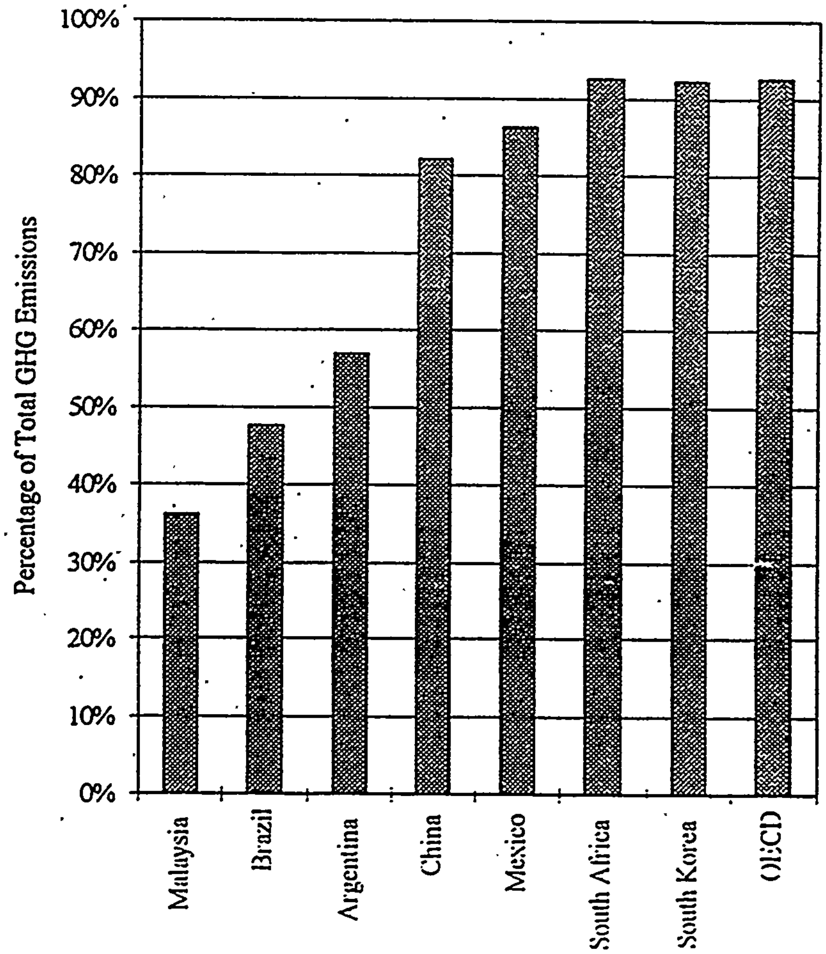
Figure 3. Sources of Greenhouse Gas Emissions Controlled by the FCCC, 1991 [a]



Source: Carbon Dioxide Information Analysis Center, 1995.
Notes:
a. Greenhouse gas emissions controlled by the FCCC do not include CFCs.
b. Fossil fuel consumption includes the global warming potential of methane from oil and gas production, and coal mining.
c. Non-fossil based methane includes solid waste, wet rice, agriculture and livestock.

The importance of fossil fuel consumption to the rapid growth of anthropogenic GHGs is even more critical when viewed from the perspective of the distribution of GHG emissions from the OECD countries. Figure 4 illustrates that over 92 percent of the OECD's anthropogenic GHGs originate from fossil fuels. If the non-OECD countries develop along a path similar to that of the OECD countries, then non-OECD GHG emissions also will be dominated by emissions that originate from energy consumption.

Figure 4. Contribution of Fossil Fuels to Total National GHG Emissions



Source: Carbon Dioxide Information Analysis Center, 1995.

The Projected Growth of GHG Emissions

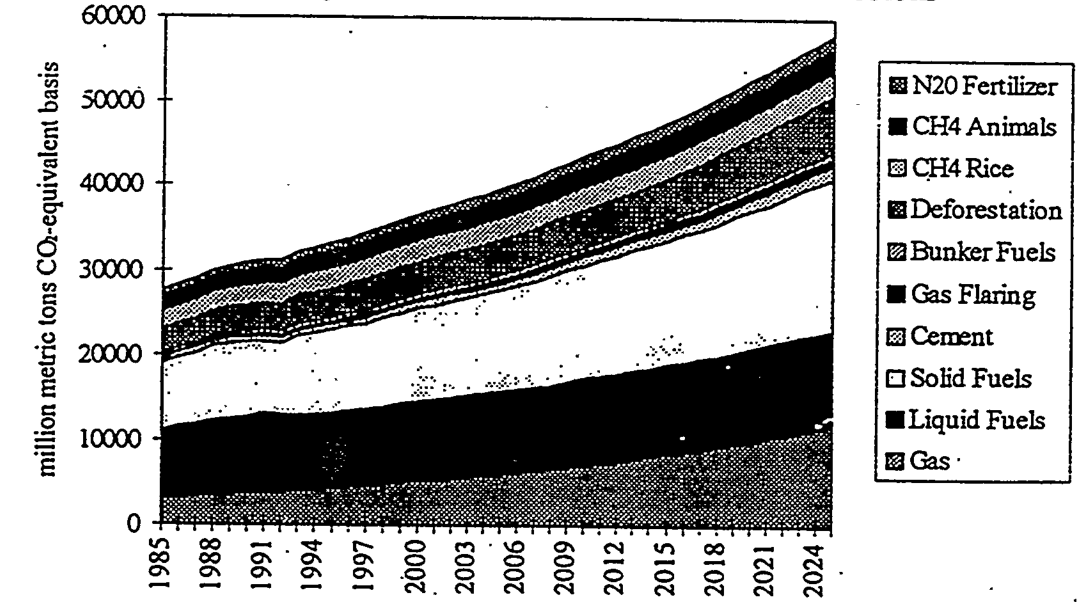
In 1991, the OECD countries (or Annex II countries, as they are referred to in the FCCC) accounted for 37 percent[2] of total global GHG emissions, and 49 percent of energy-related GHG

[2] Percentage based on only GHG emissions controlled by the FCCC. OECD countries account for 40 percent of total global emissions if CFCs are included.

emissions (authors' calculations, based on CDIAC, 1995 and WRI, 1994). Non-OECD countries accounted for 51 percent of energy-related GHG emissions. Figure 5 presents a projection of the expected growth of GHG emissions if present trends continue, showing that total global GHG emissions are expected to rise rapidly.

The most dramatic growth is expected to occur in the emerging economies of the developing countries. This is primarily due to the fact that these countries at present have relatively low energy consumption rates and per capita GDP. (Figure 6 illustrates the differences between OECD and developing country per capita energy-related GHG emissions). By the year 2025, GHG emissions (excluding CFCs) from the non-OECD countries are expected to reach twice 1990 levels, increasing to over 70 percent of total global GHG emissions (authors' calculations based on IPCC, 1992).

Figure 5. Projected Growth of Greenhouse Gas Emissions



Sources: IPCC, 1990a and IPCC, 1990b, as cited in USAID, 1990.
Note: Some minor sources of GHGs not included.

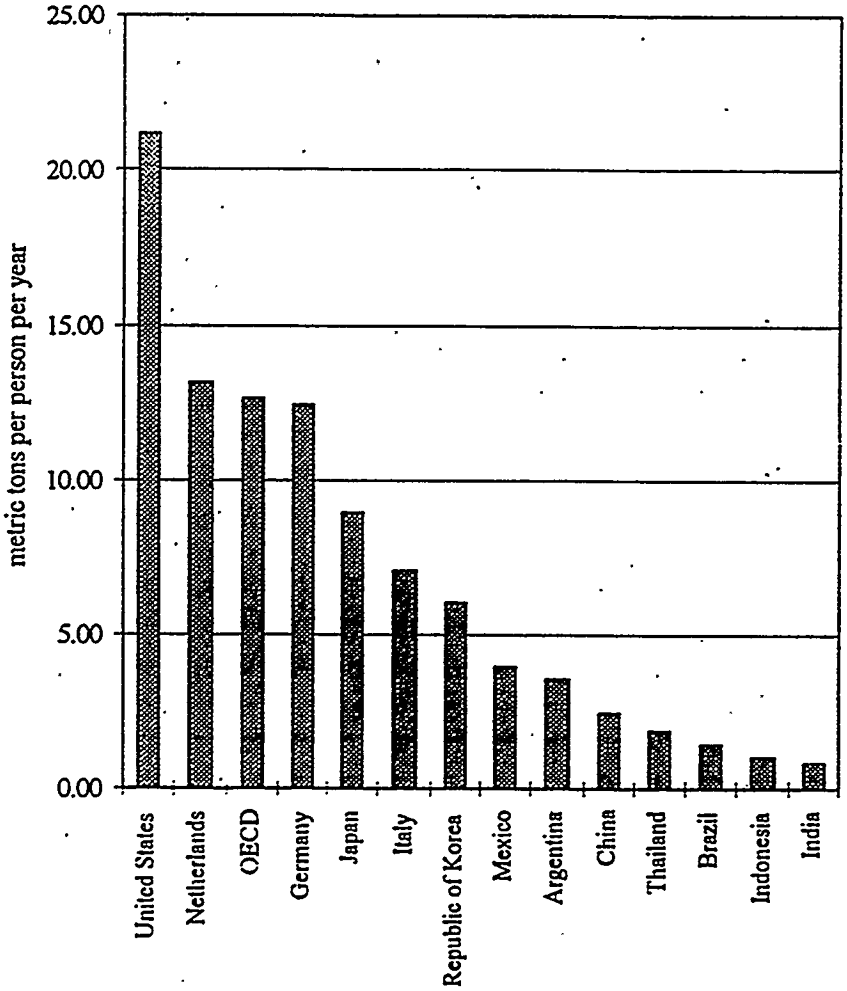
The FCCC and the Growth of GHGs

The FCCC, which has been signed by over 165 countries and ratified by over 154 countries, proposes that the Annex I[3] countries reduce their GHG emissions by the year 2000 to at least their 1990 levels and that they implement measures to stabilize their emissions at these levels pending further resolution by the FCCC Conference of Parties (CoP). The FCCC urges non-Annex I countries to try to reduce the rate of growth of their GHG emissions while recognizing their need for financial resources and transfer of technology and the fact that "economic and social development and poverty eradication are the first and overriding priorities of the developing

[3] Annex I countries as defined in the FCCC include the OECD countries, the Eastern European countries that are undergoing the process of transition to market economies and the Russian Federation.

country Parties". There are no targets established for the non-Annex I countries and no mandates to enforce any reductions. Without specific programs, such as the Global Environment Facility, there is no real economic incentive for the non-Annex I countries to reduce the rate of growth of their GHG emissions.

Figure 6. Per Capita CO_2 Emissions, 1991



Source: Per capita emissions based on fossil fuels only, adapted from World Resources Institute, 1995.

Keys to Future Growth of GHGs

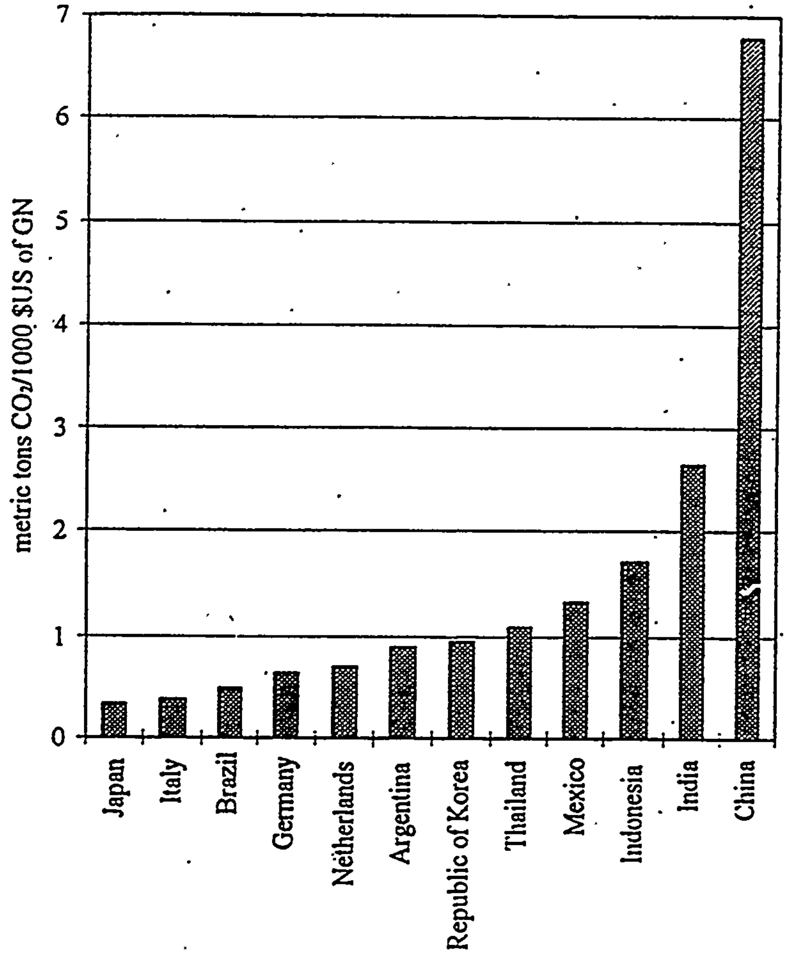
There are two key issues relating to the future growth of GHG emissions that are worth exploring. The first is that the Annex I countries will have to consistently reduce their GHG emissions per unit of GDP if they are to allow their economies to grow and to simultaneously meet their commitment to the FCCC of stabilizing their GHG emissions at 1990 levels. Assuming a modest average annual economic growth rate of two percent per annum, the Annex I countries would have to reduce their GHG emissions per unit of GDP by 70 percent of their 1990 value by the year 2050 to meet their stabilization commitment. If the average annual economic growth rate were three percent, the GHG emissions per unit of GDP in the year 2050 would have to be reduced by 83 percent of the 1990 value to meet the commitment. Given the fact that the majority of GHG emissions from the Annex I countries originate from the consumption of fossil energy, there are no alternatives other than to reduce the reliance on heavy carbon fossil energy (i.e., the intensity of coal and oil per unit of GDP) and to replace this energy with light carbon fossil fuels (i.e., natural gas and its derivatives) and non-fossil based sources such as renewable (i.e., solar, wind, biomass, hydro and geothermal) or nuclear energy. The prospects for increasing GHG sinks to offset increases in GHG sources is a challenging one that is proving to be progressively impractical. Additionally, the increasing of sinks, in many cases, is land-intensive and unattractive due to mounting pressures for productive land use and the need to commit sequestered land in perpetuity.

The second key issue relates to the fact that the non-Annex I countries, which do not have any mandatory commitments to reduce their GHG emissions, are presently in a phase of rapid growth in energy consumption and, in many cases, economic growth as well. By the year 2025 energy consumption in the developing countries is expected to double or even triple from 1985 levels (USAID, 1990), this growth being a primary reason that total global non-CFC-related GHG emissions are expected to rise by between 54 and 133 percent during the same time period (IPCC, 1990a and IPCC, 1990b, as cited in USAID, 1990). Again, the only real alternatives for significantly reducing this rate of growth of GHG emissions is to have the non-Annex I countries consume energy more efficiently and to rely more on light carbon fossil energy and non-fossil based energy sources.

Sustainable use of energy may be measured by the amount of GHG emissions per unit of GNP, with higher per capita GHGs per unit of GNP signifying a less sustainable and efficient use of energy. Figure 7 indicates the relative efficiency of energy use for various countries, showing that non-Annex I countries tend to utilize energy less efficiently. This provides an opportunity for some reductions in GHG emissions while allowing for economic growth. However, the expected growth in energy demand will also mandate the need for new sources of energy. If the growth of GHG emissions is to be reduced in the developing countries, then renewable sources of energy must be aggressively developed and utilized.

All of the data and illustrations presented above lead to one inescapable fact: **If the Framework Convention on Climate Change is an agreement among countries to either reduce, stabilize or even slow the growth of GHG emissions, then any protocols that derive from the Convention must directly address the challenge of reducing the consumption of fossil energy.** If this premise is accepted, then the obvious conclusion is that the FCCC is *de facto* a convention on energy use. Fossil fuels are finite and the world's economies must gear themselves up for alternate energy sources. Unless a transition is mandated early for both OECD and non-OECD countries, major corporations in OECD countries will simply shift the bulk of their operations to non-OECD countries, thereby offsetting any GHG reductions in OECD countries. This already may be happening in countries such as India and China with the full backing of the respective OECD governments, and private and international financial institutions.

Figure 7. Ratio of Carbon Dioxide Emissions to GNP for Various Countries



Source: World Resources Institute, 1994.

This paper identifies sustainable energy options and strategies that can support economic growth while reducing GHG emissions. Specifically, the paper explores the potential role of renewable energy and energy efficiency in moving economies to compliance with the FCCC. The paper also discusses the existing, technical, economic, policy and institutional barriers that must be overcome if the present energy consumption patterns are to be significantly changed. Finally, the paper proposes a number of strategies and actions for stabilizing or reducing GHG emissions that should be considered by the CoP.

III. ENERGY OPTIONS FOR REDUCING GHG EMISSIONS

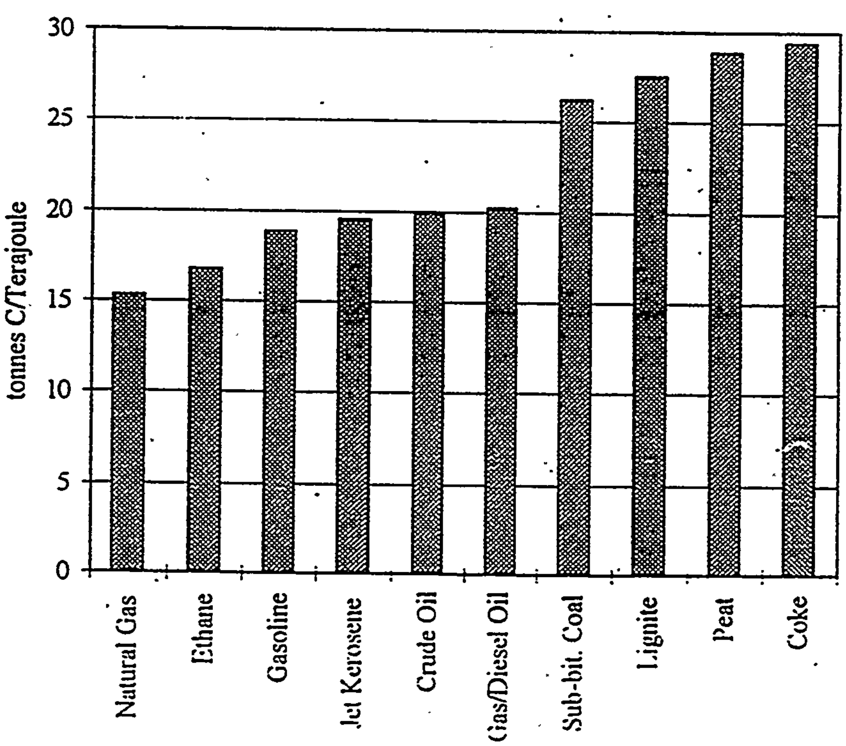
The recent IPCC report provides strong evidence that there is a very real threat of global warming due to anthropogenic GHGs. The previous section clearly demonstrates that the majority of anthropogenic GHGs derive from fossil energy production and consumption. The efficient use of fossil fuels will only reduce the rate of increase of GHG emissions in the short-term. While this is a necessary condition for reducing GHG emissions, it is not a sufficient condition. If GHG emissions are to be stabilized and eventually reduced, then energy production and consumption patterns will have to switch to low- or non-GHG emitting energy resources and energy will have to be consumed as efficiently as feasible.

Comparison of GHG Emissions from Energy Resources

The sources of GHG emissions from fossil energy resources stem primarily from carbon found in the fuels. This carbon oxidizes during combustion and results in CO_2 and CO emissions. The higher the carbon to hydrogen ratio of the fuel, the greater the resulting CO_2 emissions per energy unit out. Additionally, CH_4 emissions result from the production and handling of solid, liquid and gaseous fossil fuels. Figure 8 presents the tonnes of carbon per Terajoule of energy for a range of fossil fuels.

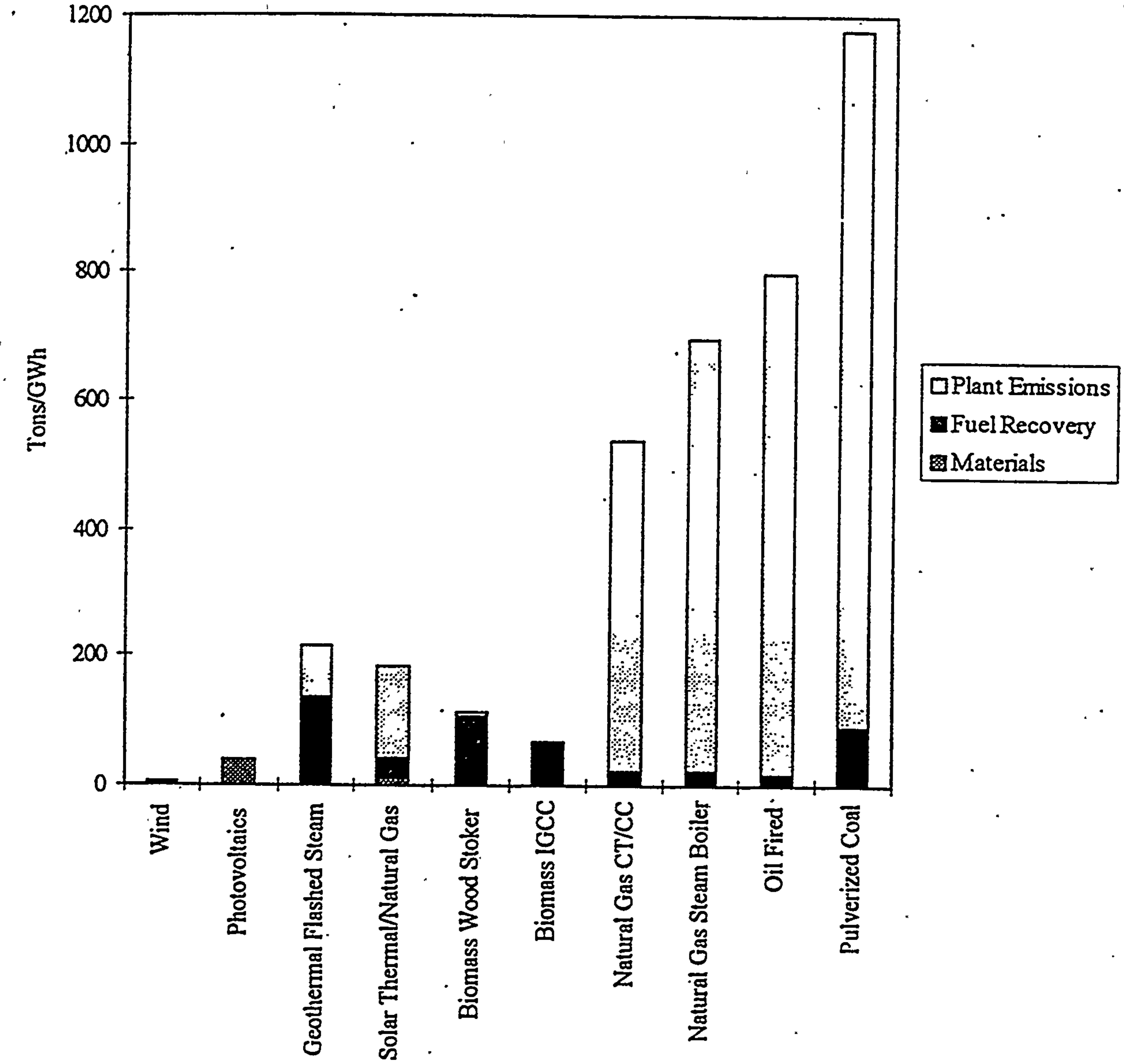
In contrast to fossil fuels, renewable and nuclear energy resources produce little or no GHG emissions. Solar energy is the principal renewable resource. Secondary sources of renewable energy (i.e., energy that derives directly from solar insolation) are biomass, wind, ocean thermal and hydro. Other sources of renewable energy that are not directly solar-derived are tidal power, wave energy and geothermal energy. All renewable energy resources, except for geothermal power, have no direct GHG emissions. Some renewable resources have GHG emissions associated with their production, however.

Figure 8. Carbon Emission Factors for Fossil Fuel Sources



Source: Intergovernmental Panel on Climate Change, 1995b.

Figure 9. Direct and Indirect Greenhouse Gas Emissions for Various Power Generating Technologies



Source: DynCorp EENSP, Inc., for National Renewable Energy Laboratory, 1995.

The conversion of renewable resources to usable energy (i.e., heat, shaft power or electricity) may result in the generation of some GHGs if conversion technologies have embodied fossil fuels. For example, if sustainable biomass fuels are harvested using petroleum for cutting and transport, the net result is the generation of some GHGs from the petroleum consumption. The GHG emissions from the combustion of the biomass fuels are reabsorbed during the growth of the next biomass crop, however. Similarly, if solar photovoltaic panels are manufactured using materials that require fossil fuels in their production (e.g., steel, glass, silicon, etc.) the net result is the production of some GHGs in the total fuel cycle. Geothermal energy can release methane when hot steam is extracted from the ground. When the renewable energy conversion systems are also produced with sustainable renewable energy, resulting GHG emissions will be zero.

Figure 9 presents a comparison of the total fuel-cycle CO_2 and CH_4 emissions per unit of electricity produced for a number of renewable, nuclear and fossil fuel systems. The data in this figure are based on present practices (i.e., the use of fossil fuels for the production of the energy conversion systems) and clearly indicate that renewable energy systems are significantly lower in GHG emissions even when the total fuel-cycle is taken into consideration and where fossil fuels are assumed to support the production of the technology. Therefore, it is clear we must consider renewable energy options as one of the principal options for energy in the future if GHG emissions from the energy sector are to be reduced. Nuclear energy options also result in lower GHG emissions per unit of usable energy output. Due to reasons of global security, safety, waste disposal problems and costs, however, the nuclear energy option is not considered, for the present, as a suitable and sustainable option for the future.

Potential of Renewable Energy Resources

The potential of renewable energy resources is enormous and could, in principal, meet all present and future energy needs of the globe. Table 1 presents a summary of both the potential annual output and actual electricity production of the major renewable energy options that are commercially or near-commercially available (i.e., demonstrated in the pilot phase). Table 1 also indicates how global potential and actual production compare to 1990 global electricity consumption of 10,382 TWh. Two obvious observations emerge from these data. The first is that the potential of renewable energy resources far exceeds that of the actual electricity demand and is sufficient to meet future annual global demands for energy. The second is that these resources are presently not being exploited to any significant degree. It is the second observation that deserves further analysis and holds the key to a sustainable energy future.

Table 1. Alternative Energy and Low Greenhouse Gas Emitting Energy Technologies: Potential and Output Compared to World Electricity Consumption in 1990.

Technology	Potential Annual Output (TWh)	% 1990 Electricity Consumption[a]	Estimated Annual Output (TWh)	% 1990 Electricity Consumption
Hydro[b]	15,090	145%	2,161[c]	20.8%
Wind	50,000[d]	482%	6.3[e]	0.06%
Biomass[f]	20,700	200%	89.5	0.86%
Solar Photovoltaics	2,000 MW[g]	NA	NA	NA
Solar Thermal[h]	NA	NA	2.45	0.02%
Geothermal[i]	1,750[j]	17%	35	0.34%
Tidal	500 to 1,000[k]	3%	0.58[l]	0.01%
OTEC	100,000[m]	963%		0.00%
Wave	NA	NA	NA	NA

See notes at end of paper.

Cost Comparison of Renewable Energy and Fossil Fuel Options

There are a number of reasons that renewable energy resources have not been fully exploited, the primary one being the widespread perception of higher financial costs associated with renewable energy conversion systems. Renewable energy resources, in most cases, are available at very low costs. Converting them to usable forms of energy, however, is perceived to be financially more costly than for most fossil fuels. This perception is often outdated, as many renewable energy conversion technologies at present are being utilized profitably around the world.

One prominent use of renewable energy is large-scale hydropower, which continues to be significantly developed where available and financially attractive. The remaining local environmentally attractive large-scale hydropower opportunities are declining, however. Alternately, a large amount of financially viable medium- and especially small-scale hydropower potential is still unexploited globally. The production of electricity from wood and waste agricultural residues is also a significant financially attractive source of energy. Windpower systems are also increasingly gaining acceptance by the electricity generation and financial communities in developed and developing countries, notably OECD and India. Geothermal energy also, in some cases, can provide electricity and process heat at attractive prices. Finally, small-scale renewable energy systems such as solar photovoltaics, small windpower systems and community biogas systems can be competitive with small-scale isolated fossil fuel systems. Over the past five years many renewable energy technologies have increased in commercial application.

Table 2 presents a comparison of a range of estimated average costs of electricity produced by fossil fuel and renewable energy systems, clearly indicating that electricity costs of some of the more commercially developed renewable energy systems are competitive. Furthermore, most renewable energy systems are still undergoing reductions in costs due to technological advances. Specifically, technologies like solar photovoltaics, solar thermal electric and ocean thermal electric will, after further cost reductions, represent major alternatives for electricity production -- and ultimately for production of hydrogen energy, which could be a sustainable energy substitute for liquid and gaseous fossil fuels.

There are a number of reasons why fossil fuel systems presently enjoy a cost advantage over most renewable energy systems. The main reasons stem from the fact that these fossil fuel systems are mature technologies that now benefit from: (a) significant amounts of research and development expenditure to optimize the technology; (b) an established infrastructure to support the production and use of these fuels; (c) fully developed economies of scale and efficiency; and (d) a great deal of internal and external subsidies. The above factors combine to severely inhibit the adoption of renewable energy systems, which do not benefit from these entrenched and traditional sources of support. A more detailed discussion of these barriers is presented in Section IV of this paper. A brief presentation of the commercial readiness and technical potential of the primary renewable resources is presented in Annex A, which demonstrates that most renewable resources can and should play a greater role in the development of a sustainable energy future. Because fossil fuels are finite, the world's economies must begin to make the transition to alternative energy sources.

Table 2: **Comparison of Cost of Electricity Production from Renewable Energy Systems and Fossil Fuel Systems**

Energy System	Cost (¢/kWh)	Comment
Coal-Fired Power Plant	4 to 10+	Costs vary as a function of coal price and environmental controls required.
Oil-Fired Power Plants	4 to9+	Costs vary as a function of oil price and environmental controls required.
Natural Gas Power Plants	3 to 7+	Costs vary primarily as a function of natural gas price.
Small Diesel Power Generation	10 to 30+	Costs vary principally as a function of costs of diesel (including transport costs).
Biomass Generation/Cogeneration	3 to 25	Costs vary as a function of the costs of biomass fuel delivered to the plant and price paid for cogenerated steam.
Geothermal	3 to 12 +	Costs are very sensitive to site-specific conditions.
Hydro	2 to 25 +	Costs are very sensitive to site-specific conditions.
OTEC	<6 to 25+	Costs are hypothetical, as no commercial plants have been built. Potential for low costs is dependent on large scale plants.
Solar Photovoltaics	<10 to 50+	Costs at the low end of the range are for systems Without storage in large scale applications. Higher end costs are for SPV solar home systems.
Wave	<9 to 20+	Costs are very sensitive to site-specific conditions.
Wind	5 to 12 +	Costs are very sensitive to site-specific conditions.
Tidal	<9 to 18+	Costs are very sensitive to site-specific conditions.

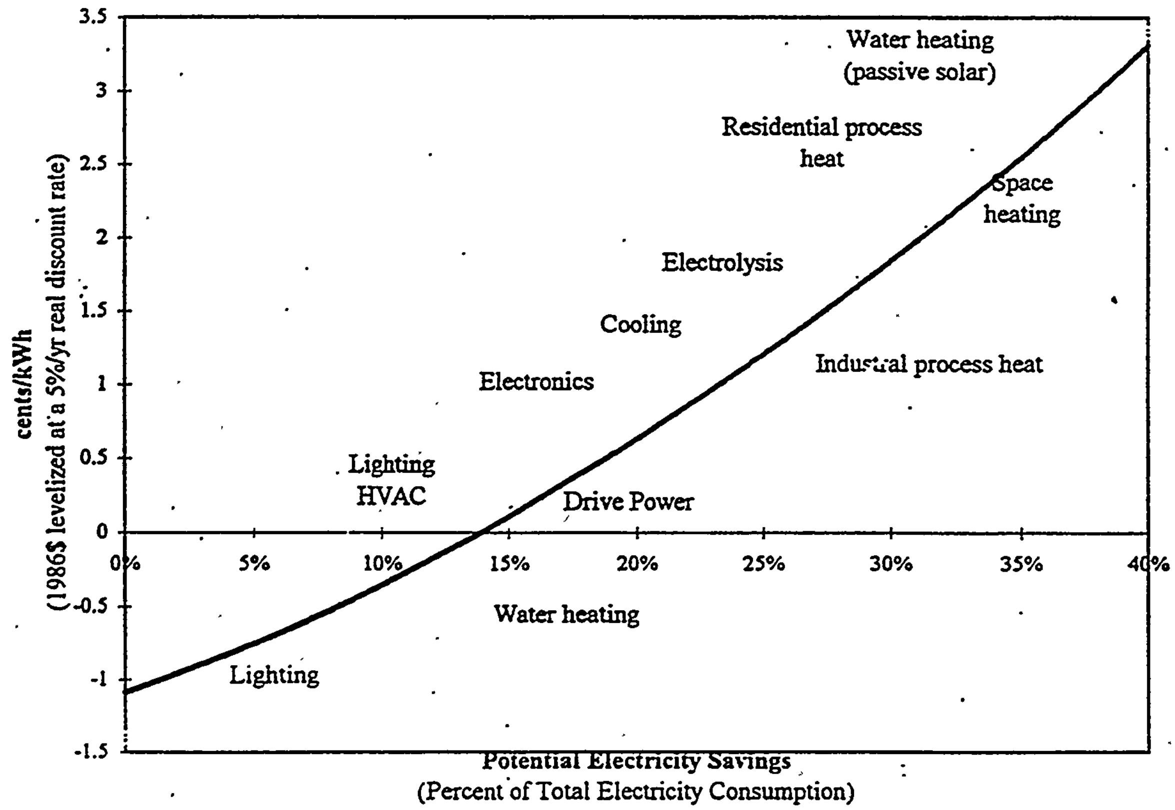
Sources: Burnham et al. editors, 1993; Ahmed and Anderson, 1994.

Opportunities for Energy Efficiency

In addition to renewable energy, more efficient production, conversion and use of the stream of fossil fuels that presently powers the global economy represents one of the most cost-effective means of reducing GHG emissions in the short term. In many cases, the cost of reducing fossil fuel consumption by adopting more efficient conversion and end-use technologies is significantly lower than the cost of producing and converting those fossil fuels. The net result is a similar or superior energy service obtained with an economic savings along with a reduction in GHG emissions. Demand side energy efficiency has major significance in most developing countries. In India, for example, transmission losses and theft of electricity are well-documented. Technically, more than half of the current and projected gap in demand for electricity in India could be met through improvements in efficiency in the production and use of electricity. This great potential calls for giving top priority to energy efficiency in proposed protocols of the FCCC. The obstacles to this approach would be much fewer than those to other measures suggested for stabilizing GHG levels. There is also greater scope for using this option in Activities Implemented Jointly pilot projects without off-set provisions. National enforcement also would be feasible.

A number of examples of cost-effective energy efficient technologies include compact fluorescent light bulbs, high efficiency motors, energy efficient homes and buildings (including appropriate design, materials, lighting and appliances), combined-cycle steam injected gas turbines, advanced industrial processes, materials recycling and a host of other options. Figure 10 presents an illustration of the potential for reducing long-term U.S. electricity consumption versus the cost of electricity, based on estimates by the Rocky Mountain Institute and the Electric Power Research Institute. The data clearly indicate that a large portion of present electricity consumed could be saved for less than the cost of producing that electricity. Similar data can be derived for direct uses of fossil fuels in the residential, commercial, industrial and transport sectors.

Figure 10: Potential for Energy Efficiency versus Costs in the USA



Source: Rocky Mountain Institute and Electric Power Research Institute estimates, as cited in Fickett et al., 1991.

IV. BARRIERS TO ADOPTING NON-GHG BASED ENERGY OPTIONS

Shifting to renewable energy and energy efficiency as the primary response actions to reducing GHG emissions is presently not the major objective of most OECD and developing countries' energy planners or ministries. While most countries' climate change action plans note the role for these options, few explicitly call for any major changes to reorient their national energy mixes. Even where renewable energy and energy efficiency are recognized as one component of a GHG-neutral development path, domestic renewable energy and energy efficiency industries are not being aggressively supported or brought in as actors in national climate change programs and dialogues. Rather, the resources of government and GHG-emitting industries, which are dedicated to climate change R&D or pre-feasibility project funding, typically support short-term options such as forest conservation/afforestation, shifting from coal to natural gas use or improvements in supply-side efficiency. The variety of economic, institutional, accounting, and infrastructural barriers that prevent a quicker transition to renewable energy and demand-side energy efficiency actions include:

* *Economic Externalities/Market Failure:* Existing energy market prices that signal users to change consumption patterns presently do not reflect the full costs to society for GHG emissions from fossil fuels as well as, in many cases, the local and regional environmental impacts of these fuels;

* *Biased Policy Framework:* Fossil fuels and nuclear power benefit from favorable national policies that support and perpetuate their use and provide biased advantages over renewable energy and energy efficiency options;

* *Accumulated Institutional Momentum:* The widespread and accumulated global investment in fossil fuels has resulted in an institutional momentum and bias that is difficult to slow down, least of all reverse; and

* *Market Rigidity:* Vertical integration within the existing energy sector, specifically with regards to fossil fuel production, transport, conversion and supply, creates institutions with rigid and vested market interests and considerable political power.

Economic Externalities / Market Failure

International and national energy markets are increasingly being governed by a "free market" planning strategy. However, existing energy market prices, which signal users to change consumption patterns, presently do not reflect the full costs to society of GHG emissions from fossil fuels as well as, in many cases, the local and regional environmental impacts of these fuels. Often, renewable energy and energy efficiency options are ruled "uneconomic" compared to fossil fuel systems because analysts and decision makers consider only a system's current market prices (i.e., financial costs). The fact that renewable energy applications often are or almost are competitive with conventional energy systems is generally ignored by the political, investment and business communities. Market biases against the widespread commercialization of renewable energy and energy efficient systems include:

* *Financing Barriers:* Most renewable energy systems, even those with high rates of return, suffer from two major financing constraints: (a) higher up-front capital costs per unit of installed capacity and; ironically (b) a relatively smaller scale of

capital required, due to the smaller size of renewable energy projects in comparison to fossil fuel projects. The higher ratio of capital to operating expenses make renewable energy projects more capital intensive and therefore more risky from a financing perspective. The smaller scale of most renewable energy projects (0.1 to 30 megawatts (MW)) and their resulting smaller total capital requirements when compared to fossil fuel projects make it more costly to appraise and process the required financing per unit of capacity. It may cost the same amount to appraise and process a ten million dollar loan for an renewable energy project as it does a one hundred million dollar loan for a fossil fuel project. Other financing barriers that work against renewable energy projects include: (a) unfamiliarity with technologies; (b) limited commercial experience to assess technology performance and reliability; (c) uncertain resale markets for renewable energy project assets; and (d) sometimes, relatively lower short-term returns on investment when compared to fossil fuel projects or other investment opportunities.

* *Environmental Externalities:* Financial or market prices are misleading from a societal perspective as they do not include all of the current and future societal costs related to the use of a resource. The negative environmental consequences (externalities) related to fossil fuel systems, including their GHG emissions, are presently largely ignored by market prices. This means that consumers of fossil fuels do not pay directly for the resulting environmental damage or the costs of prevention. Hence, in relative price terms renewable energy and energy efficiency appear more expensive than conventional fossil fuels. As long as the environmental costs of fossil fuel systems are ignored, renewable energy systems will have an economic disadvantage.

* *Inter-generational Costs:* If the present generation continues to increase its annual GHG emissions rather than stabilizing and eventually reducing them, it will in effect be passing on to future generations the costs associated with accumulating environmental damage and the impacts of climate change. Within the context of the inter-generational perspective, it is an interesting dichotomy that we appear to have a good indication of the extent of global fossil fuel reserves and are able to confidently indicate that there are sufficient global reserves to last past the next century. However, we appear to have no clear idea or, more likely, political desire to truly assess the extent of the globe's environmental and atmospheric reserves or absorptive capacity. The primary reason for this state of affairs is that fossil fuels can be marketed as "private goods" while the environment and especially the global environment remain a "common good".

Biased Policies

Fossil fuels and nuclear power benefit from favorable national policies that support and perpetuate their use and provide biased advantages over renewable energy and energy efficiency options.

Specifically, current energy pricing policies highly distort the financial prices that energy users see, resulting in an uneven playing field that financially favors the market selection of fossil fuels over renewable energy and energy efficiency. Primary among these are: (a) direct and indirect subsidies for fossil fuel production and use; (b) waiving of import duties for fossil fuels and large-scale power generation equipment; (c) accelerated depreciation and tax holidays for fossil fuel projects; and (d) favorable loan guarantees and power purchase agreements for large scale conventional power projects. Taken together, these tax and pricing policies add to the financial hurdles faced by renewable energy and energy efficiency projects, which do not benefit from such favorable policies.

A major institutional barrier for renewable energy and energy efficient technologies is the dependency upon national environmental rather than energy agencies for setting national climate change strategies. The fact that environmental agencies in most countries are not viewed as "revenue generating" agencies has placed them in direct conflict with the energy agencies which are viewed as "revenue generators". This is especially true when it comes to implementing climate change action plans that call for changes in the national energy mix. In most countries, the energy, finance and planning ministries are far more influential in formulating policies that ultimately affect energy consumption patterns.

The conflict between the objectives of the environment agency on the one hand and those of the economic ministries on the other is fundamental in developing countries like India, where any talk of holding back a fossil-based power project because of climate change considerations would be totally unacceptable at this stage of the country's development. The problem has hardly been solved by establishing a separate Department of Non-Conventional Energy in 1982, upgrading it to a full-fledged ministry status in 1992 and promoting Energy Development Agencies in all the states. These organizations worked outside of "business as usual" in the energy sector. (Wind energy has come into it's own only through economic and market factors). Unless these other agencies are fully integrated into the process of environmental protection, are convinced of the value of the global environment, and recognize the economic benefits of renewables and energy efficiency, they will not promote policies that are favorable for the environment. As developing countries have extremely limited technical and financial capacities to address climate change, the effectiveness of their environmental ministries in addressing these issues without the support of the energy and finance ministries is, in many cases, extremely limited.

Another barrier is the governments' and international donors' initial reliance on the non-profit, NGO and environmental communities -- almost to the exclusion of the for-profit private sector -- to draw up national strategies and response plans. This reliance has created a diversion in the climate change dialogue. Private sector companies -- both emitters and potential innovators (e.g., the renewable energy industry) -- have been sidelined in the OECD and developing countries with regards to the FCCC deliberations and national policy formation. Their potential contribution and role in the formulation of national energy policy needs to be considered if they are to eventually play a pivotal role in promoting and implementing sustainable energy technologies.

Institutional Momentum

The widespread and accumulated global investment in fossil fuels has resulted in an institutional momentum and bias that is difficult to slow down, let alone reverse. Not only do the economic and political *status quo* continue to perpetuate fossil fuel use, but such areas as infrastructure development, technology research and development, secondary education, professional training, and national development budgets have structural biases that accelerate this momentum. For example, energy engineers, analysts, and economists who advise on future energy options are mostly trained in understanding fossil fuel and nuclear power systems and are therefore not comfortable in proposing non-GHG emitting options such as renewable energy technologies and demand-side energy efficiency. Hence, national ministries, state utilities and large corporations naturally find that, at the operational levels, their people are most comfortable with conventional fossil energy systems. The same situation occurs in the financing community, where knowledge about the risks of alternative energy options are distorted or misunderstood.

The institutional momentum of conventional energy systems is a very difficult barrier that may be only slowly overcome. The problems of biased policies and institutional momentum can be dented only when there is major shift from fossil fuel dependency to the other energy sources. As long as fossil fuels are the prime movers of almost all economic and social activity, all structures will be geared to them. Without complete dedication and large investments in education, training, infrastructure and technology, the process of overcoming institutional inertia will be piecemeal and progress will be slow or non-existent.

Market Rigidity

Vertical integration within the existing energy sector, specifically with regard to fossil fuel production, transport, conversion and supply, has created institutions with rigid and vested market interests and considerable political power.. National and international energy industries hold enormous economic dominance and political power. Over the years, fossil energy companies (e.g., oil refineries, gas companies, power generators/distributors) have matured and consolidated their market positions through vertical integration. These companies would face significant market share losses if present beneficial subsidies and policies were equalized, i.e. a level playing field is created. Infant industries such as renewable energy and energy efficiency service companies face high market-entry barriers, policy disincentives, and limited R&D support.

Coal, oil and gas resources are owned by major energy companies (private and national). In the case of the OECD countries, private utilities that own such fossil fuel resources are more apt to develop these resources for domestic use. Oil and gas companies are more likely to invest and develop oil and gas consuming industries and technologies (e.g., automobiles, turbo-generators, boilers, etc.). In the case of developing countries, coal, oil and gas resources are mostly owned by the national governments, which tend to develop these resources for domestic use as well as exports (which are viewed as an immediate source of revenues). In countries like India and China, coal is sold to large state and provincial utilities at subsidized rates resulting in taxes on other sectors of the economy to support coal consumption. Similarly, in countries like Indonesia and Mexico, oil and gas are sold at subsidized rates to state-owned utilities.

Hence, the prevailing "free market" energy paradigm does not really exist due to structural biases, policy distortions and market externalities. It is interesting that in the recent influx of multinational energy corporations into India and China, in all the controversies, the main issues pertain to government guarantees, costs and tariffs and possible kickbacks. Not a word has been said about the ill-effects of large scale exploitation of high carbon fossil fuels and the missed opportunity to funnel international capital into sustainable energy projects and industries. Until energy markets are completely diversified and truly competitive, a bias for conventional energy systems will remain. To encourage this diversification and competition, economic instruments and energy policies must be implemented that discourage vertical integration of the energy industry.

V. FCCC STRATEGIES FOR SUSTAINABLE ENERGY DEVELOPMENT

Clearly the barriers to sustainable energy development are significant. The FCCC recognizes that reaching its "ultimate objective" of "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" will not be a simple task. In recognition of this fact, Article 4. of the FCCC defines a number of general commitments for all Parties to the Convention and some specific commitments for the Annex I and Annex II countries. The general commitments for all Parties to the Convention relate primarily to the reporting requirements of Article 12 and, more importantly, to a "commitment" to "take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions". There are a number of specific commitments for the Annex I countries but the most important is their commitment to implementing policies and measures "with an aim of returning individually or jointly to their 1990 levels these anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol". Finally, two important commitments outlined for the developed country Parties listed in Annex II are their commitments to provide the developing countries with: (a) "new and additional financial resources to meet agreed full costs incurred by developing country Parties in complying with their obligations under Article 12, paragraph 1" (i.e., the reporting requirements) ; and (b) "the agreed full incremental costs of implementing measures that are covered in paragraph 1 of this Article" (i.e., implementing mitigation measures and preparing for adaptation to climate change).

In the case of the commitments of the Annex I countries, the CoP has the responsibility to review the actions taken by the Annex I countries in meeting GHG stabilization targets and to propose additional measures that are necessary to meet the objectives of the convention. At the second meeting of the Conference of Parties (CoP2) just concluded in Geneva, most parties endorsed a U.S. proposal to establish medium-term emissions targets for industrialized countries. This proposal is to be finalized for the third meeting of the Parties, to be held next year in Japan. Additionally, the CoP is responsible for reviewing and advising the developing countries on their national plans for mitigation of climate change. The FCCC does not endow the CoP with any clear enforcement powers to meet the objectives of the Convention, however, and does not clearly define the strategies to be used for meeting its objectives and commitments, instead leaving this task to the participating countries.

What are the principal national and international strategies that the CoP could adopt to help meet the objectives of the Convention? Given that the energy sector dominates the present production and growth of GHGs, the CoP should strongly consider promoting strategies for sustainable energy development, i.e., the production and use of energy resources that result in low or no GHG emissions. The range of possible actions that may be considered by the CoP to promote sustainable energy development, in the order of increasing direct incentives or penalties are:

(a) Voluntary programs for reducing GHG emissions;

(b) Individual or jointly implemented actions with the possibility of claiming GHG offset credits;

(c) Reimbursement for the agreed incremental costs of actions that result in reducing GHG emissions;

(d) Imposition of penalties and benefits for GHG emissions (e.g., an international GHG tax and credit system); and

(e) Mandate of GHG emission quotas.

A brief discussion of each of these possible actions is presented below followed by a brief indication of the types of national and international initiatives that should be promoted if we are to move toward a path of sustainable energy development. It should be noted that these policy options are not mutually exclusive of one another.

Voluntary Programs for Reducing GHG Emissions

Because the FCCC, as presently formulated, has no mandatory requirements for the reduction of GHG emissions from the non-Annex I (or developing) countries, it is essentially relying on the commitment and goodwill of these countries to meet its objectives and principles. The Annex I countries, however, do have a commitment to stabilize their GHG emissions at 1990 levels. This is essentially a quota system and will be discussed later in this section.

To promote the voluntary approach to reductions, the FCCC requires all participating countries to "formulate, implement, publish and regularly update national and, where appropriate, regional programs containing measures to mitigate climate change". For most developing countries, their "initial communication" must be submitted within three years of the entry into force of the Convention for that country[4]. Thus the FCCC would appear to be trying to publicly pressure the developing countries into some level of compliance in reducing GHG emissions. However, the Convention is clearly formulated to avoid placing any undue or additional economic burdens on the developing countries in the process of their complying with the Convention. Specifically, Article 4, paragraph 6 states that the Convention "will take fully into account that economic and social development and poverty eradication are the first and overriding priorities of the developing

[4] Parties to the Convention that are defined as "least developed countries" may make their initial communication at their discretion. At present there are 34 developing country Parties that are classified as least developed.

country Parties". Thus, it is unlikely that developing countries will act or can afford to implement any drastic measures for reducing GHG emissions that are not already financially attractive or relatively easy and inexpensive to implement (e.g., the "no regrets" or "win-win" measures).

With regard to the energy sector, what can be expected is that the developed and developing countries may consider some policy actions that both remove the more obvious and detrimental market distortions and barriers that presently work against sound and competitive economic development and also happen to reduce GHG emissions. Considering that there are also several other more subtle barriers that work against the adoption of GHG reducing energy options, it is unlikely that policy reforms alone will result in reducing or stabilizing the growth of GHG emissions from the developed and developing countries. Policy reforms can serve as the necessary, but not sufficient, condition to move the energy sector toward a more sustainable path.

A key point worth noting is that as long as the environmental sector is not linked to the energy sector through appropriate market incentives and economic instruments, the voluntary approach will have little impact. In most countries, energy agencies have the objective of ensuring that energy is available so that, in the short-term, "economic development" and the "quality of life" can improve. The energy agency is usually a revenue generator in this process. It has the support of the big utilities, corporations, energy producers and, most importantly, the ministry of finance. On the other hand, the environment agency is burdened with the responsibility of ensuring that environmental standards are met. However, the environment agency is usually seen as a hindrance to economic development and a drain on public revenues and is generally at odds with the "money-generating" sectors of the economy and, in many cases, the ministry of finance. Relying on the environment agencies to adopt and implement policies that reduce GHG emissions will only work if the environment agencies are directly linked to policymaking at the finance and energy ministries. As long as the environment sector is de-linked from energy and development, its impact will be minimal. At the national level, governments should establish administrative and legal mechanisms which integrate the roles of the environment and economic agencies in the decision-making process on climate change matters. Such mechanisms should be appropriately empowered and have clear mandates. The FCCC also needs to link the issues of the global environment to those of energy and economic development. Failing this, the voluntary approach to reducing GHG emissions is unlikely to produce any major reductions in global GHG emissions. While the voluntary process respects the rights of countries to develop economically and along their path of choice, it does not ensure that this will be the path of sustainable energy development. At their recent meeting in Geneva, the Parties to the Convention demonstrated that they recognized this when they agreed on the need for future emissions targets.

Joint Implementation for Reducing GHG Emissions

Article 4, paragraph 2, subparagraph (a) of the FCCC indicates that the Annex I countries may "implement ... policies and measures jointly with other Parties and may assist other Parties in contributing to the achievement of the objectives of the Convention". This clause is commonly referred to as the "joint implementation" or JI provision of the Convention. It is important to recognize that the JI provision was provided for in the Convention to allow the developed countries to demonstrate their willingness to take the lead in modifying the longer-term trends in anthropogenic GHG emissions, consistent with the objectives of the Convention. In this respect, JI was initially conceived to create and foster a partnership between and among the developed and developing countries to reduce the global growth of GHGs. The ensuing debates and interpretations of JI, however, have focused more on the possibility of the transfer of GHG reduction credits as GHG offsets from developing countries to the developed countries to help the developed countries meet their FCCC target of reducing their GHG emissions by the year 2000 to their 1990 levels. This offset policy means that developed countries need not internally reduce their GHG emissions below 1990 levels if JI offsets are counted in their baselines. In March 1995, at the first CoP meeting in Berlin, it was agreed that JI was to be recognized only among Annex I countries. However, it was also agreed that a pilot program of "Activities Implemented Jointly" (AIJ) could proceed between developed and developing countries and that the issue of recognizing the resulting GHG credits would be considered by the CoP no later than the year 2000.

If JI or AIJ becomes a tool for trading GHG offsets, then the net global benefit of this strategy will be minimal. The principal reason is that the developed countries are already mandated to reduce their GHG emissions by the year 2000 to 1990 levels. If they are not held to this target but are allowed to trade offsets with other Annex I or accommodating developing countries, then the net result would not differ significantly from a scenario in which there was no JI or AIJ allowed and the developed countries were forced to meet the 1990 target with only domestic reductions or offsets. While JI or AIJ would allow Annex I countries to pursue the global least-cost options for GHG reduction first, it may also reduce the incentive of the developing countries to mitigate their GHG emissions independent of JI. Clearly, if JI or AIJ is to be allowed, then the ground rules must be carefully formulated to ensure that the objectives of the Convention are not compromised in the process.

Within the context of the FCCC, AIJ could serve as a catalyst for promoting sustainable energy paths in the developing countries. However, as catalyst, AIJ would only start the process of demonstrating least-cost short-term options for GHG reduction. This is primarily because AIJ investments will be made only in technically proven, low-cost and commercially ready options. AIJ will not accelerate the development of medium- and long-term solutions to GHG reductions, because it will not necessarily help develop and foster those technologies that are presently more costly or in need of further technical development but which ultimately may significantly reduce GHG emissions. As such, JI and AIJ may help point countries toward the path of sustainable energy development but it will not place them on that path.

Agreed Incremental Costs for Reducing GHG Emissions

The concept of agreed incremental costs for reducing GHG emissions derives directly from the FCCC. Article 4, paragraph 3 states that the developed country Parties "*shall also provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the **agreed full incremental** costs of implementing measures that are covered by paragraph 1 of this Article and that are agreed between the developing country Party and the international entity or entities referred to in Article 11, in accordance with that article.*" This statement indicates that the responsibility of the developed country Parties is to pay the "full incremental costs" of any actions to mitigate climate change that are undertaken by a developing country Party in agreement with the Global Environment Facility (the international entity referred to in Article 11).

In practice, what has transpired is that the *developed country Parties have provided very limited funding (US $1 billion per year)* to the Global Environment Facility (GEF) to be transferred to Non-Annex I Countries. This level of support contrasts with the World Bank's estimate that *nearly $100 billion of investments is needed annually in the energy sector of the developing countries alone.* The GEF has the difficult responsibility of equitably disbursing these limited resources to achieve the maximum impact in mitigating climate change. The end result has been the establishment of a great deal of guidelines, procedures and criteria that must be met before a developing country Party is able to secure the incremental costs for any of its actions to mitigate GHG emissions. The GEF has gone to great lengths to define what it considers an acceptable incremental cost.[5]

The primary problem with the incremental cost concept is that it attempts to create the condition where the developing country is neither rewarded nor penalized economically for selecting the alternative option which helps mitigate climate change. The developing country is supposed to select the alternative option because of its commitment to the principles of the FCCC. However, because incremental cost does not effectively account for the non-economic (i.e., social, institutional and habitual) barriers to change, it does penalize countries for selecting the low-GHG option. Furthermore, the concept of incremental cost as defined in the FCCC does not apply to GHG mitigation projects in the developed countries. Given that these countries must stabilize their emissions, they will need to consider other incentives to stimulate the implementation of GHG mitigation activities that do carry an incremental cost.

Finally, the concept of incremental cost is applied on a project by project or action by action basis. This is valid in the short-term to help mitigate climate change. However, application of the concept via this approach will not effectively change the course of development, as this requires investments in research, development and fundamental changes in infrastructure for which the incremental costs can be argued to be the total costs of the action. The resources required to accomplish these actions also would be considerably greater than what is presently available to the GEF. As such, the incremental costs provided by the GEF can only make minor contributions to the mitigation of climate change in both the short-term and the long-term.

[5] The concept of "incremental costs" as defined by the GEF can be stated as the additional cost incurred as a result of redesigning an activity or selecting an alternative activity relative to a baseline plan. However, the practical application of the incremental cost concept within the GEF is proving to be quite complicated. To avoid abuse of the limited resources of the GEF, a number of strict criteria have been developed to ensure that only the incremental costs of actions over that of the "optimum baseline" are considered. Thus the definition of the "optimum baseline" becomes crucial. If the baseline does not represent the most economically efficient option, calculating the incremental costs against this less than efficient option would effectively reward countries for economically inefficient behavior.

Penalties and Benefits for GHG Emissions: A GHG Tax and Credit System

The FCCC does not specifically provide for direct penalties for exceeding GHG emission targets or benefits for beating them. If a penalties and benefits system were adopted under the mandate of the FCCC it would first have to be drafted and adopted as a protocol by the CoP. This does not presently appear to be a likely prospect.

Carbon taxes and credits have received some interest among economists and energy planners, yet only minimal interest among national leaders. A few OECD countries (e.g., Sweden) place taxes on GHG-emitting fossil fuels; most, however, have backed away, although the idea has floated around many parliaments and legislative branches. Most European and North American countries have decided to wait for others to adopt carbon taxes, with the idea of then observing the results of these actions. A primary reason for this approach is the prospect of carbon taxes tilting the terms of trade against the adopting country. Given this national bias against unilateral adoption, there is a need to explore the options for an international carbon tax and credit system.

Because the energy sector is the primary source of GHG emissions, one option in designing penalties and benefits is to consider carbon taxes and credits on energy resources. Energy resources could be taxed according to the degree of their carbon content, while tax revenues would be recycled to those energy resources with no carbon.

FCCC carbon taxes could be established and placed in a value-added tax fashion on GHG-emitting resources and processes, so that the end user as well as the energy generator/processor would see the mark-up due to potential climate change damage. Taxes could be set either in terms of damage costs, a quite difficult price to determine, or prevention costs. The sticky issue is the distribution of taxes to the non-GHG emission options, either domestically or internationally. One approach would be that each OECD country set up its own GHG tax fund (similar to a highway development fund supported from gasoline taxes) dedicated to investment in national non-GHG emitting industries or to targeted R&D. This fund also could be used by national industries investing in verifiable overseas GHG-reducing JI or AIJ activities.

Alternatively, a GHG crediting or emissions trading system would send market signals without the political damage aroused by raising taxes. A crediting or emissions trading system is being advocated by many in OECD countries as the only realistic means of providing benefits to those investing in low or non-GHG development paths. Under this system, the Conference of Parties could recognize international credits (e.g., JI or AIJ), and might allow nationally monitored mercantile trading boards to manage trading. This approach would allow futures trading, which could internalize the value to future generations of GHG emission reductions. Recognition and evaluation of these credits by oversight boards would be necessary to ensure that verifiable, credible GHG mitigation activities were being undertaken.

A combination of taxes with credits could move OECD countries most efficiently, equitably and rapidly into non-GHG development paths and would be favored by industries as a market-oriented solution. However, credits alone may not be able to capture the significant number of non-point sources of GHG emission reductions (e.g., transport system changes to electric vehicles) as the latter types of benefits may be far more difficult to track than point source pollution changes. This combination of market solutions is probably the most desirable and equitable strategy from most countries' perspectives. Establishing credits first, then moving into a tax/credit system might ease countries into raising financial prices of GHG emitting resources without creating economic shocks.

Mandate of GHG Quotas

Article 4, paragraph 2(b) of the FCCC suggests a quota on anthropogenic GHGs for the Annex I countries. The FCCC calls for the Annex I countries to individually or jointly return "to their 1990 levels these anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol". The FCCC does not place a definitive time frame for the return of Annex I GHG emissions to the 1990 levels but calls for the CoP to periodically review the adequacy of this requirement starting from its first session (which was convened in March 1995). It presently appears that many of the OECD Annex I countries will not return to their 1990 levels by the year 2000, which was floated as the initial target. As already noted, the Conference of the Parties has just agreed on the need for emissions quotas and expects to adopt an emissions protocol at its next meeting, to be held in late 1997 in Kyoto, Japan.

A principal problem with the existing quota approach of the FCCC is that it does not apply to all countries. Unless a new, tougher protocol is adopted, total global GHG emissions will continue to increase in spite of the proposed quota for the Annex I countries. Application of the 1990 GHG emission level target to all countries would be inherently inequitable, however, in that it would reward the worst polluters and penalize historically low GHG-producing countries. To apply a quota system for GHG emissions fairly, drastically different criteria would need to be established to determine the allocation of allowable emissions within the quota.

One possibility would be to tie allowable GHG emissions to a per unit GDP of output. However, this would penalize countries with economies that were dependent on GHG-producing activities. Another possibility would be to allocate GHG emissions on a per capita basis. However, this would reward countries with large populations who are low on the development scale and penalize those with small populations that are highly developed. Several other quota schemes have been proposed but have been rejected for various reasons of equity and practicality.

Given that the majority of GHG emissions derive from the use of fossil energy, one possibility is to "tax" the use of this energy by implementing a quota on the allowable average GHG emissions per unit of energy consumption in a country. Such a strategy would favor the introduction and use of low or non-GHG emitting energy resources. For example, an average GHG emissions quota for energy consumption could be set at say 15 tonnes of carbon per Terajoule, which is about the level of GHG emissions for natural gas. A country would have to balance its energy consumption to attain this average emissions rate per unit of energy consumption. This approach would result in countries that are presently heavily dependent on high-carbon fossil fuels to consider other sources of low- or no-carbon energy resources. It would require developing countries to select more balanced energy development paths while it would force many developed countries to eventually move their energy consumption to low- and no-carbon energy resources.

There are a number of drawbacks to the energy/GHG quota strategy. The first is that energy efficiency is not necessarily rewarded if quotas are set on GHG emissions per unit of energy consumption. However, energy efficiency is usually rewarded financially and, as stated earlier, is a necessary but not sufficient condition for the ultimate reduction of GHGs. A second drawback is that this strategy would be difficult to monitor and implement because it would require an elaborate accounting and enforcement system. Finally, and most importantly, to be effective an energy/GHG quota strategy would require an international "command and control" administrative process. International bodies historically have not been well-equipped for local enforcement on a global basis.

The idea of quotas to control environmental pollution is not new. Many countries have established quotas for emissions of pollutants based on some information of the damage function of the pollutant or the absorptive capacity of the environment. A classic example is the quotas established for sulfur oxide (SO_x) emissions in specific air quality control areas of the United States. Similar approaches have been utilized for water pollutants in rivers and lakes. Quotas are periodically modified as more information on the damage function and absorptive capacity of the environment are established.

It should be noted that both credits for emissions reductions and emissions quotas may be most effective when implemented in tandem. Under such a "cap and trade" system companies that reduce their emissions below allowable levels may sell their excess credits to companies exceeding their quotas, thereby earning profits by "over-complying" with environmental regulations. In fact, the U.S. SO_x system just mentioned is a cap and trade system.

Lessons from the Montreal Protocol

To identify the criteria that make for an effective protocol, one need only look to the ***success of the Montreal Protocol.*** Within a very short period, this Protocol has effectively changed global use of CFCs and other ozone depleting chemicals emitted by humans. More importantly, it has met its targets, within a reasonable time frame and with the support of both the industrialized and developing countries' business, government, and environmental communities. Fundamental to its success has been its reliance on private sector economic incentives and support.

The targets of the Montreal Protocol were initially objected to by those responsible for the majority of the ozone depleting substances (ODSs). However, the key OECD businesses responsible for the majority of ozone depleting chemicals possessed the technical capacity to change *while still making money on shifting to non-ozone depleting resources.* As all businesses world-wide faced the same penalties, all companies had to convert. This leveled the playing field across firms globally, so that a major emitter could not simply move to another province or country to avoid penalties. Also, the developing countries signed on because they stood to gain from technological exchange and innovation benefits. These unequivocal penalties, benefits and ceilings were the economic and non-economic instruments that allowed the marketplace to work efficiently and effectively in solving a global environmental problem.

Several critical protocol conditions created the necessary instruments that spurred universal compliance. These included:

* Mandatory ODS emission phaseouts and timetables for all countries;

* Establishment of national regulations to ensure compliance;

* Allowing technology leaders to benefit from early compliance; and,

* Wealth sharing from technology innovation between developed and developing countries.

Box 1
Key Elements of Montreal Protocol Success

* *Industrialized-country businesses had replacement technologies available and benefited financially from conversion to non-ozone depleting chemicals;*

* *Developing-country businesses gained from technological exchange, innovation and improvements; and,*

* *ALL countries HAD TO CHANGE, as there were mandatory ceilings and timetables. Thus, all businesses world-wide faced the same financial burden of technological conversion and technology leaders could capture economic benefits of innovation.*

The authors recognize that there are major differences between the Montreal Protocol and the FCCC. For instance, the Montreal Protocol addresses one substance which arises from the production processes of a limited number of easily identified producers. Also, economically viable and proven alternatives were available that made substitution away from ODSs painless and even profitable for ODS producers. In contrast, the production and use of fossil fuels affect almost all aspects of modern day living. Nevertheless, the Montreal Protocol is an apt example of international action that is working and proves the efficiency of market instruments.

The FCCC does not have a similar or clear set of effective enforcement and economic instruments. For example, the FCCC presently allows OECD countries to make their best efforts to reach 1990 GHG emission levels by 2000. The *FCCC unlike the Montreal Protocol does not establish mandatory emission reductions even for the OECD countries, does not create clear penalties for transgressors,* *and does not allow trading of GHG emission credits globally*[6]*. Hence, no financial marketplace benefits can be captured by market leaders and technology innovators from altering energy use/supply patterns. The work of the Parties to the FCCC at their meeting next year will be to craft a system that creates a playing field where energy producers and consumers are rewarded for choosing clean energy options.*

VI. CONCLUSIONS AND RECOMMENDATIONS

It is clearly evident that the FCCC, as presently operating, cannot achieve the objective of stabilizing GHG concentrations in the atmosphere unless it adopts a major protocol to significantly reduce anthropogenic GHG emissions. As demonstrated in this paper, a good starting point in determining the steps the Parties to the FCCC should take in designing a protocol is to remember that the primary source of anthropogenic GHG emissions is the consumption of fossil fuels and the future growth of GHG emissions will derive primarily from the ever-increasing demand for and consumption of these fuels. In the final analysis, both the developed and developing countries must work together to develop new instruments, under the mandate of the FCCC, to control the use of fossil fuels. Only then will there be hope of a stabilization of GHG concentrations in the atmosphere.

To jointly achieve the objective of reducing fossil fuel consumption, the FCCC must address and foster the adoption of an **international sustainable energy policy** that recognizes the true costs to the global environment of fossil fuels and reduces the constraints and barriers to renewable energy and energy efficiency options. Only within the context of such a policy can we expect to halt and ultimately reverse the growth of GHG emissions.

The barriers to formulating and adopting an international sustainable energy policy are significant. The challenge is to utilize the instruments of the FCCC to structure a protocol that will require and assist nations in moving toward sustainable energy paths. The FCCC represents the best terms and conditions that could be negotiated in 1992 among over 165 countries, which had varied objectives and interests. As a result, the Convention did not include the clear and well-defined economic (e.g., emission credits and trading) and non-economic (e.g., quotas, emission caps etc.) instruments that would lead to the reduction of GHG emissions. The Parties to the Convention can adopt these instruments now, however, as they craft an emissions reduction protocol.

The current lack of economic instruments and enforcement noted in the previous section creates major FCCC compliance loopholes. Indeed, it creates incentives for OECD industries to drag their feet. Governments are fearful about implementing tough climate change action policies least they cause business flight and loss of national income. For example, most OECD countries do not want a "carbon tax" unless the other OECD countries, notably the U.S., follows suit. Similarly, developing countries are not interested in seeing their cheaper (and even profitable) GHG offset projects to be selectively picked by industrialized countries under joint implementation programs unless they are assured that

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[6] It does allow Annex I countries to carry out activities jointly implemented, but again this may not lead to the least-cost options or global solutions to GHG emission reductions.

they will not face future GHG emission limits or reduction targets, or can benefit substantially by early technology exchanges*.

In summary, in designing a protocol the CoP needs to establish broader economic and policy instruments than those of the Montreal Protocol within the FCCC. Policymakers and business executives around the globe should forge alliances to adopt GHG-neutral energy paths. The FCCC must consider a stronger set of economic and policy measures that help promote sustainable energy development. Box 2 outlines a summary package of recommended FCCC actions that could speed up energy sector changes that would lead to sustainable energy development.

Box 2

Recommended FCCC Modifications for Sustainable Energy Development

1. *Setting of national GHG emission ceilings and timetables* for all countries (based on historic emissions responsibility, expected emissions growth, and relative socio-economic development achievement);

2. *Establishment of an international GHG tax framework* ($/ton GHG emitted above limits) to be administered nationally, with revenues recycled internationally;

3. *Development of an international GHG emission credit trading system* to allow polluters to purchase emission offsets and to pay energy leaders for responsible behavior; and,

4. *Establishment of mechanisms that ensure equitable wealth sharing from technology innovation. Specific actions include* support for the GEF and technology exchanges between developed and developing country participants.

This paper has demonstrated that in addition to establishment of an international climate change protocol, several other actions are needed to bring about the development of an international sustainable energy regime. These actions include:

* See Mendis and Gowen (1994) for a discussion about the conditions under which it is in a developing countries' economic interests to undertake activities implemented jointly (AIJ).

- At the international level, more credible and effective integration of environmental issues with the economic and financial factors that will ultimately dominate decision-making processes;

- At the national level, establishment of administrative and legal mechanisms which integrate the roles of environment and economic agencies in the decision-making process on climate change matters. Such mechanisms should be appropriately empowered and have clear mandates;

- National and international action to prevent undesirable vertical integration in the energy industry; and

- Development and advocacy of a formalized international sustainable energy policy. A number of United Nations organizations and international meetings have adopted international policies/strategies on subjects far less significant, often not having serious international implications. A draft policy which spells out specific steps to be taken should be proposed for the consideration of the world community.

ANNEX A

COMMERCIAL FEASIBILITY OF RENEWABLE ENERGY SYSTEMS

HYDROPOWER

Hydroelectric and hydro-mechanical power are well developed and installed throughout the world. Hydroelectric systems convert the kinetic and potential energy in water flow into rotational kinetic energy through a hydro-turbine. The mechanical movement of the turbine is then transformed to electric power through a generator. In a hydro-mechanical system, the rotational energy of the turbine is directly transformed to mechanical power to run a machine, rather than generating electricity. Commercial hydropower systems are available for applications from as low as a few kilowatts to as large as thousands of megawatts. Table A-1 shows the world's technically exploitable hydropower potential and existing development as reported by *International Water Power & Dam Construction* (1989). As of 1989, it is estimated that only

Table A-1. Global Potential and Existing Development of Technically Exploitable Hydropower

Region	Technically exploitable potential (TWh/year)	Total hydro installed capacity (GW)	Hydro Generation in 1988 (TWh)	Percent Used (generation/ potential)
Africa	1,150	15.84	36	3
South Asia and Middle East	2,280	45.44	171	8
China	1,920	32.69	109	6
Former Soviet Union	3,830	62.20	220	6
Japan	130	20.26	87	67
North America	970	129.09	536	55
South America	3,190	75.98	335	11
Central America	350	10.71	32	9
Eastern Europe	160	16.56	49	31
Western Europe	910	128.44	436	48
Australasia	200	12.00	37	19
World	**15,090**	**549.2**	**2,040**	**14**

Source: Burnham, et al., citing The World's Hydro Resources, *International Water Power & Dam Construction*, September, 1989.

14 percent of total global hydropower potential had been tapped and that total technically exploitable hydroelectric power could provide approximately 150 percent of the global electric power consumed in 1989. The cost of installing hydropower ranges from $750/kW up to $3500/kW, depending on the given site and design. Many hydroelectric sites produce electricity as low as $ 0.02/kilowatt-hour (kWh). More remote and difficulty locations may be as high as $0.15/kWh. Costs at more typical sites are equal to or below those from fossil fuel-based electricity generation systems.

BIOMASS

Biomass energy resources include the woodfuel gathered in developing countries used for cooking and heating; agricultural residues such as sugarcane bagasse, straw, rice husks, and nutshells; forest and timber residues; animal and human wastes; and energy crops grown specifically to produce biomass fuels. Most biomass fuels can be easily converted to useable energy either in the forms of heat, electricity, or intermediate liquid and solid fuels. More importantly, biomass fuels can be produced on a sustainable basis if proper measures are implemented.

Land resources present the main constraint to biomass energy. Nevertheless, estimated total biomass energy available annually is 620.2 exajoules (Hall et al., 1993), which, assuming a 20 percent energy conversion factor for the biomass energy, translates to 13,252 TWh per year. This is equivalent to 128 percent of the 1990 global electricity consumption.

WINDPOWER

Wind conversion energy technologies have advanced tremendously within the last 5 to 10 years. Commercially available wind turbines range in size from a few kilowatts up to one megawatt. They are found in applications for pumping water in remote sites, providing power in hybrid systems in remote villages and providing large amounts of electricity to the grid from wind farms. As of January 1995 there were 3573 MW of wind turbines installed throughout the world (communication, Costedo, Oct. 3, 1995). Wind turbines are attractive from an economic perspective because electricity can be produced as low as $ 0.08 to 0.06/kWh. This is competitive with most large fossil fueled thermal power plants that must meet strict environmental regulations.

Wind resources have just begun to be exploited. According to the United States Department of Energy, the U.S. has enough wind resource to produce 4400 TWh of electricity each year. This represents almost half the electricity the U.S. used in 1990 (U.S. DOE, 1994). One analysis (Grubb and Meyer, 1993) estimated that there is enough wind potential to generate almost 500,000 TWh/year. Once population and siting constraints are taken into consideration wind power could still conservatively provide 50,000 TWh per year. This is almost five times the total net electricity consumption for the world in 1990. Since wind turbines draw on the wind for creating electricity, they emit no greenhouse gases.

GEOTHERMAL ENERGY

Geothermal energy consists of extracting thermal energy from the ground and using it either directly in the form of high temperature steam or hot water, or indirectly to heat a working fluid. Direct sources can provide high pressure steam for industrial processes and water distillation, while lower temperature direct applications includes such processes as heating greenhouses. In indirect applications, thermal energy extracted from the ground can be used to generate electricity or provide heat for space heating and hot water.

In 1989, estimated geothermal electricity production totaled 35 TWh, or only 0.3 percent of total world electricity production (Palmerini, 1993). If growth trends of geothermal electric power continue, by the year 2000 geothermal will constitute approximately 0.58 percent of the worlds electricity capacity. Geothermal direct uses (of fluids with temperatures above 35°C only) amounted to $3.1x10^6$ tons oil equivalent (TOE), or 0.04 percent of the total world energy use. Following past trends, direct geothermal use could expand to 0.07 percent by the year 2000 (Palmerini, 1993). Geothermal electric power is limited by site availability, economic and financial concerns and some local environmental concerns. However, geothermal energy for electricity and especially heating, emits significantly fewer greenhouse gases than does fossil fuel combustion (see Figure 9).

TIDAL POWER

The ocean is a tremendous energy resource. One such way to exploit this resource is tapping into the natural energy from the tides, which is especially feasible in regions where the tidal range is three meters or more. Presently there are four working tidal plants located in France, the United States, Russia, and China. The 240 MW system in La Rance, France has successfully produced electricity for more than 25 years. Tidal energy power is technically proven and dependable. As of 1990, tidal power potential totaled more than 270 TWh of electricity per year at the known possible development sites. Based on 1990 figures, this potential represents only 2.7 percent of total world electricity consumption. Impediments to tidal power include the high cost of construction and the potential environmental impact on local estuarine ecosystems (Cavanagh et al, 1993).

WAVE ENERGY

Several countries have conducted extensive research and funding for wave energy technologies, and successful prototypes are operating and generating electricity (Cavanagh et al, 1993). Energy from waves could provide a long-term renewable energy supply within the next two decades. This energy source could replace diesel energy systems on remote islands and coastal areas, thereby reducing greenhouse gas emissions and providing a reliable energy source. The actual amount of wave energy potential in the world has not been accurately quantified (Cavanagh et al, 1993).

OCEAN THERMAL ENERGY CONVERSION

Ocean Thermal Energy Conversion (OTEC) energy systems draw on the temperature difference between the ocean surface water and deep water (500 - 1000 meters) found in the tropical and subtropical regions. The technology requires a temperature difference of at least 20°C, which is only found between the tropics of Cancer and Capricorn.

Open and closed cycles are possible with the OTEC system. In closed systems the warm ocean surface water is used to evaporate a working fluid such as ammonia or freon. This working fluid then passes through a turbine which is attached to a generator. The cold deep ocean water condenses the working fluid coming out of the turbine and the loop starts over. In an open system, the warm surface water passes through a flash evaporator to become steam. This steam then passes through the turbine which in turn generates electricity. The colder deep ocean water then condenses the steam, which was originally the warm surface water. Condensation of the steam produces fresh water, a by-product of growing global importance, especially in remote island locations.

A commercial OTEC system has not yet been installed. Several countries have conducted research and demonstration programs for pilot scale plants, however: India recently announced that it will participate in a commercial OTEC venture with a U.S. based firm, and a pilot plant operating in Hawaii has successfully demonstrated that most of the technical barriers associated with OTEC can be overcome. However, because the costs of OTEC are very sensitive to economies of scale, a plant in excess of 100 MW will be required to ensure that costs are competitive with fossil fuel systems.

Approximately 60 million km^2 of the world's surface area is suitable for possible OTEC development (Cavanagh et al, 1993). The total theoretical energy that could be generated is approximately ten times global electricity production in 1990 (Cavanagh et al, 1993).

SOLAR ENERGY TECHNOLOGIES

Energy from the sun that reaches the earth every year could provide enough energy to supply 15,000 times the world's annual energy demand. Several energy conversion systems exist to directly capture the sun's energy and convert it to electrical or thermal energy. These technologies include solar thermal collectors (to produce hot water, steam or other hot working fluids), photovoltaics (to directly convert the suns light to electricity) and passive solar energy systems that make use of solar energy for light and space heating. The first two of these potentially could make large contributions to electricity production and are described below.

Solar-Thermal Electric Technology

Solar thermal electric technologies generate electricity in a manner similar to that of a conventional thermal energy plant. In a solar-thermal plant, solar concentrators utilize the sun's energy to generate a high-temperature working fluid for the power plant, whereas in a traditional thermal power plant fossil fuel is combusted to heat the working fluid, which is normally steam. Solar thermal plants must be located in areas where there is very high, clear and stable solar insolation; on the order of 2500 kWh/m^2 annually (De Laquil, et al., 1993). Most solar-thermal electric plants presently operating are coupled with fossil-fired backup systems. The nine commercially operating parabolic trough solar thermal systems located in the Mojave desert of the United States generate 350 MW of electricity annually (De Laquil, et al., 1993). Solar-thermal electricity has a levelized electricity cost of approximately eight to 33 cents per kWh, depending on the solar receiver technology installed. Technological advancements are expected to reduce costs to eight to twelve cents by the year 2000 or 2005.

Photovoltaic Technology

Photovoltaic (PV) technologies differ from typical heat energy plants in that PV systems convert the sun's energy directly into electricity. There are numerous PV technologies that use an array of different materials and manufacturing techniques. The main categories of PV cells include crystalline and polycrystalline-silicon solar cells, amorphous silicon photovoltaic systems, and polycrystalline thin-film photovoltaics. In the present state of the technology's development, PV systems are generally more expensive for large scale utility electricity generation than traditional thermal energy plants. However, PV costs have been declining rapidly over the past 20 years and are expected to eventually be competitive over a wider range of applications.

The costs for the PV systems depend on: the costs of the PV module installed; costs of other system components; the amount of sunlight available; and the cost of operating the system and replacing parts (Kelly, 1993). The main focus for reducing the costs of PV systems has been in improving the manufacturing of the cells and improving cell efficiency. As manufacturing costs decline and efficiency improves overall cell cost will decrease. However, the balance of the system and system configuration also adds to the overall system cost, so developments in these components also need to be pursued.

PV systems tend to be cost-effective in areas where grid electricity is not available. Extending the utility transmission line 3 km for an average 300 kWh per month demand is less cost-effective than installing a stand alone PV system, based on 1990 prices (Kelly et al, 1993). Isolated markets where PV systems would be cost effective are numerous in the developing world but also exist in the OECD countries. Other niche markets for PV cells include: small-scale markets such as pocket calculators (PVs represented 22 percent of U.S. sales in 1989); and isolated systems such as buoys, communication sites, and pumping stations. Worldwide photovoltaic sales reached 61 MW in 1994 (Johnson, 1995).

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Notes for Table 1:

a. 1990 world electricity consumption totaled 10,382.6 TWh (Energy Information Administration, 1995).

b. Moreira and Poole, p. 77.

c. Energy Information Administration, 1995, p. 14.

d. Grubb and Meyer, p. 198.

e. Costedo, 1995.

f. Authors' calculations, based on Hall et al., p. 632.

g. Represents expected global production in the year 2010, per Johnson, 1995. Annual sunlight falling on the Earth exceeds annual energy use.

h. De Laquil et al.,. pp. 213-296.

i. Palmerini, p. 582.

j. Author's calculations, based on Palmerini, p. 551.

k. Cavanagh et al., p. 528.

l. Ibid., p. 517.

m. Ibid., p. 539.

Mitigation Assessment Results and Priorities in China

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Oct. 1996

Abstract

In this paper energy related CO2 emission projections of China by 2030 are given. CO2 mitigation potential and technology options in main fields of energy conservation and energy substitution are analyzed. CO2 reduction costs of main mitigation technologies are estimated and the AHP approach is used for helping assessment of priority technologies.

1. Introduction

Since early 1990s, China put great emphasis on global climate change issues in some key science and technology projects of the Eighth-five Year Plan. Besides, some international cooperation projects in this research field with the assistance of the Asian Development Bank, the World Bank etc. were also conducted. These projects were mainly focused on macro study at either state or sector levels and accumulated a large amount of data, few model systems and study experience that could benefit the follow up projects in this topics.

The current study on energy sector is characterized by: (1) establishing of a China-specific methodology guideline in collaboration with appropriate US departments and institutions, which directs analysis of adaptive/abatement technologies as well as the socio-economic evaluation of scenarios and response policies. (2) carrying out case studies for some selected regions and chosen technologies following the methodology guideline and aiming to provide demonstration projects for further research in China. (3) undertaking national assessments based on research outputs, case studies and prior researches. (4) supporting national policy dialogue on GHG emission mitigation options.

The results of this study show that: (1) since population expansion and high GDP growth, energy-related CO_2 emissions will increase reasonably in China. Production and consumption of fossil fuel are the main emission sources. (2) heavy coal share and high energy intensity of GDP display that there exists a comparatively big energy conservation potential in China, and energy supply and energy end-use are the major areas for implementing GHG mitigation technologies. (3) adjustment of industry structure and increase of shares of products with high added value do and will play a very important role in reducing energy intensity of GDP. (4) both energy conservation and energy substitution by natural gas, nuclear power, hydropower and renewable energy will be the key technological measures and a long-term strategy to reduce GHG emission. (5) identification and implementation of GHG mitigation technologies are consistence with the targets of sustainable development and environmental protection of China. (6) energy efficiency improvement is a no regret option as usual for CO2 reduction, e.g. a negative mitigation cost of 10-15 yuan/t-c is expected for improving boilers' efficiency. Whereas an incremental cost is always needed to develop hydropower and renewable energy.

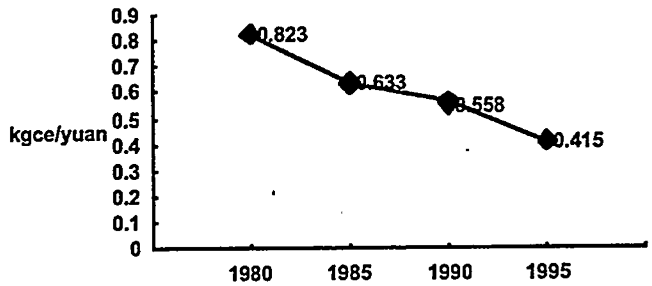
2. Current energy consumption in China

In 1990, China total energy consumption was 987 Mtce, and in 1995 it reached 1,290 Mtce. In past decade, coal consumption in China always accounted for 76% of total commercial energy consumption, which was quite different to the pattern in most countries of the world, shares of oil, natural gas and hydropower were 17%, 2%, and 5%, respectively.

China's population was 1,211 billion in 1995, the average commercial energy consumption per capita was almost 1 tce, which was about 55% of the world average.

The effectiveness of energy utilization of China is quite low in terms of the much higher energy consumption intensity of GDP, i.e. 2.66 kgce/US$ (1990 prices) in 1990. In comparison with the average intensity of 0.366 kgce/US$ (1990 prices) in OECD countries, China was about 7 times as higher as OECD countries. Since 1980, China energy consumption intensity per GDP has dropped by more than 45%, corresponding to an average annual decline rate of 4.2% (Fig. 1). During the period of 1980-1995, by contrast to 10.2% of annual GDP growth rate, the average annual growth rate of energy consumption was 5.2%, the energy consumption elasticity was 0.51. It shows a significant outcome from great efforts of energy conservation . Improvement of energy utilization effectiveness is mainly attributed to following factors: (a) economic reform and economy structure adjustment; (b) adoption of new technologies and new processes with high energy efficiency in newly installed capacity; (c) retrofit of existing facilities by high energy efficient equipment and processes.

Fig. 1 Energy intensity of GDP in China



Based on an investigation of efficiency, improvement of technical performance only contributes a small part, about 20%, in total energy saving. The remained large part was contributed by economic reform and economy structure adjustment. Table 1 shows the result of the investigation and Table 2 shows the improvement of specific energy consumption for major industrial products, that also indicates the improvement rates of technical performance were much lower than that of energy intensity of GDP. CO_2 emission from fossil fuels in 1990 was 590 Mt-c, accounted for 95% of total CO_2 emission in China.

Table 1 Investigation of Energy Efficiency in China and Comparison with OECD Countries

	China		OECD
	1985	1992	Early 90's
Energy system utilization efficiency (%)	25.9	29.0	34.0
Energy intensity of GDP (kgce/US$(1990))	3.81	2.43	0.366
Contribution of improvement of energy efficiency in reducing GDP energy intensity (%)	-	20	-

Note: 1. Energy utilization efficiency = conversion efficiency × (1-loss rate) × efficiency in end-use devices.

2. Foreign exchange rate in 1990 was 1US$ = 4.77 Yuan.

Table 2 Improvement of Specific Energy Consumption in China and Comparison with OECD Countries

	China				OECD
	1985	1990	1994	average yearly reduction rate	90's
Energy intensity of GDP (kgce/yuan)	0.600	0.532	0.418	4.1%	-
Comparable energy consumption for steel (kgce/t)	1,746	1,611	1,519	1.56%	629
Gross coal consumption for power generation (kgce/kWh)	398	392	380	0.49%	310
Synthetic ammonia (kgce/t)	2,358	2,263	2,093	0.46%	1,000
Cement clinker (kgce/t)	206.5	185.3	175.3	1.84%	113

3. Establishment of scenarios

(1) Baseline scenario

In China the national goals of energy development strategy emphasize energy conservation and efficiency improvement and substitution of coal by other energy with less carbon content. They are consistent with the goals of GHG emission mitigation. Therefore, the energy development plan, as an important part of national social and economic development plan, includes most of GHG mitigation policies and measures in energy aspect. The national energy development plan and programmes are taken as a principal background of baseline scenario. Following major assumptions for energy development are made in establishing the baseline scenario:

- New technologies and processes with high energy efficiency and cost-effectiveness will be applied as far as possible in newly installed capacity.
- Retrofit of existing facilities by use of high energy efficient and cost-effective equipment and processes will be encouraged.
- Primary energy supply will continue to depend largely on the exploitation and utilization of domestic energy resources. Import of a large amount of natural gas and oil will become a long-term energy strategy.
- Hydropower resources will be exploited accelerately.
- Nuclear power is expected to play an important role in easing the pressure of fossil energy supply, especially in coastal areas where economic growth is rapid and a serious energy shortage exists.
- New and renewable energy will be an important supplementary energy for meeting energy demand in rural and remote areas.

Besides, some other general assumptions are also involved in the baseline scenario:

- Population

It is assumed that China's basic, long-term policy on family planing and population control, which has led to a dramatic decline in the population growth rate in past decade, will be continuously implemented in the future. The current population of 1,211 million in 1995 is expected to grow to 1,294 in 2000 and 1,386 million in 2010.

- Urbanization

Along with the industrialization, the growth rate of urban population will be greater than that of rural population. The share of urban population will rise from 26.4% in 1990 to 32.4% in 2000 and 38.4% in 2010.

- Economic Growth

In past decade, China economy has experienced a quick growth rate. It is expected to continue the trend but at a moderate high rate: 8.5% AAGR in 1995-2000 and 7.2% in 2000-2010. And, economic reform and economy structure adjustment will continue until a rational economy mechanism is formed.

CO_2 emissions of baseline scenario is estimated by INET* model and shown in Table 3. The results show that in the next decades, energy intensity of GDP, CO_2 emission intensity of energy, and CO_2 emission intensity of GDP in China will continue to decline dramatically. The economic reform and structure adjustment will go on to follow the current trends and still be a dominant factor in reduction of CO_2 emission. The contribution of technical efficiency improvement and energy substitution is expected to be within the range of 15-20% and 2-16%, respectively.

Baseline scenario reveals that hydropower and nuclear power in 2030 will be as high as 217 GW and 60 GW respectively, resulting in 26% of total power generation and 11% of total primary energy supply. Since they are carbon free energy, the energy substitution of them for coal power will be of much importance in the long-term.

Table 3 Energy-related CO_2 Emissions in China for Baseline Scenario

	1990	2010	2030
Population (million)	1,143	1,386	1,550
GDP (billion yuan, 1990 prices)	1,768	9,900	31,750
Primary energy consumption (Mtce)	987	2,242	3,556
CO_2 emission (Mt-c)	590	1,324	1,855
GDP energy intensity (kgce/yuan)	0.55	0.23	0.11
CO_2 emission intensity of energy (t-c/tce)	0.60	0.59	0.52
CO_2 emission intensity of GDP (kg-c/yuan)	0.33	0.13	0.06
Contribution in reducing CO_2 emission intensity of GDP:			
technical performance improvement	-	15-20%	15-20%
energy substitution	-	1.9%	16.6%

* INET model is consist of two main submodels. One is Energy Demand Model (EDM) for analyzing trends of production and service activities levels as well as energy intensity in five major sectors, and generating final energy demand projections of the country. The other is INET model for calculating optimal future primary energy demand and mix as well as energy related CO_2 emission under different social and economic development scenarios and GHG abatement policies.

(2) Mitigation Scenarios

It is very difficult to distinguish baseline and mitigation scenarios in practice, because some major mitigation technologies and measures available have been involved in baseline scenario and analysis of a scenario combining several mitigation measures may not reflect the separate roles played by each measure. Alternatively, it could be useful to define a mitigation scenario in which a specific mitigation technology or measure is emphasized and acceleratively developed, such as:

- enhancing energy efficiency improvement
- accelerating utilization of new and renewable energy
- encouraging energy substitution of coal by hydro power and nuclear power

4. Priority technologies for GHG mitigation

Priority technologies for GHG mitigation in China have been developed by AHP* methodology with respect to a set of assessment criteria, including: (a) mitigation potentials; (b) local environmental impacts; (c) energy and resources efficiency; (d) economic costs; (e) consistency with national development goals; (f) availability of resources; (g) manufacturing localization and infrastructure requirement.

Technical options for GHG mitigation in two main areas are analysed: energy efficiency improvement and renewable energy development.

(1) Energy Efficiency Improvement

1) Energy end-use sectors

1.1) Industry Sector

In 1994, the final energy consumption of industry sectors accounted for 70% of the country total, hence industry sector is considered as a priority sector for energy efficiency improvement. In general, the measures include upgrading processes in

* The AHP (analytic hierarchy process) method is a decision analysis tool that breaks down the constituents of a problem into parts and allow s comparisons and rankings of them. For example, the AHP can rank technologies in terms of specific criteria that may be quantitative (such as specific cost data) or qualitative (such as the social acceptance of a given energy technology).

manufacturing major industrial energy-intensive products and general industrial equipment.

- Industry process

As shown in Table 2, the reduction of specific energy consumption for major energy-intensive products has been achieved by processes improvement. There will still be a large potential in GHG mitigation in future, it has been studied in Word Bank and ADB projects and is not repeated here.

- Boilers

There are approximately 0.41 million industrial boilers with an average capacity of 2.3 t/h in China in 1990 consuming about 305 million tons of coal, which corresponds to 22% of total energy consumption and 25% of total CO_2 emission in China. The current efficiency of operation performance of 60-70% could be improved by 10-15% toward nominal design efficiency.

The improvement measures include: (a) fuel quality by preparation; (b) boiler combustion technologies; (c) auxiliary equipment, and (d) process control. In general, the benefits of fuel saving could cover the capital investment needed for adopting the measures.

- Electric motor and speed adjustment

Electric motors are the main electricity-consumption devices in China. Electric motors for fans and pumps consume 35% of total country's electricity and electric motors for other equipment consume 30%.

About half of fans and pumps need variable speed operation. At present, flow variable operation of fans and pumps by valve adjustment can be replaced by speed adjustment of motor using frequency variable device, and at least 30% of electricity could be saved. Referring to the motors for other equipment, the electricity saving rate could be up to 20%. Furthermore, high-efficient electric motors may be used to replace low-efficient ones. Replacing the JO_2 series of low efficient electric motors with YX series ones could result in an electricity-saving rate of 3-4%. By improving motor efficiency, a no-regret cost of CO2 mitigation is estimated to range -65 to -150 yuan/t-c.

1.2) Residential and commercial sectors

With the urbanization in China, energy consumption among urban residents and commerce grew by a large margin. In 1994, final energy consumption accounted for around 20% of national total, the electricity consumption was 87.4 TWh, an increase of 84% over that of 1990.

Mitigation technologies in residential and service sectors of China mainly cover the measures such as fuel substitution for cooking, district heating, energy saving in buildings, green lighting and electric appliance.

- Lighting

In 1994, electricity used for lighting accounted for 10% of national total electricity consumption. In lamp production, output ratio of efficient fluorescence tube to incandescent lamp was 1/9.

The estimated electricity use for lighting will increase to 120 TWh in 2000 and 230 TWh in 2010, respectively. According to the target set by Green Lighting plan, the ratio of high efficiency lighting to incandescent lamp will increase to 1/3.9 in 2000 and 1/2.5 in 2010. The energy-saving lighting is a cost-effective mitigation technology with an incremental cost from -55 to -12 yuan/t-c.

- City Gas

In 1990, energy consumption for households cooking (including hot water supply) was 98 Mtce, accounting for 10.3% of national total energy end-use. Within the total energy consumption for household cooking, city gas amounted to 5.4 Mtce, serving about 62.3 million population. About 91.3 Mtce of coal was burned directly by millions of small stoves. Amount of about 66 Mt-c emitted by household cooking each year accounts for 10.8% of total energy-related CO_2 emissions.

From the point of view of both reducing indoor air pollution for household and mitigating GHG emissions, development of city gas to substitute coal stoves for household cooking should be placed at a higher priority. Possible options include speeding up exploitation of domestic natural gas resources, making full utilization of domestic LPG, and meanwhile, importing natural gas, LNG and LPG as a supplemental gas source.

1.3) Transportation sector

Transportation sector is a fast growing sector in China during the period of 1980 to 1994, the motor vehicles increased from 1.8 million to 9.4 million. The energy consumption rose from 8.0% of national total final commercial energy consumption in 1980 to 10.0% in 1990. Transport gasoline and diesel consumption accounted for about 90% and 30% of the national total consumption, respectively.

As the transportation is becoming a more and more important sector in China, improving transport performance will benefit not only the global environment, but also the local environment. Effective options to which more attention should be paid include: phasing out steam locomotives in railway, upgrading vehicle design, replacing diesel vehicles for gasoline ones, optimizing mix of trucks' tonnage capacity, improving transport management and dispatchment, and establishing better urban transportation system.

2) Energy supply sectors

Power generation is the most important energy supply sector and its development has been put in a priority position in China. Up to the end of 1990, national total installed capacity was 138 GW with an annual electricity generation 621 TWh, in which thermal power capacity and annual generation were 102 GW and 495 TWh, respectively. It is estimated that by the year 2000 and 2010 the national total installed capacity will reach around 290 GW and 580 GW, respectively.

Constrained by domestic energy resources, coal-fired power contributes over 90% of total thermal power generation, which accounts for over 80% of national total electricity generation. Specific fuel rates for power generation were 392 gce/kWh in 1990 and 381 gce/kWh in 1995, 60-100 gce/kWh higher than the fuel rates of thermal power in developed countries. In 1994 coal consumption for power generation amounted to 400 million tons, accounted for 31% of national total coal consumption, and the corresponding CO_2 emission was about 207 million tons of carbon.

Three major measures to mitigate CO_2 emissions of power generation sector can be summarized as follows:

- adopt advanced thermal power technologies

Total thermal power generator commissioned into operation during the period of 1990-2000 will be more than half of total existing generation capacity. 300 MW and 600 MW sub-critical units with net efficiency over 37% will dominate the newly installed units, so that the average fuel rate of thermal power will decrease notably from 392 gce/kWh to 365 gce/kWh.

More advanced generation technologies, such as Integrated Gasification Combined Cycle (IGCC), Pressurized Fluidized Bed Combustion (PFBC) in second generation, will be commissioned into operation in succession beyond 2000 to realize desulphurization as well as to improve net generation efficiency to 39-45%.

- speed up hydropower exploitation

China is abundant in hydropower resources, but its exploitation and utilization level is much lower, e.g. hydropower capacity by 1990 was only 9.5% of total 378 GW exploitable capacity. Priority will be given to exploitation of large hydropower bases at the trunk and branches of the upper and middle reaches of the Yangtze river, the Yellow river and the Hongshuihe and Lancangjiang. A number of pumped-storage power station will also be built for peak load adjustment.

- step up nuclear power development

Nuclear power will be developed preferably in the coastal areas of East and South China, where there is shortage of primary energy resources and can accept high price of electricity because of being economically developed regions.

(2) Renewable energy development

1) Biomass

Consumption of biomass energy resources, including straw and crop stalks, fuelwood, and all kinds of wastes, amount to about 250 million tce in 1994, which made up about 40% of energy consumption for daily life in rural areas in China. Direct burning of biomass is an usual but inefficient way to utilize biomass nowadays.

High yield tree species for fuel forests, and their cultivation and plantation technologies will be developed and commercial forests fields will be constructed.

A programme to accelerate the application of new technology in terms of utilizing farm biomass energy and developing manufacture and market service system will be implemented. The technologies include: (a) high efficient direct burning (improved stoves); (b) anaerobic digestion (household, medium and large digestors); (c) biomass densification (biomass briquetting); and (d) biomass gasification.

In 1994, 1.2 billion m^3 biogas were produced mainly for rural household use. The targets of biogas development will reach 2.3 billion m^3 in 2000 and 4 billion m^3 in 2010, which could supply 7.55 million families in 2000 and 12.35 million families in 2010.

2) Solar energy

There are rich solar resources in China: two thirds of China's territory possess a solar radiation intensity above 600 MJ/m^2-yr. Regions where space heating is needed in winter are sunny belt; thus it provides a possibility to use solar energy for buildings.

Great efforts will be focused on diffusing energy saving buildings, solar water heater, and photovoltaic power system. It will be necessary to develop manufacturing capacity in a large scale and create a marketing service network for accelerating their application, especially in the regions where solar energy resources are quite abundant.

According to incomplete statistics of 1994, solar water heater installed were up to 2.9 million m^2, passive solar house 2.6 million m^2. Citing the development target, solar energy heater and passive solar house will increase to 10 million m^2 and 50 million m^2 in 2000, respectively.

3) Wind Energy

Total wind energy potential of China which could be utilized is estimated to be 250 GW. In east coast areas and nearby isles of Southeast China, the average annual wind speed reaches 6-9 m/s (meter/second) and the accumulated duration of the wind speed ranging 2-20 m/s lasts more than 6,000 hours per year. These are the right places for building wind power farms equipped with medium and large wind turbines and connected with power grids. Regions with great wind energy potentials also locate in the Northeast, North and Northwest China, where average wind speed reaches 4-6 m/s, and the accumulated duration of wind speed in the scope of 3-20 m/s lasts 5,000-6,000 hours per year. Considering such conditions being over vast prairie and scattered rural areas, mini or/and small wind generators have been introduced for herdsmen and peasant households use.

Application of mini and small wind generators will be facilitated by establishing a system of production, market and maintenance service. At the same time, it is necessary to make great efforts for manufacturing localization of large wind turbine at the unit capacity of 200-600 kW.

In 1994, total installed capacity of grid-in and stand-alone wind power generation reached 30 MW and 19 MW, respectively. According to the development targets, total capacity of wind power generation will be 300-400 MW in 2000 and 1,000-1,100 MW in 2010.

5. Summary of Mitigation Potentials

Share of energy use in primary energy for power generation will gradually go up from the current 30% level, and share of thermal power will increase too. Since coal will still be a dominant source in primary energy for a long time in China, adoption of advanced and more efficient coal-fired generation technologies will become a very important GHG mitigation option. There would be a potential of reducing 114 Mt-c in 2010 compared with 1990 by improving power generation efficiency alone.

Share of hydropower and nuclear power is 19% of total generation in 2010 in Baseline scenario, the effect of CO_2 reduction is quite obvious as they are generation technologies of CO2 zero-emission. Compared with 1990, potential of reducing CO_2 emission in terms of substituting hydro and nuclear power for thermal power would be 90 Mt-c.

There will be great potential of energy conservation and CO2 mitigation by improving the energy utilization efficiency of large quantity of universal equipment in the industry and residential sectors, such as boiler, motor, lighting etc. Adoption of advanced technologies for these three kinds of equipment could result in 90 Mt-c of CO2 reduction in the year 2010 compared with 1990.

CO_2 Emission mitigation potential in improving energy efficiency, power generation, energy substitution are summarized in tables 4, 5 and 6, respectively. Finally, assessment of CO2 mitigation options of priority technologies in terms of some important criteria is shown in table 7.

6. Conclusion

China is a developing country and facing a problem of keeping a balance between social and economic development and environmental protection. China gives a priority to economic development, at the same time also pays great attention to environmental protection. Energy is an important material base for economic development and a major source of causing many environmental issues as well. Key energy issues analyzed in this paper are strategic and aimed at creating an energy system compatible with China's sustainable development over a long term. This requires energy efficiency improvement in both supply and demand sides, wide utilization of clean and renewable energy, and cost-effective performance.

There exists a great potential for energy efficiency improvement and it is often a no regret option for CO2 reduction. Development of renewable energy of biogas, wind power, solar heater etc. have not only good environmental benefits in substituting for fossil fuels, but also great social and economic benefits in providing rural residents (two thirds of China's total population) with energy necessary for improving living standard and promoting rural economy development. Thus, they are GHG mitigation options to which attentive consideration and implementation have to be given.

Practices in the economic reform started since later 1970s showed that economic structure adjustment played a key role in reducing energy intensity of GDP in past more than ten years, and will continue to have great impacts on the efforts of GHG mitigation in the future until a national economy system with reasonable mix is established.

Some important issues, faced in making a strategic and long-term energy system program soundly compatible with environment, should be paid enough attention and solved well by implementing corresponding policies and measures.

In energy supply area: (a) to use coal more cleanly and more efficiently; (b) to establish national and regional pipeline network for supplying cities with large amount of natural gas; (c) to realize modernization of biomass energy use, such as biomass gasification for turbine power generation; (d) to make a comparison among nuclear power, advanced coal power and power generation by importing natural gas in terms of detailed analysis on investment requirement, foreign exchange requirement, costs and safety etc.; (e) to adopt the Integrated Resource Planning (IRP) approach for choosing the least-cost options among alternatives of energy supply and demand ranked in terms of cost and influences on society and environment; (f) to create laws and regulations such as energy law, energy conservation law etc.; (g) to arrange demonstration projects for advanced technologies.

In energy demand area: (a) to set energy prices by the market for the goals of stimulating efficient use of energy and production of energy-saving products; (b) to reduce or cancel subsidies for current technologies, then shift to demonstration projects of energy conservation in order to promote researches and utilization of new technologies; (c) to cover the external costs of energy production and use into energy prices by tax imposition or government's regulation control; (d) to develop performance standards of energy end-use, and institutionalize the energy audit; (e) to enhance and diffuse Demand Side Management (DSM); (f) to strengthen information exchange, education and training of energy efficient use.

While China establishes its energy system to support the sustainable development, obstacles in natural resources, funds, technology and management institution will occur:

- Imbalance of resources kinds and distribution with abundant coal and hydropower and limitation of oil and natural gas. On one hand, resources should be used reasonably and efficiently. On the other hand, oil and natural gas could be imported, e.g. importing large amount of natural gas from Siberia of Russia.

- Shortage of funds that restricts resources exploitation and technology import. Ways to address the issue include: to raise funds through multi-channel domestically and abroad, and to make a good use of funds. At a GDP growth rate of 10% per year, the capital stock will double in about seven years, performance of new investment will have a overwhelming influence on economic development in the future.

- Lack of advanced technology for energy use. In contrast to developed countries, capital funds are in shortage and expensive whereas labour forces are relatively cheaper in China, which could influence, more or less, the application of new energy technologies. Based on the current technological status and allowance of technical, financial and security factors, adoption of technological leapfrogging manner might be an effective way to move more quickly to the latest and most advanced technologies and to speed up the improvement of energy efficiency.

- A set of proper institutions should be organized in the current dual system of planning economy and market economy in China to perfect energy management and promote energy development.

Table 4 Energy efficiency improvement and conservation in demand side

technologies	share in total energy use (%)	incremental cost (yuan/t-c)	mitigation potential 2010 target		mitigation/reference technologies	main barrier in implement
			energy saving compared with 1990 (%)	mitigation Potential (Mt-c)		
boiler	22	-15 to -10	11.8	43.4	M: high efficiency R: conventional	funds, market, service
electric motor	18.2	-150 to -65	14.7	41	M: high efficiency with speed adjustment R: conventional with valve adjustment	funds, market, service
lighting	2.8	-55 to -12	22	9.5	M: fluorescence/compact and electronic ballast R: incandescent lamp	quality, market service

Table 5 CO_2 Emission Mitigation Potential in Power Generation Sector

	1990	2000	2010
Electricity Generation (TWh)	621	1,350	2,770
thermal power	495	1,096	2,248
hydropower	126	240	400
nuclear power		14	122
Specific fuel rate of thermal power (gce/kWh)	392	365	330
Energy saving in thermal power* (Mtce/yr)	-	30	140
CO2 emission mitigation potential* (Mt-c/yr.)	-	22	101

Notes: 1. Electricity generation is for baseline scenario.
2. Compared with the specific fuel rate in 1990.

Table 6 Fuel Substitution with New and Renewable Energy

Technologies	Application	Incremental cost (yuan/t-c)	Capacity			Fuel substitution (Mtce)	Reference technologies	Main barriers
			1994	2000	2010	2010		
Biomass • S-digestor • M/L-digestor	R-household R-household	800-900 800-930	1.06 Mtce 0.03 Mtce	1.45 Mtce 0.33 Mtce	2.36 Mtce 0.78 Mtce		direct burning direct burning	efficiency community system
Wind energy • Stand-alone • Grid-in	Household power supply	600-700	19 MW 30 MW	30 MW 350 MW	85 MW 1000 MW	0.1 1	kerosene and coal power generation	funds, technical transfer, market service
Solar energy • Hot water • Energy saving house	household household	840-920 120-170	$2.9\ M\text{-}m^2$ $2.6\ M\text{-}m^2$	$10\ M\text{-}m^2$ $50\ M\text{-}m^2$	$30\ M\text{-}m^2$ $100\ M\text{-}m^2$	4 3	coal coal	funds, market service

Notes: 1. S-digestor : small digestor
M/L digestor : medium/large digestor
2. R-household : rural household
H-household : herdsmen household

Table 7 Assessment of priority mitigation technologies

Mitigation measures	Technologies	GHG mitigation potential	Local pollutants reduction	Local eco-system impacts	Technology availability	Economic benefits	Social benefits
Energy efficiency improvement	Advanced thermal power generation technologies	Low	High	Low	Low	Low	High
	High efficient motor	Medium	Low	Low	High	Uncertain	High
	High efficient lighting	Medium	Low	Low	High	Uncertain	High
	Industrial boiler renovation	Medium	High	Low	High	High	High
Fuel substitution technology	Hydropower generation	High	High	High	High	High	High
	Wind power generation	High	High	Low	Medium	Low	High
	Solar thermal	High	High	Low	High	Medium	High
	Solar PV generation	High	High	Low	Low	Low	High
	Biogas generation	Low	High	Medium	Medium	Medium	High
	Biogas utilization	Low	High	Medium	Low	Low	High

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MITIGATION OF CARBON DIOXIDE FROM THE INDONESIA ENERGY SYSTEM

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INTRODUCTION

Energy consumption in Indonesia is growing fast in line with the development of national economy. During (1990-1993), emission of CO_2 gas coming from energy sector increased from 150 million tones to 200 million tones in 1993. Whereas, the total methane emission from the oil, gas and coal sub-sector reached 550 kilo tones in 1991 and increased to 670 kilo tones in 1994. This amount of CO_2 and Methane from energy sector was 26% and 10 % respectively of the total it's emission of Indonesia.

Based on the last two decades of Indonesia's economic growth experience, as a developing country this high economic growth rate of Indonesia in the future will be kept until reaching the newly industrialized country level, which is more than 6% annually in the next decade. This high growth rate economic projection will also added the level of GHG emission in the future.

As a developing country Indonesia is one of the fast growing countries. The GDP growth in the year 1995 was more than 7 percent, therefore growth rate of energy consumption in this country also rose follows the economic growth.

Sources of GHG Emission Mitigation

Main direction of the GHG mitigation is through minimizing the use of fossil fuels. This minimizing, in the area of energy can be achieved through fuel diversification (switch to non fossil fuels) or conserving the utilization of energy.

Scenarios

In term of the controlling of GHG emission due to the energy utilization, the mitigation scenario tries to control Indonesia's GHG at least 10 % in the year 2010 and 20% in the year 2020 below the emission level of business as usual (BAU) scenario.

For the BAU scenario, we adopt from the doing nothing case result of the Environmental Impacts of Energy Strategies for Indonesia studies that is completed in 1993 done by joint research study between BPP Teknologi Indonesia and KFA-Juelich Germany[3] with updating the national economic projection growth rate which follows the official GDP growth rate target released by National Development Board (BAPPENAS), and initial mitigation option.

In the BAU scenario, MARKAL model applied for analyzing the optimum energy system cost, through the determine the final energy supply mix as well as technology mix for the utilize energy such as final utilization, energy transportation and energy conversion (refineries and power plants). The energy conservation, such as maintaining efficiency processes was introduced in this model beside choosing the cheapest fuel supply selection.

BAU Scenario Projection

The current energy demand in Indonesia, including non-commercial energy so far is dominated by residential sector, with the share of 46% of the total domestic energy need , followed by transport and commercial sectors as the second and the third energy. Starting from around 2000, the industrial sector share increased to approximately 40%, followed by transportation sector at 25%. This trend indicates that the industrialization process takes place in Indonesia. Electricity demand is expected to increase steadily at the rate of 8.2% annually up to the year 2020. The demand industrial energy in 1990 was 789 Peta Joule (PJ) and is projected to grow at the rate of 6.6% annually, and will reach the figure of 5,979 Peta Joule in the year 2020. The commercial sector, currently, consumes energy accounting for 18.5 Peta Joule and is projected to reach 279 Peta Joule in the year 2020 (table 1).

Table 1 Final Energy Demand by Sector (PJ)

	1990	1995	2000	2005	2010	2015	2020
Industry	789.41	1,159.17	1,612.17	2,210.62	3,055.44	4,265.53	5,979.40
Commercial	18.24	29.32	47.23	73.25	113.93	178.23	279.60
Govern Public	11.11	17.63	27.12	41.45	63.82	100.01	158.00
Residential	1,140.99	1,274.10	1,390.07	1,489.60	1,583.67	1,676.79	1,772.30
Transport	538.77	777.52	1,106.64	1,560.75	2,218.51	3,210.44	4701.30
Power Plant*)	717.90	1,078.63	1,549.33	2,247.16	3,261.00	4,837.03	7,234.58
Total	3,216.42	4,336.37	5,732.56	7,622.83	10,296.37	14,268.03	20,125.18

*) Fuels input for power generation

Considering the Markal model optimization, the primary energy supply mix, for the year 2020 will be 18,551 Peta Joule increased at the rate of 5.9% annually compared to that in the year 1990 (3,369 Peta Joule). The supply mix also changed, in the year 2020 will be oil (37%), coal (34%), gas (16%), and biomass, hydropower & geothermal accounted for 13%. In the year 1990, the fuel mix was dominated by oil (39%), and biomass (30%). The natural gas supply reaches 21% and the rest comprises of coal, hydropower and geothermal. (see table 2)

Table 2 Primary Energy (PJ)

	1990	1995	2000	2005	2010	2015	2020
Coal	194.95	351.61	754.46	1,442.65	2,468.64	4,094.30	6,476.80
Oil	1,333.34	1,739.32	1,967.93	2,502.32	3,356.10	4,729.98	6,814.32
Gas	693.85	1,063.96	1,362.35	1,623.69	1,991.72	2,409.47	2,998.79
Geothermal	72.53	91.02	100.22	108.13	109.96	103.84	102.49
Hydropower	69.22	97.76	349.04	426.46	449.32	449.30	453.89
Biomass	1,005.38	1,134.34	1,238.39	1,333.79	1435.84	1,553.22	1,705.15
Total	3,369.27	4,478.01	5,772.39	7,437.04	9,811.58	13,340.11	18,551.44

GHG emission of the energy system is as follows: CO_2 emission from the utilization of energy in Indonesia increased from 150 million tones in 1990 to around 200 million tones by the year 1993. Oil combustion accounted for approximately 60% of the total CO_2 released followed by natural gas (30%) and the remainder released from utilization of coal. (Figure 3)

MITIGATION OPTIONS

Residential sector

In this sector, the options that can be applied to reduce the energy consumption are:
- substitution of electronic ballasts of fluorescent lamps for conventional ballasts;
- substitution of compact fluorescent lamps (CFL) for incandescent light bulb;
- substitution of solar home system (SHS) for kerosene lamp;
- improvement of efficiency for refrigerator;
- improvement of efficiency for air conditioning
- substitution of LPG stove for kerosene stove.

- **Lighting**

Lighting is the most important. Expanded use of compact fluorescent lamps (CFLs), which require less electricity than standard incandescent lamp to produce the same light output, could have a major impact. A lamp ballast is needed to provide a suitable starting voltage, thereafter limiting current flow during operation of fluorescent (and mercury) lamps. Ordinary magnetic ballasts dissipate about 20--30 percent of the total power entering fixture. More efficient electronic ballast (also known as core/coil ballast) makes use of better materials to reduce ballast losses to about 10 percent. Such ballasts will increases the efficiency of the ballast/lamp system approximately 20 to 25 percent relative to that of system with an ordinary ballast.

Most solar home system (SHS) is 50kWe per system, use solar collector and battery can operate 3 unit fluorescent lamp (6-10 watt), a radio cassette and 1 B/W television set [salim]

Electrified households in Indonesia, it is assumed use 2 light bulb of 40 W during 4 h/d, 2 light bulb of 25 W during 6 h/d and 2 fluorescence lamp of 20 W during 5 h/d for each household. Non-electrified households consume 100 liter kerosene per house per annum. About 10 % of non-electrified household is potentially use SHS.

The total cost of CFL (including the cost of the lamp and the electricity to power it) is roughly one fourth the cost of an incandescent bulb, but the initial capital cost for a CFL is about twice higher. While for electronic ballast for fluorescent lamps the initial capital cost is three times higher than conventional ballast.

The parameters of today's lamps and of the suitable replacement options are shown in table 3.

This option was applied in some household, specially in urban household. The penetration of this option is about 5% in 1995 and will increase to 30 % in 2010 and 60 % in 2020.

Another option for lighting is switching from kerosene to electric lighting. In rural area, in addition for stove cooking, kerosene is used for lighting. In new electrified household most of people change from kerosene lamp to electric lighting. Switching from kerosene lamp to incandescent bulb saves energy in many applications (depending in part on size of electric T&D losses) and also improves lighting quality. Using a small fluorescent tube or a CFL is more efficient, though more expensive, option.

Table 3. The parameters of today's lamps and of the suitable replacement options

	Lamp type/parameter	Conventional	Replacement
1.	Bulb	Incandescent lamp	CFL
	Power consumption	40 Watt	11 Watt
	Life time	1000 hours	8000 hours
	Cost per unit	0.5 $ US	5.5 $ US
	Investment Cost (8000 h)	4 $ US (8 x 0.5 $ US)	5.5 $ US
	Inv. per household per year	1.5 $ US	2 $ US
	Electricity cost per year	5.8 $ US	1.6 $ US
	Total cost per year	7.3 $ US	3.6 $ US
2	Fluorescent tubes	Conventional ballast	Electronic ballast
	Power consumption	20 Watt	20 Watt
	Life time	8000 hours	8000 hours
	Cost per unit	2.5 $ US	7.5 $ US
	Inv. per household per year	1.1 $ US	3.4 $ US
	Electricity cost per year	4.9 $ US	3.7 $ US
	Total cost per year	4.8 $ US	7.1 $ US
	Total Cost per year	12.1 $ US	10.7 $ US

Note : Electricity cost per-kWh 0.05 $ US (PLN Regulation)

- **Refrigeration**

Refrigerators are a key appliance to target for efficiency improvement, since their significant electricity use is growing rapidly. Application of energy efficient features such as increased insulation, more efficient compressors, and improved door gaskets can reduce their energy use significantly.

The estimated 60 % of urban household and 3 % of rural household that operate refrigeration in 1995 will increase to 75 % and 5 % in 2010 and 90 % and 10 % in 2020. The number of refrigerator in operation in Indonesia that is estimated 2.5 million in 1995 will increase to 25 millions in 2010 and 50 million in 2020

For the consumption of electricity, assumed that availability (time of operation per year) is 90 % or 7884 hours per year. Electricity consumption of every refrigerator in 1995 is 100 watt, 70 watt in 2010 and 60 watt in 2020. In 1995 all capacity refrigerator is 100 watt. In 2010, 90 % of refrigerator operate by 80 watt, and 10 % of remaining refrigerator by 100 watt. In 2020, 60 % of refrigerator operate by 65 watt and 40 % operate by 80 watt. The specific consumption of a typical refrigerator in 1995 is 788 kWh/a, 646 kWh/a in 2010 and 578 kWh/a

- **Air Conditioning**

The use of air conditioning in homes is growing in many cities. Efficiency improvements for air conditioners include better internal insulation in the equipment, larger heat exchanger, higher evaporator temperatures, dual speed or variable speed compressor motors to reduce on-off cycling, more efficient rotors and compressors, advanced refrigerants and more sophisticated electronic sensors and controls. The value of reduction does not yet give information because of incomplete data information about them. Therefore this option haven't apply for mitigation scenario.

Industrial Sector

GHG mitigation option in the industrial sector areas in Indonesia is identified as using variable speed motor, and cogeneration of heat and power for captive power.

Motors is the dominant appliances in the industrial sector. There is big energy saving potential through industrial motor's efficiency improvement. Motors assumed consume 75 percent of the total industrial electricity consumption. Use of the variable speed motors will replace ordinary motors step by step, all new motor installation assumed using variable speed motor. In the year 1995, variable speed motor assumed already accounted for 10% of the total motor installation, in the year 2010 will reach 25% share, finally accounting for 50% in the year 2020.

Electricity consumption can be saved 11 percent by utilizing variable speed motor. With 20 hp average motor utilization in Indonesia, availability 60% (5256 hours p.a.), capacity factor 80%, and load factor 60% this condition requires 37.64 MWh p.a. electricity with ordinary motors. By utilizing variable speed motor that condition only requires 33.20 MWh p.a., or 12% saving.

Cogeneration and diesel combined cycle are waste heat recovery technologies. Cogeneration is conversion technology that produces electricity and heat/steam simultaneously. This system can improve efficiency from 30% to 80%. Heat/steam is generated by utilizing waste heat from conventional power generation. Usually industries that use diesel, just throw away waste heat to atmosphere directly. Whereas waste heat can be use for heating hot water or produce steam. Theoretically, heating hot water utilize 80% of the total waste heat from industry, however generating steam can utilize only 60-70%.

Industrial cogeneration usually is a modification of the conventional power generation with installing additional heat exchanger. Based on the its output, cogeneration can be categorized as bottoming cycle and topping cycle.

Bottoming cycle uses 400-600 °C waste heat temperature as the input of the power generation. This high temperature waste heat is usually produced by heavy industry such as basic metal industry. Due to the medium temperature level, steam power generation performance also is not so high, therefore, steam power generation efficiency is relative low. This condition is the main reason why this technology has limited market share.

Another cogeneration technology, is topping cycles, differ with one before, the process of this technology is starting with generating electricity then by installing absorption chiller the waste heat can be used for various uses such as industrial processes, and air conditioning. Based on its main generation types, topping cycles cogeneration can be categorized as steam turbine cogeneration (STC), gas turbine cogeneration (GTC), and diesel engine cogeneration (DEC).

Due to the complicated modification needed for cogeneration installation, in the year 1995 the cogeneration utilization in the industrial sector accounted for 5% only. In the future, the new industrial design is assumed to use cogeneration. Share of cogeneration in the industrial sector is assumed to reach 25% for the year 2010 and increase to 40% for the year 2020. In term of the energy consumption, fuel for the power generation can be saved about 2.5% in the year 1995, 12.5% in the year 2010, and 20% in the year 2020.

Commercial Sector

According to the study of Research Agency of Bandung Institute of Technology it is shown that:

- energy consumption in hotels is 49 % for air conditioning system, 17 % for lighting system, 19 % for utilities system, 8 % for transportation system, 2 % for laundry system and others 5 %.
- energy consumption in office building is 56 % for air conditioning system, 15 % for lighting system, 17 % for utilities system, 15 % for transportation system and others 3 %.
- energy consumption for public building (such as hospitals) is 57 % for air conditioning system, 19 % for lighting system, 16 % for utilities and 3 % for laundry system.

- **Lighting**

Energy consumption for lighting in commercial, public and office building is about 15-19% of total energy consumption in this sectors.

Lighting in commercial building is provided by three types of systems: incandescent, fluorescent and high-intensity discharge (HID). As with residential applications, replacing incandescent lamps with CFLs in commercial building is a viable option. Fluorescent lighting systems are the most common type of lighting in commercial buildings.

A number of energy saving lighting controls is now on market, including multilevel switches, timers, photocell control, occupancy seniors and daylight dimming system.

- **Air Conditioning**

49-57 % of the electricity consumption of the two sectors are for air conditioning. As in residential sector, the reduction of energy consumption in this technology can be done by efficiency improvements include better internal insulation in the equipment, larger heat exchanger, higher evaporator temperatures, dual speed or variable speed compressor motors to reduce on-off cycling, more efficient rotors and compressors, advanced refrigerants and more sophisticated electronic sensors and controls.

- **Solar Collector**

Solar collector is used for heating warm water (< 50^{o}C) for hotel. Due to the geographical position of Indonesia this option has great potential. The usual ways for heating warm water consumes 130 kJ per liter, which shows that this purpose consumes about 10 % of the total energy demand for heating.

Power Generation

Power generation technology is growing, and the development power plant technology is adapted to be more environmental friendly. Power plant technology option in the BAU scenario such as gas combined cycle, coal fired with flue gas desulphurization and denitrification, nuclear, coal fluidized bed combustion, gas turbine and other conventional power plants have been taken into consideration. Technology mix result for the BAU scenario pure base on the economic perpective, in this scenario model only find the minimun cost. The efficient technology, such as nuclear power plant and coal fluideized bed combustion don't come into solution due to the high cost requirement for these plants.

In the Mitigation scenario the advanced power plant technology such as integrated coal gasification combined cycle, pressurized coal fluidized bed combustion, and fuel cell added to the model.

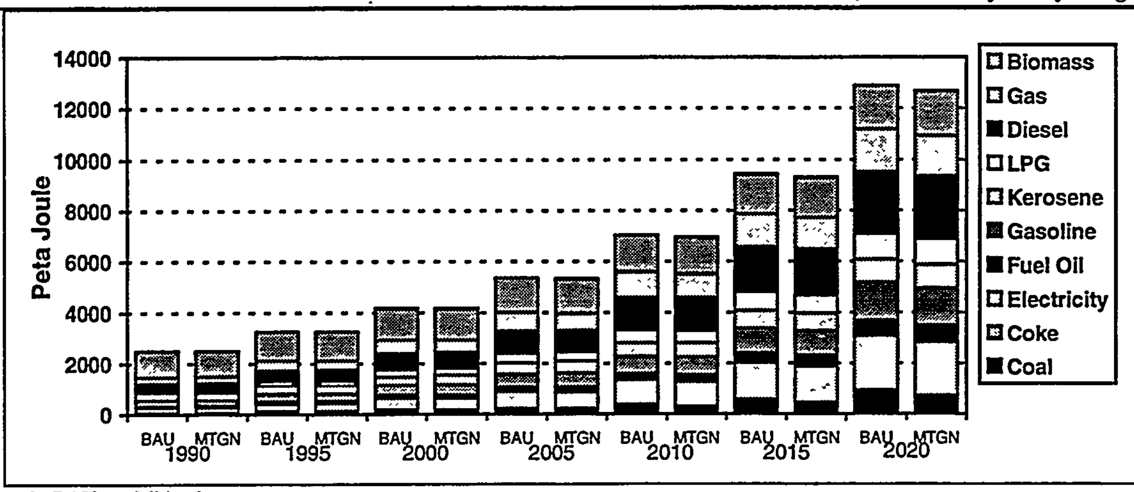
With regard to the non-fossil fuels, Indonesia have 75 GW of hydropower, and 16 GW of geothermal[3]. Actually Indonesia also have big reserve of natural gas but natural gas plant is far away from the demand (geographical constraint), therefore these resource not utilise maximum for domestic used.

MITIGATION SCENARIO RESULT

From the result of the BAU scenario, by introducing CO_2 constraint result, the MARKAL model calculates the optimal solution, an optimum energy system cost that produces less CO_2 emission.

Reduction of CO_2 emission by 10 % in the year 2005 and 20% in he year 2020 of its level in the BAU scenario will change the final energy mix. The demand of coal as a dirtiest final energy will be reduced by 8% in the year 2005 and 30% in the year 2020 compare to the BAU scenario result.

Some demand side management and energy conservation are already introduced in the BAU scenario, in the mitigation scenario this program will be more interesting ******. Lower final demand in the industry, and residential is advance achievement of these programs.

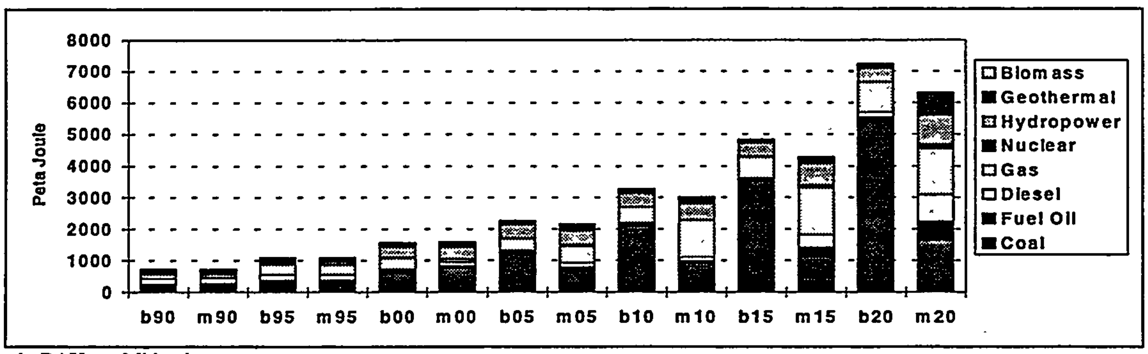


note: b=BAU, m=Mitigation

Figure 1 Comparison of Final Energy Consumption (BAU-Mitigation)

The mitigation result for the power generation is very different from the result for the demand sectors. The total fuel input for power generation is growing ten folds during 30 years from 700 Peta Joule in the year 1990 to 7000 PJ in the year 2020 for the BAU scenario. For the mitigation scenario, as a result of utilization of more efficient power generation the fuel input for power generation will decrease by 5% in the year 2005 and 13% in the year 2020 from that level in the BAU scenario. Total fuel input for the mitigation scenario in the year 2020 will be about 6300 PJ.

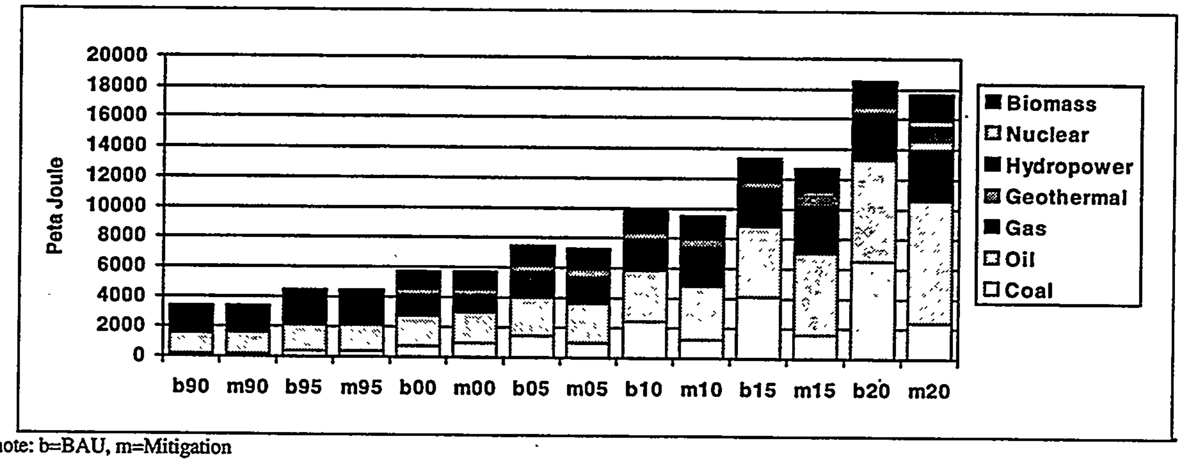
Fuel input mixes for power generation will also greatly differ For the BAU scenario coal will be the dominant fuel input, accounting for more than 75%, but for the mitigation scenario the domination will be disappear. Coal and gas will have similar share (25%) followed by hydropower and diesel fuel with more than 10% share respectively. Nuclear will come to the solution but still with limited share (2.5%).



note: b=BAU, m=Mitigation

Figure 2 Comparison of Fuel Input for Power Generation (BAU-Mitigation)

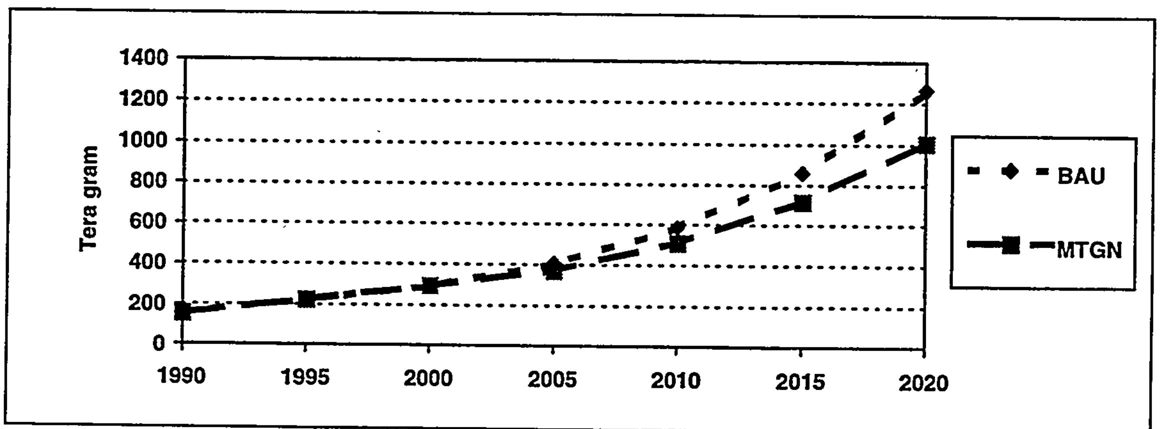
Total primary energy of Indonesia for the mitigation scenario will be lower than that in the BAU scenario, a reduction of 5 % in the year 2020. The primary energy mix will also be different. In the BAU scenario primary energy dominated by coal and oil, accounts for 25% respectively, followed by natural gas (16%). For mitigation scenario, oil will be the highest source, accounting for 47%, followed by natural gas (19%), coal share remains 13%, biomass (10%), and the remainder is supply by hydropower, geothermal and nuclear.



note: b=BAU, m=Mitigation

Figure 3 Comparison between Primary Energy Supply (BAU-Mitigation)

The projected total CO_2 emission for energy sector will grow at the rate of 7.4 percent annually from 150,600 Giga gram in the year 1990 to 1,264,500 Giga gram in the year 2020 for BAU scenario. The most possible target of the CO_2 mitigation is 10 percent reduction from the BAU scenario CO_2 level in he year 2005 and interpolated until 20 percent reduction in the year 2020. The CO_2 level for the mitigation scenario will grow one percent less than BAU scenario (6.5%) from 150,600 Gg in the year 1990, 374,800 Gg in the year 2005, and will reach 1,006,800 by the year 2020.



Tera gram = 1000 Giga gram = Million Tones

Figure 4 Comparison of CO_2 Emission

Cost Requirement

Energy diversification and other CO2 mitigation action will required another 43 billion US$89 discounted energy system cost during year 1990-2020 compare to 600 billion US$ (BAU scenario requirement). Annual investment requirement comprised of the private sector as well as goverment expenditure for energy system in the year 2020 will be 47 billion US$89 for BAU scenario more than 20 fold compare the annual investment in the year 1990. For the mitigation scenario the additional investment in the year 2020 will be about 3 billion US$.

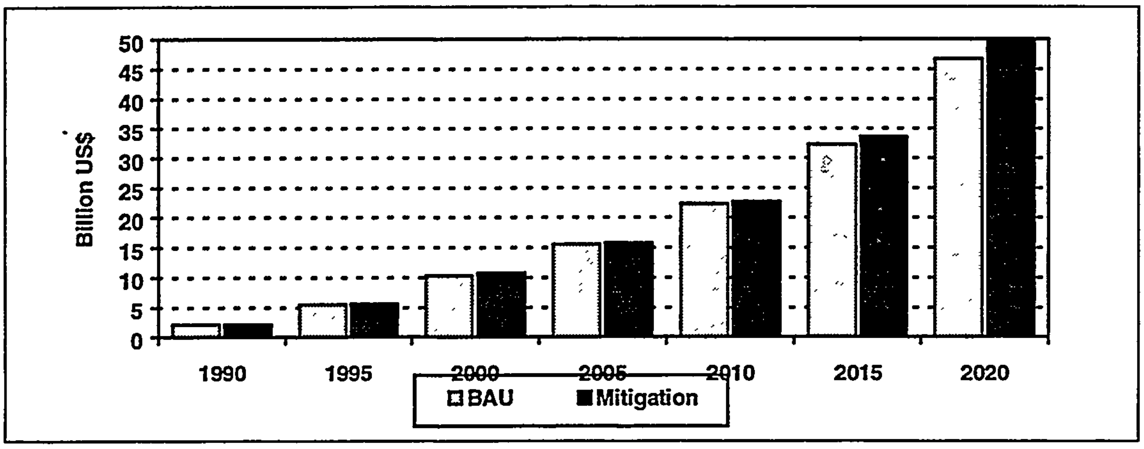


Figure 5 . Annual Energy System Invesment Cost Requirement by Scenario

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Development of the Mitigation Plan for Slovakia
Energy sector

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1. General

According to the review of national communications from Annex I countries (FCCC/AGBM/1996/7), Slovakia is in 21st place among countries in descending order of GHG emissions. With respect to GHG emission per capita Slovakia is in 14th place and from the point of view of GHG emissions per GDP unit Slovakia is in 7th place. However, within world wide GHG emissions those originating from Slovakia are nearly negligible, but GHG emissions related to per capita or even to GDP are significantly high. Since energy production is responsible for more than 70% of GHG emissions (88% of CO_2 emission) the high ranking of Slovakia is evidence of the high energy intensity of the Slovak Economy.

2. Position of Slovakia with regard to the Berlin Mandate

As is common in countries with economies in transition there is no stable trend in macroeconomical values in Slovakia. Although the general shape of possible development curves is known, in fact the exact level of the real curve is not predictable. The history of CO_2 emission in Slovakia is in accordance with the starting part of the curve (Fig.1).
According to our analyses the Slovak Republic surely will meet the basic UN FCCC obligation for Annex I countries, i.e. to limit anthropogenic emissions of GHG in the year 2000 to the level of 1990. However, the above mentioned uncertainties are the main reason why we have no firm guaranty of fulfilling our domestic target (20% CO_2 reduction in 2005 compared to 1988). Analyses made within the Country Study program have indicated that there is good possibility of reaching the domestic target but uncertainty is high and certain conditions have to be met.
In addition, due to expected trends of development (more or less steep increase) we are not sure we will be able to keep with the reduced GHG emission level beyond 2005. Therefore, the Slovak Republic can accept strengthening of the FCCC commitments as follows: 10% GHG emissions reduction in 2005 based on the 1990 emission inventory. Further reduction related to the year 2010 would require measures not yet considered realistic.

3. Measures with impact on GHG reduction

Carbon dioxide emission from fossil fuel combustion activities (excluding transport) is responsible for 71% of the overall GHG emission recalculated with GWP (Fig.2). This is why attention is focused primarily on measures in that sector. It is necessary to improve both implementation and effectiveness. The original purpose of those measures is not connected with climate change. However, the impact of the listed measures on GHG - and carbon dioxide reduction in particular - is substantial. Mitigation scenarios analyzed later deal with the intensity, extent and quality of implementation of the measures. In accordance with the first national communication of Slovak Republic, the most important measures are as follows:

- Act on production, distribution and consumption of heat

- addresses heat consumption efficiency in public sector

- Act on consumption tax

- tax exemption for owners of small hydropower plants, cogeneration cycles, renewables (wind, solar, biogas, geothermal)

- Liberalization of energy and fuel prices

- At the present time, energy prices in Slovakia do not reflect the production cost. The intention of the energy policy is to remove in stages the fuel and energy price subsidies. In the case of electricity, there is cross-subsidising with regard to the industrial v. the residential sector. In spite of the approved policy, subsidy removal from small consumers has been postponement couple of times as because it would potentially increase social tension. Recently (August 1996), the electricity price for small consumers was increased by 10% while for large industrial consumers by only 5%. Although it was a step in the right direction the price increase was strongly criticized by trade unions.
The coal price is also highly sensitive. Slovak mines produce low quality coal at high costs because of underground mining. To sustain employment in the region the coal price is subsidized. Natural gas price for small consumers is also subsidized.

- Programs for supporting energy saving
    - ⇨ Program supporting activities resulting in savings of energy and imported raw materials - annual savings about 2.3 PJ
      Projects for this program were chosen with an emphasis on savings and payback. Investments of total USD 36 million have been supported.
    - ⇨ Program supporting the building of renewable energy sources - the annual production of 8570 MWh
    - ⇨ Program of additional insulation and removal of defects in apartment houses - the annual savings about 120 TJ
      Governmental subsidies are provided to owners of apartment houses for improvements of thermo-insulating properties of building structures.
    - ⇨ Program of energy consumption reduction in apartment and family houses - annual savings about 130 TJ
      The program is designed for owners of apartment and family houses and their heat suppliers. The maximum support for one project is USD 10 for 1 GJ saved heat per year or 17 USD for 1 MWh of electricity saved per year.

- Air Protection Act

- surprisingly the most effective measure for CO_2 emission reduction
According to this law and related regulations existing sources of emission have to comply with a set of emission standards expressed as pollutant concentration in flue gas. the deadline for compliance with the first level of emission limits is 31 December 1998. There is no limitation of CO_2 but for fossil fuel combustion the standards for SO_2 also highly important from the point of view of CO_2 emission reduction.

For numerous boiler operators/owners the fuel switch from coal (or heating oil) to natural gas is the most convenient way to fulfil the required emission limits. In addition, in many cases it is also the least cost solution. The specific price of 1 GJ for coal is comparable with the price of natural gas and in case of coal there are costs for waste disposal to pay and the need to install and operate equipment for fly ash and sulphur dioxide emissions control. Since the emission factor of CO_2 per 1 GJ produced is significantly higher for coal the fuel switch option is positive with regard to SO_2 emission reduction as well as CO_2 emission reduction.

4. The baseline scenario

The baseline scenario has been defined as the behavior of the society (producers, consumers, government etc.) if no action to reduce greenhouse gases emission is needed. Thus carbon dioxide emission reduction is not required and is not taken in account as motivating factor in decision making.
Under such a condition a set of key elements was assumed to be in force:

- Public and industrial energy production

All boilers will comply with required emission limits either by replacing of outdated coal and oil boilers with new or retro-fitted equipment with abatement technology in order to achieve emission limits.
Options considered:

⇨ fuel switch from coal/oil to natural gas
⇨ lower sulphur coal
⇨ desulphurization - wet scrubber, semidry, dry
⇨ fluidised bed combustion
⇨ combined cycle and boiler retrofit in order to achieve higher efficiency

- Electricity production

The baseline scenario assumes the electricity production from nuclear power plants remains at current levels during the analyzed period. Power supply from nuclear power plant in Bohunice will be replaced by production from the new nuclear power plant at Mochovce.
The structure of the electricity supply system plays a positive role in the CO_2 emission level. The fact that more than 50% of electricity is produced from non-fossil sources (nuclear and hydropower) causes the low level of aggregate CO_2 emission factor (226 kg CO_2/MWh) for electricity from the grid.

- Prices

The heat price will continue to be regulated and subsidized in order to keep low price level and partially cover a limited price increase in following years. Electricity and natural gas price will also be subsidized.

- Transportation

Road transport is the source of approx. 90% of CO_2 emissions from transportation. The baseline scenario assumes the growth of transportation to be proportional to the GDP growth with some positive impact due to the improvement of the energy efficiency of vehicles engines.

- The GDP growth

For the period 1995-2010 the average annual GDP growth was assumed to be 5.4%. Separate GDP projection for relevant sectors of the economy was made (Fig.5 for selected sectors). No different scenarios for GDP development have been constructed. The energy demand for each sector is consequently based on respective GDP development.

Understanding the baseline in accordance with the definition above, we had to include all measures taken to comply with the Air Protection Act. Since the Act is currently the most powerful force for GHG reduction, substantial GHG reduction is already included in the baseline.

5. The analysis of available options

In order to prepare the CO_2 emission scenarios and to analyze the possible CO_2 mitigation options, the following steps and sector breakdown were used:

I. Analyzing and modelling the system of electricity and heat supply from public power plants, cogeneration and heating plants.

II. Analyzing and modelling the system of district heat supply from local private and municipal heating plants

III. Bottom-up analysis and CO_2 scenarios modelling of each of the following sectors:

Industrial sector:

- chemistry
- metallurgy (except steel production, see item V)
- machinery
- pulp & paper industry
- construction materials (cement, lime, bricks, etc.)
- food production- wood products (furniture, etc.)
- other industry

Construction

Agriculture and forestry

Services (hospitals, institutions, schools etc.)

Retail

Residential sector (part of energy consumption not covered by the centralized supply)

IV. Analyzing of the transportation system

V. Analyzing steel production in VSZ Kosice enterprises (the source with the largest share of CO_2 emission

VI. Data aggregation and total energy sector modelling.

Since the Air Protection Act is to be fully effective in the beginning from the point of view of influence on emission limits on behavior the main task was to analyze the impact of the Act on CO_2 emission levels.

As shown in the Table 1 and Figures 3a-c for the industrial and nonindustrial sectors and for district heating supplies, the efficiency increase and fuel switch from coal to gas are the most effective measures with the highest CO_2 reduction potential. Introducing combined cycles would lead to significant CO_2 reduction as well, but typically needs more than twice the cost per tone of CO_2 saved. Cost is understood as an investment cost (discount rate 8%) and the cost of fuel burned within a lifetime of 25 years. From the industrial sector measures for iron and steel enterprises VSZ Kosice are excluded; however, they are taken in account in the construction of scenarios.

6. CO_2 emission scenarios

6.1 Industrial and nonindustrial sectors

Scenarios for industrial (Fig.4a) and nonindustrial (Fig.4b) sectors are described as follows:

Scenario 1: The fuel switch and new technology implementation is assumed for outdated boilers that have to be replaced anyway within the analyzed period. No carbon tax.

Scenario 2: The fuel switch and new technology implementation is assumed at boilers that have to take measures to comply with emission limits within the analyzed period. No carbon tax. This is in fact the baseline scenario.

Scenario 3: The fuel switch and new technology implementation is assumed at boilers that have to take measures to comply with the emission limits within analyzed period. A carbon tax at the level of 10 USD/t CO_2 is imposed.

The solid line in Fig.4a and 4b corresponds to scenario 1. The impact of applying emission limits to all regulated boilers (scenario 2) is expressed by the dashed curve. This is almost identical with scenario 3 meaning that, imposing of a carbon tax, even at relatively high level (approx. 50-100% from coal price), has practically no effect on CO_2 reduction. This is because within the effort to comply with the applied emission limits, low cost options will be chosen. Only relatively expensive additional CO_2 mitigation options will be left. Imposing a carbon tax at the same time as emission limits compliance is required would cause decisions to be made in favour of more expensive options with higher CO_2 reduction in a few cases only. The main reason for it is the lack of financial means for investments in hence investors are looking for the least cost investment options even if not so profitable in the long-term. In addition, the investor's choice is also influenced by the availability of alternatives. Presently, there is a dearth of viable and readily accessible alternatives to fossil-fuel energy sources.

6.2 Centralized heat supply

The influence of emission limits, heat and fuel price regulation and the imposition of a carbon tax imposing has been considered in constructing scenarios. Scenario 2 corresponds with the baseline as defined above.

As can be seen on Fig.4c, there is a relevant CO_2 emission reduction expected under conditions of scenarios 3, 5 and a little less reduction scenario 6. The significant attributes common for the scenarios 3 and 5 are subsidy removal and deregulation of heat price while keeping fuel and electricity price regulated. Electricity price is important because the competitiveness of this medium, if the heat price is increased. Scenario 6 shows the slowing effect of the deregulation of fuel/electricity price on CO_2 emission reduction. The difference between scenario 3 and 5 is in the imposed of a carbon tax. In the sector of centralized heat supply the most positive option is clearly the removal of the subsidy from the heat price and general price deregulation.

6.3 Electricity generating system

Scenarios of electricity supply sector (Fig.4d) are described as follows:

Scenario 1: Electricity is produced from the nuclear power plant at the same level (i.e. 4x440 MWe installed capacity). The retired NPP Jaslovske Bohunice is replaced by a new NPP Mochovce with the same electricity output.

Scenario 2: After closing down of NPP Jaslovske Bohunice no electricity is produced from nuclear power. Electricity demand is covered by new combined cycles.

Scenario 3: After closing down of NPP Jaslovske Bohunice only half of the original electricity output is produced from NPP Mochovce (i.e. 2x440 MWe installed capacity). The rest of the electricity demand is covered by new combined cycles.

Scenario 4: After closing down of NPP Jaslovske Bohunice only half of the original electricity output is produced from NPP Mochovce (i.e. 2x440 MWe installed capacity). Electricity demand is covered by coal-fired power plants equipped with additional fluidised bed combustion.

It is no surprise that the lowest CO_2 emission level is forward in the case of keeping the whole electricity output from nuclear power on the original level. In case of the scenario 2, production of such volume of electricity that is produced in present time from NPP would increase release of CO_2 by approximately 8000 Gg (22 % of CO_2 from energy production in 1994) if produced from fossil fuel (the combined cycles).

6.4 Iron and steel enterprises VSZ Kosice

The steel production in VSZ Kosice represents the biggest CO_2 source among individual enterprises (19% of CO_2 emission in 1994). The energy supply - steam and electricity - is assured by 6 boilers using anthracite as the main fuel and process gases as the auxiliary fuel.
The electricity grid of the VSZ is connected with the national transmission system and VSZ participates in the electricity supply regulation. Nevertheless, the total yearly balance is in equilibrium. In our modelling the electricity produced in the VSZ is balanced separately from the national electricity grid. The electricity and heat demand as well as the cocking coal and other energy inputs are driven by the steel demand for production.

The modelling of the VSZ considers two scenarios only:

Scenario 1: (the baseline scenario) with the present technology and present industrial energy source. The use of low sulphur coal imported from Russia will ensure of the requirements of new emission limits for SO_2 and other pollutants are met.

Scenario 2: (the mitigation scenario) with the implementation of continuous casting and combined cycle. The combined cycle will include a gas turbine heat recovery steam generator in order to supply the steam in the operating steam turbines. As the fuel in the gas turbine, natural gas is designed. In the heat recovery boiler the blast furnace and converter gases will be used to obtain the superheated steam of the same parameters as from the current coal boilers.

The results of modelling are presented in Fig.4e. Implementing of the combined cycle and continuous casting will bring the reduction of CO_2 emission to the level of 550 Gg in the year 2000 and 524 Gg in 2005.

6.5 Transport

Transport in Slovakia is responsible for only 10% of GHG emission (1994). There are no reliable assessments of the impact of possible measures addressed to GHG reduction. That is why only a baseline emission projection has been made and no scenarios constructed (Fig.4f).

6.6 Aggregated energy sector modelling

In the aggregated model three scenarios were applied.

Scenario 1: pessimistic scenario that expects no or only poor implementation of emission limits

Scenario 2: the baseline scenario with the full impact of emission limit implementation

Scenario 3: represents the scenario with the impact of the following mitigation options:

- DSM
  The total yearly electricity conservation of 742 GWh has been estimated.
- Continuous casting and combined cycle implementation in metallurgy enterprise VSZ Kosice.
- Residential sector
  Energy saving measures as assessed within several studies. The realistic decrease of heat demand is considered on the level 15.6 PJ and is based on better insulation and implementation of delivered heat measuring for individual flats.
- Nonresidential buildings
  Energy saving measures representing a total decrease of 60% of heat demand is achieved in the year 2005.

The aggregated scenarios as the results of modelling are presented in Fig.6. Differences in the year 2000 between scenarios 1, 2 is 357 Gg and between scenarios 2, 3 is 1648 Gg CO_2. In the year 2005 the differences are 487 Gg and 2223 Gg respectively. The distance between scenario curves represents in the year 2000 less than 5% of total value. However, values of scenario 1 are over the domestic target level after the year 2002 and values of scenario 2 are over the target after the year 2003.

7. Summary and discussion

Having all the analyses and modelling completed the most effective measures could be identified as follows:

- increase in boilers effectiveness
- fuel switch (as a consequence of emission limit implementation)
- deregulation of heat price while keeping fuel and electricity price regulated
- unchanged level of the electricity production from nuclear power plants
- continuous casting and combined cycle implementation in VSZ Kosice enterprises

Imposing of a carbon tax, even at relatively high level (approx. 50-100% from coal price), has surprisingly, practically no effect on CO_2 reduction. On the energy production side it is because all low cost options will be chosen within effort to comply with applied emission limits. On the demand side it will not affect consumers' behavior because while heat and electricity prices are under regulation the energy producers would cannot include any part of the cost increase into the consumer price. Thus there will not be higher motivation for energy savings.
Deregulation of fuel and electricity price although having a with negative effect on carbon dioxide reduction should be applied together with deregulation of the heat price in favour of price system consistency.Introduction of emission limits is measure with a high positive impact on carbon dioxide reduction through the most frequently accepted option, i.e. fuel switch. Recently the pressure towards postponing the deadline for complying with emission limits is getting stronger from source owners. It is highly probable that effort will be successful, although to what extent is not yet known. Regardless of the time frame introduction of emission limits can move the CO_2 emission curve to the right only but cannot lower the angle of increase significantly. That can be reached through a change of economic structure towards less energy intensive GDP production.
The above listed measures are not equally feasible:

- The increase in boilers effectiveness will proceed continuously due to the necessary equipment modernization.
- The fuel switch depends on the timing of emission limit enforcement, but sometime within 10 years it will take place.
- The nuclear program is highly dependent on the availability of financial resources. It is almost certain that electricity production from NPP will not be lower in the future than at the present time.
- The continuous casting and combined cycle implementation in VSZ Kosice enterprises is not implemented from the governmental level since VSZ Kosice enterprises are privatized and there is no reason to use legal tools for the enforcement or encouragement of such an action. There is only one possible force: the market.
- Last but not least: deregulation of the heat price within the five year time frame is unlikely.

The above listed measures represent the current base for the mitigation plan. Since all but the last one (the deregulation of the heat price) are either out of the influence of government or in force already the main effort should be focused on the heat/energy price system. Related auxiliary measures addressed to energy saving should not be forgotten.
Within the Slovak Country Study a first - and only general - draft of action plan to mitigate climate change is expected to be prepared. This will be worked out in detail in the framework of the Slovak Action Plan that should describe specific measures to be taken by particular enterprises.
Efforts will be focused mainly on measures for complying with the Air Protection Act. The time frame for elaborating of the Slovak Action Plan is dependent on when and in what volume financial resources will be available (domestic or from abroad).

8. Conclusions

There are high uncertainties of the projection of both the methodological nature and applicability of individual mitigation measures.Methodological uncertainties are very difficult to overcome currently because all the relevant economical values in Slovakia are not developing in clear trends. This is typical for countries with economies in transition. For that reason there is no firm base for extrapolation and all forecasts have very weak base. In addition, our economical system is still establishing the rules (within the taxation system, privatization, anti-monopoly system, bankruptcy procedure etc.) and each newly introduced rule has a significant impact on subsequent development. However, it is difficult to foresee within a 15 year time horizon what rules will be approved for introduction let alone their influence on the future behavior of the emission sources.

There are several barriers towards the implementation of mitigation measures, all of them basically of a political nature.

The leading priority in budgetary policy in Slovakia is strongly weighted towards obtaining high incomes into the state budget. All expenditures viewed to be not urgent or of high importance are ignored. In accordance with that, no new positive incentives have a chance to be approved (e.g. tax exemptions). Furthermore, the expenditures for environmental investments are limited only those necessary.Emission limits introduction requires relatively high financial expenditures both from private and public (the state budget) sources. The postponing of emission limits introduction would be facilitated by the low ranking of environmental issues within the governmental expenditure priority list. In addition, the number of emission sources are substantial e.g. for public heat supply and that is why it is not possible to apply legal consequences for not complying with required emission limits - shutting down of the emission source. **It is already obvious that carbon dioxide reduction due to the introduction of emission limits will be in full force later than expected.**

The Slovak Government is not willing to increase social tension. For that reason energy price deregulation is going very slowly and significant progress in this field is not expected in the near future. Another factor working against investments in a more effective electricity production is the existing monopoly of the Slovak Power Plants enterprise that is the only electricity producer in Slovakia. The company is in state ownership.

For social reasons (i.e. to sustain employment in region) the price of indigenous coal is subsidized despite its low quality.

As a consequence, scenario 2 from aggregated carbon dioxide emission scenarios (identified as the baseline scenario) is not very likely. Although the UN FCCC target will be kept in the year 2000, the CO_2 emission level of the year 1990 might be exceeded within 10-15 years. Further analysis will have to be carried out and additional mitigation options proposed and if evaluated as effective, also implemented. Negotiations on energy price deregulation should proceed on the interministerial level to speed up the process.

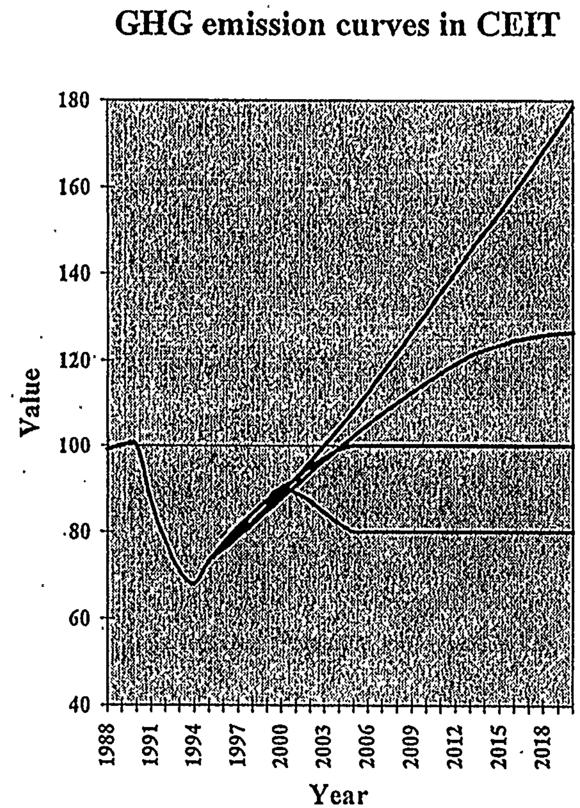
GHG emission curves in CEIT
Value
180
160
140
120
100
80
60
40
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
Year

Fig. 1

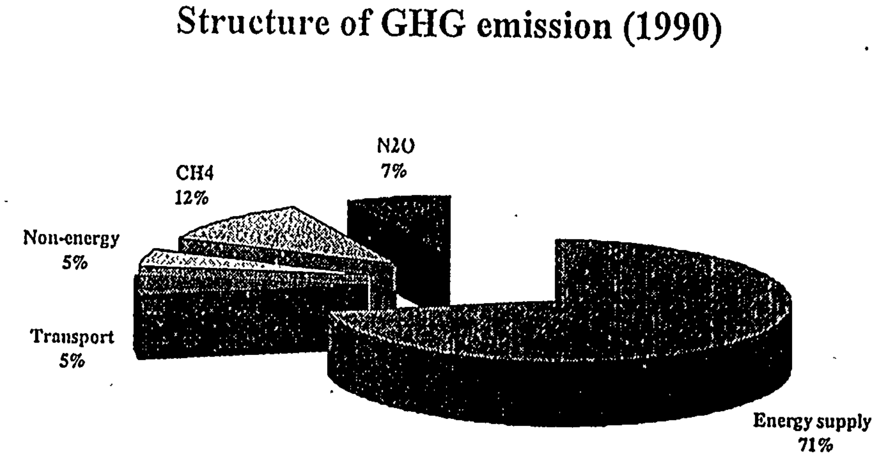
Structure of GHG emission (1990)
N2O
7%
CH4
12%
Non-energy
5%
Transport
5%
Energy supply
71%

Fig. 2

Costs of CO_2 mitigation

Measure	CO_2 specific cost [USD/tCO_2]	Reduction potential [tCO_2/y]	Yearly costs [mil.USD]
INDUSTRIAL SECTOR			
Efficiency increase	33.3	98 242	3.3
Fuel switch coal/gas	40.8	958 256	39.1
Fluid	42.6	4 335	0.2
Combined cycles	57.3	1 035 733	59.3
Low sulphur coal	105.2	108 155	11.4
NON-INDUSTRIAL SECTORS			
Efficiency increase	-61.8	9 571	-0.6
Fuel switch coal/gas	52.1	24 488	1.3
Combined cycle	114.3	21 666	2.5
Low sulphur coal	167.8	11 951	2.0
CENTRALISED HEAT SUPPLY			
Efficiency increase	- 54.8	35 468	- 1.9
Fuel switch coal/gas	38.6	83 519	3.2
Fluid	69.9	1 356	0.1
Combined cycle	105.1	24 018	2.5
Low sulphur coal	168.2	17 125	2.9
	[USD/tCO_2]	[tCO_2/y]	[mil.USD]

Tab. 1

Costs of CO_2 mitigation
Industrial sector

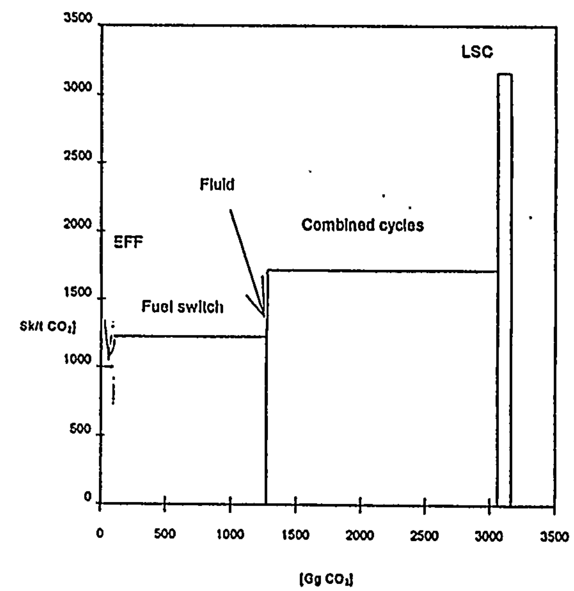

Fig. 3a

Costs of CO_2 mitigation
Non-industrial sectors

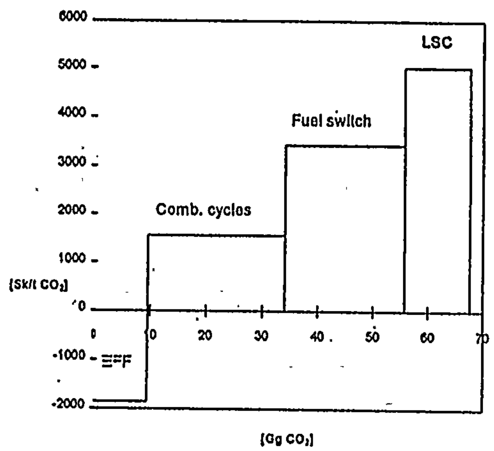

Fig. 3b

CO_2 emission scenarios - Industrial sector

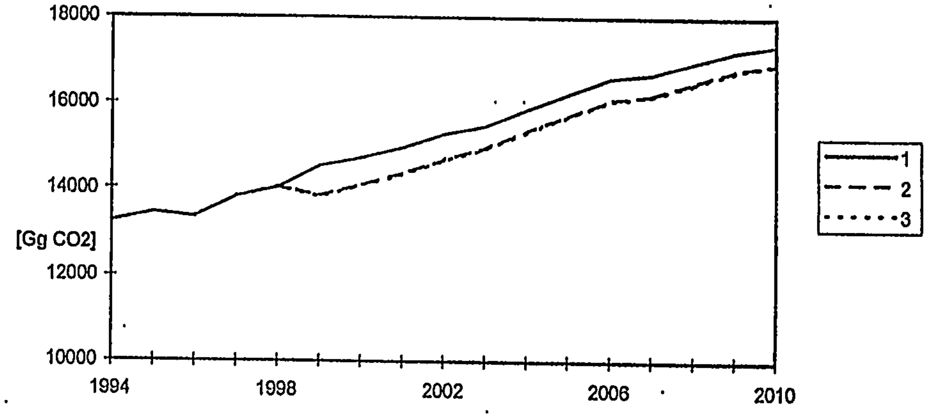

Fig. 4a

The costs of CO_2 mitigation
Sector of local district heating supply

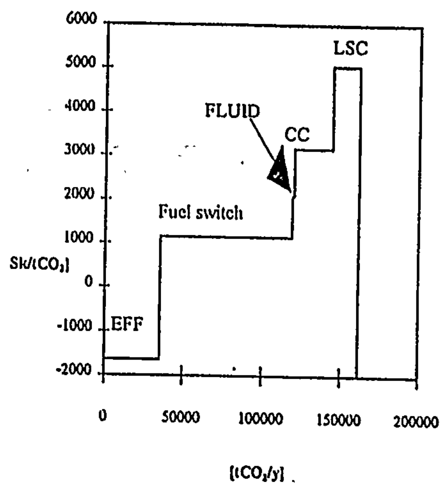

Fig. 3c

CO_2 emission scenarios - Non-industrial sectors

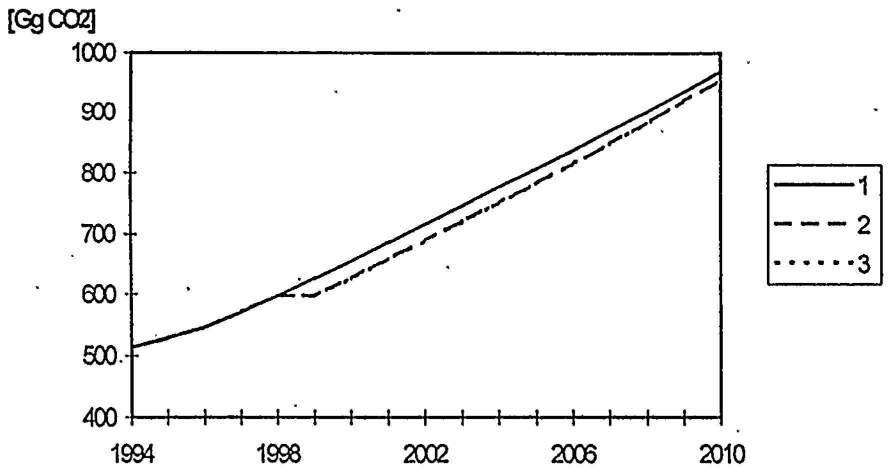

Fig. 4b

CO_2 emission scenarios - Sector of centralised heat supply

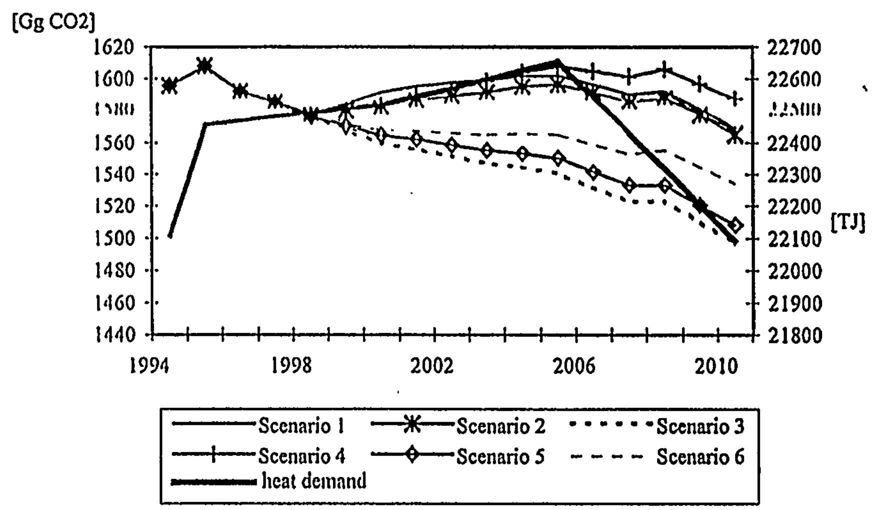

Fig. 4c

CO_2 emission scenarios - Electricity generating system

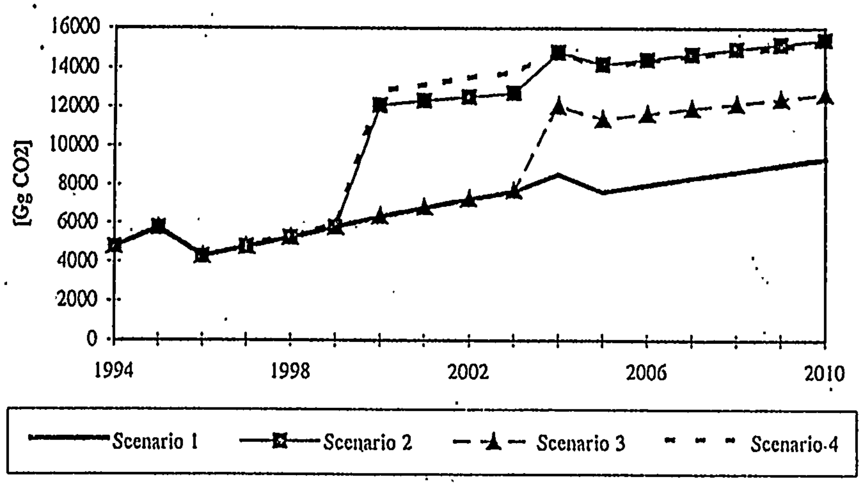

Fig. 4d

CO_2 emission scenarios - Transportation

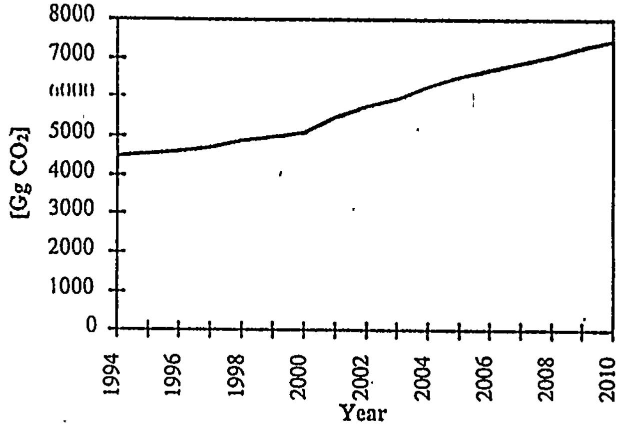

Fig. 4f

CO_2 emission scenarios
Iron and steel enterprises VSZ Kosice

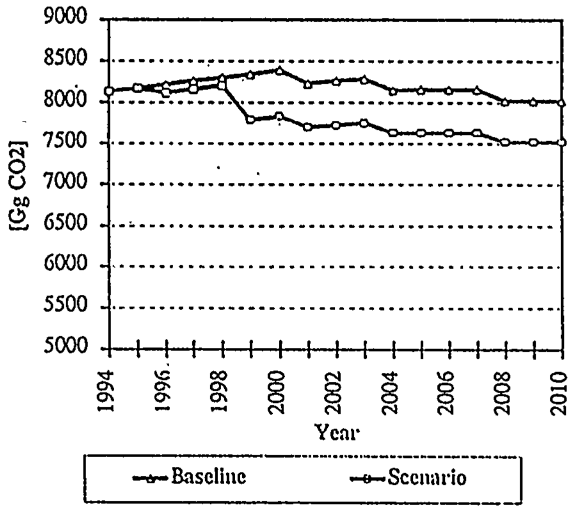

Fig. 4e

The GDP projection - sectoral split

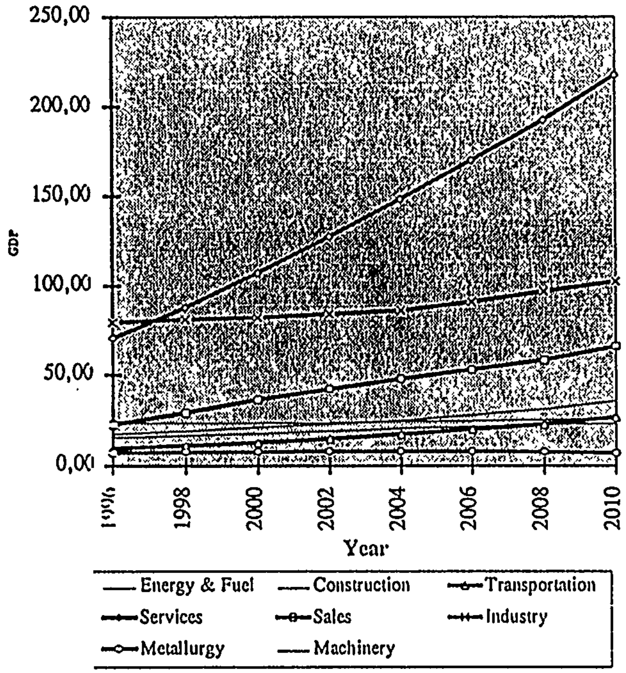

Fig. 5

CO_2 emission aggregated scenarios

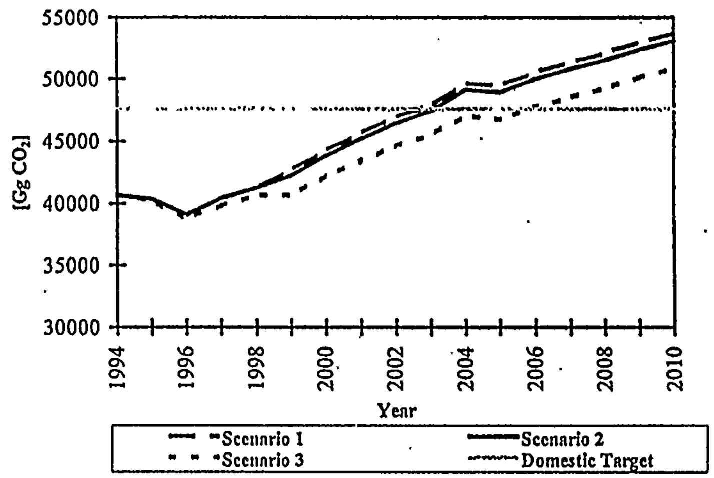

Fig. 6

Mitigation Measures and Programs in Hungary

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1. Introduction

In Hungary there are four main governmental programs, which may result in a decrease of emissions of anthropogenic greenhouse gases (GHGs):

- National program of energy efficiency improvement and energy conservation
- Afforestation program
- Volatile organic compounds (VOC) emission reduction program
- Program to reduce the use of oyone depleting substances

These ambitious programs were launched in the beginning of the 90's, but they have been slowed down because of budgetary problems. The comprehensive action plan for mitigation of GHG emissions should be based on these ongoing programs. These programs should be expanded by further measures and programs in order to fulfill the requirements of the FCCC. In the next sections the results and prospects of the above mentioned programs will be summarized. Also the results of the mitigation study supported by the U.S. Country Studies Program are included.

2. Energy efficiency improvement and energy saving

2.1 National energy saving program

The efficient use of energy should become the general habit of the actors in the economy. To reach this purpose, the preparation of the National Energy Efficiency Improvement and Energy Conservation Program was started in 1991. The Resolution of the Hungarian Parliament (21/1993./IV.9/OGY) prescribes that a program should be presented to promote energy saving, conservation, and efficiency increasing. The Ministry of Industry and Trade has elaborated the concept of the program. The Government accepted it in April, 1994.

The basic idea of the program was to set up an operational capability for the energy conservation. The main goals of the energy saving program can be summariyed as follows:

- Environmental protection
- Reducing the dependency on imports
- Saving domestic energy resources
- Postponing the construction and installation of new base load power plants
- Increasing the competitiveness of the economy

Adjusment to the energy policy of EU and to the OECD/IEA recommendations
As a result of such a program, the GHG emissions can be reduced, too.

Two targets for medium-range (by the end of a 10 year period) and other two targets for long-term (15 years) were set up. The minimum target has the following key assumptions:

- The annual growth rate of GDP is expected to increase in the next years after a long period of economic recession (cca 2-3 %/year).

- The price system of energy carriers should reflect the realistic expenditure and the cross-financing should be ceased.

- Energy awareness should be developed as a consequence of price rising of the energy carriers.

Table 2.1 presents the expected benefits of the program.

Table 2.1. Summary of targest, expenses and benefits of the energy saving program

Target	saved energy PJ/year	saved energy cost M USD	total investment M USD	relative investment M USD/PJ
medium term minimal	63.7	373.0	422.0	6.6
medium term maximal	124.4	708.0	1250.0	10.0
long term minimal	193.4	1120.0	2148.0	11.1
long term maximal	309.3	1739.0	4036.0	13.0

The breakdown of medium term minimal is presented by Table 2.2. Saving potentials have been estimated by the experts of the Ministry for Industry and Trade.

Table 2.2. Possible energy saving (per year) by measures and by sectors

Energy conservation measures (savings in PJ)	energy sector	industry	agriculture	transport	communal	residential	Total
1. Energy awareness	1.0	6.5	2.0	4.0	7.0	14.0	34.5
2. Updating energy technologies in industrial production		2.0					2.0
3. Updating energy technologies in agriculture			0.5				0.5
4. Efficiency improvement of energy production equipment	0.2						0.2
5. Efficiency improvement of energy transportation	2.5	0.5					3.0
6. Efficiency improvement of consummer's equipment	0.3	0.7	0.5		1.0	2.0	4.5
7. Reduction of energy transmission and distribution losses	0.6	0.8					0.4
8. Cogeneration	2.7	1.0					2.8
9. Improvement of energy management in duildings	0.3	0.5			1.0	1.0	2.8
10. Improvement of thermal insulation		1.5					1.5
11. Optimising the public transport cooperation				5.0			5.0
12. Reduction of energy consumption of vehicles				4.5			4.5
13. Use of renewable energy resources		0.1	0.4		0.2	0.3	1.0
Overall energy savings (PJ)	**7.6**	**12.7**	**3.4**	**13.5**	**9.2**	**17.3**	**63.7**
Total energy comsumption (PJ)	327.5	219.3					1046.5

A wide range of energy rationalisation and diversification programs has been supported by the World Bank for the last decade:

- The first agreement ("Energy Rationalisation and Diversification I") was signed in 1983 and the program finished with success in 1990. The total amount of the loan was 109 M USD.
  The main goals were as follows:
  - Energy saving
  - Fuel switching
  - Energy intensity decreasing
  - Structural changes
  - Investment of effective products and technologies
- The second loan agreement ("Energy Rationalisation II") was signed in 1986 (24 M USD) and finished in 1993. It was subdivided to two subprogrammes (A and B). The goals of programme "A" are similar to the terms under the Loan I (above), whilst programme "B" developed and established a new energy saving monitoring and evaluating system.
- The third loan programme ("Energy Rationalisation III") agreement was signed in 1989, the deadline was 1995, the total amount of the loan is 10 M USD. The main aim is energy related investments with direct energy saving.
- The fourth loan agreement ("Energy and Environment") was signed in November 1993 the amount is 100 M USD. The loan is raised by the Hungarian Power Company Ltd. The main goals are the next:
  - A new combined cycle co-generation power plant unit
  - New dispatching center
  - Enhanced environment monitoring system
  - Human resource management system development

The planned deadline is the end of 1999.

In 1991 the German Government made 50 million DEM available to support the purchase of coal by households in order to offset the unsatisfied demand for coal in Hungary ("German coal aid" energy saving credit tender system). On the basis of an agreement signed by Germany and Hungary the Government declared that 60 % of the amount received from the sale of coal, worth 50 million DEM, may be spent on preferential credit facility aimed at energy saving.

This soft loan program based on the financial service of the Hungarian Credit Bank, which developed a credit tender system with the following aims:

- Improvement of end-use efficiency,
- Reduction of energy loss,
- Utilisation of energy optimising technologies,
- Waste-heat utilisation,
- Renewable energy utilisation,
- Peak demand reduction,
- Computer controlled processing system with energy saving,
- Improved heat insulation systems,
- Lighting system modernisation.

In the last three years there were 139 applicants with 25 M USD total investment demand and with 177 M USD soft credit demand. The Tender Jury accepted 57 applicants with 72 M USD loan demand (total investment 95 M USD). The implementation of the accepted tenders resulted about 1.7 PJ in the overall energy saving. The estimated financial benefit of this energy saving is cca. 5 M USD/year.

2.2. U. S. Country Studies Program

Within the framework of the U.S. Country Studies Program, we chose the ENPEP (Energy and Power Evaluation Program) program system to develop mitigation scenarios for the energy sector. The emissions of three greenhouse gases, namely the CO2, the CO, and the NOx were modeled. In our model runs, we focused on the power generation and on the district heating. For these activities, there are several opportunities to abate the environmental pollution. In particular, the following measures are planned in the near future:

- Fuel switch to less polluting energy carriers
- Retirement of aged power plants of low efficiency

- Construction of fluidiyed bed units and combined cycle gas turbines
- Construction of a new nuclear power plant
- Increasing of the share of cogeneration in the electricity and heat supply

In our model runs, although we calculated the emissions of all the economic sectors (power sector, district heating sector, industry, households, services and transportation), we focused on the power sector in the development of the scenarios, as this is the most controllable sector. We examined two types of scenarios for the power sector: in the first one we supposed that a rather drastical retirement program will be realized, while in the second one we did not consider any retirements. For the end-use sectors, we did not assume any difference in terms of the possible end-use technologies, but we examined three demand growth scenarios, a low, a medium and a high demand growth scenario. Thus we examined six scenarios altogether:

- Case A: high final energy demand growth rate and the retirement program will be realized
- Case B: medium energy demand growth rate and the retirement program will be realized
- Case C: low energy demand growth rate and the retirement program will be realized
- Case D: high final energy demand growth rate and the retirement program will not be realized
- Case E: medium energy demand growth rate and the retirement program will not be realized
- Case F: low energy demand growth rate and the retirement program will not be realized

Figures 2.1. and 2.2. show the the final energy demands, Figure 2.1. shows the total final energy use by the three different base cases, while Figure 2.2. shows the final energy use by sectors and by cases.In Figure 2.2. only the name of the sectors are indicated, the order of the colums corresponds to the values for the high, medium and low demand scenarios, respectively.

Figure 2.1. Final energy demand in Hungary by cases

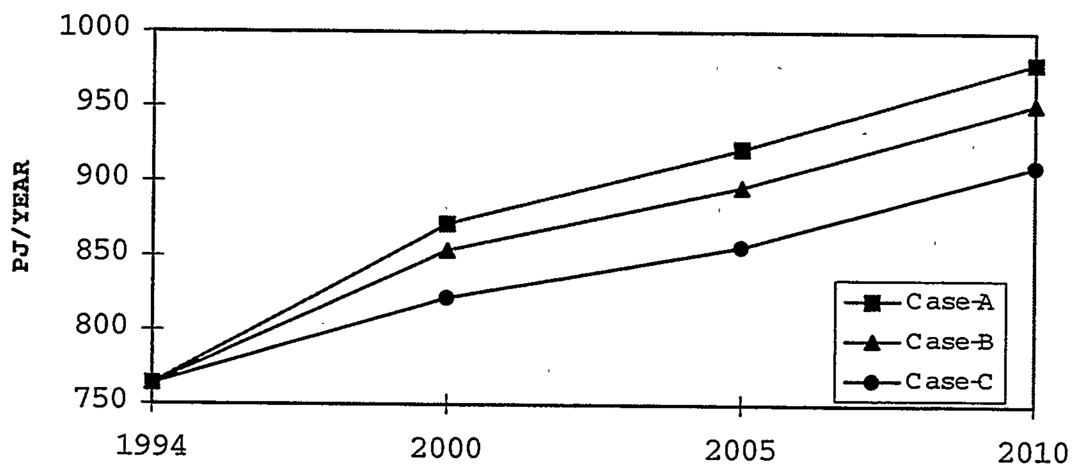
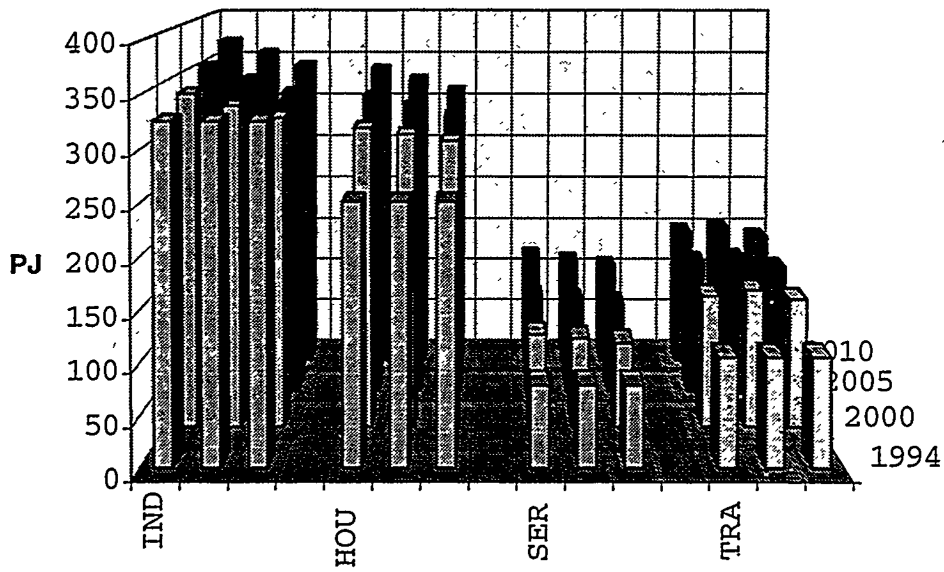


Figure 2.2. Final energy demands by sectors



Figures 2.3 through 2.5 contain the main parameters of the scenarios. Figure 2.3 shows the existing capacities by fuel type till 2010 for the cases in which the retirement program will be realized,i.e. for scenarios A-C. In scenarios D-E, we do not assume any retirements, thus the existing capacities remain the same for the whole period. Figure 2.4. shows the possible new capacities for scenarios A-C, while Figure 2.5 shows the same for scenarios D-E. As far as Figures 2.3. through 2.5. are concerned, we have to mention that the data shown in the figures correspond to the input data of the model runs, where the reconstructed power plants and the power plants with fuel switching are also modelled as retired and at the same time newly built capacity. In Figure 2.3, the cathegory „other" means those power plants which are small cogeneration units with different types of fuels, this part of the power sector is considered as constant.

Figure 2.3: Existing capacities for scenarios A-C

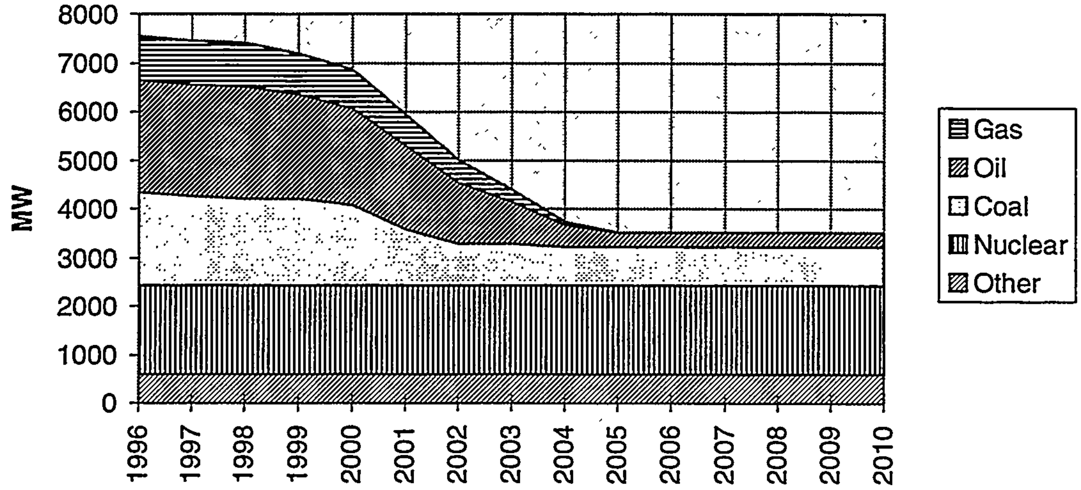


Figure 2.4: New capacities for scenarios A-C

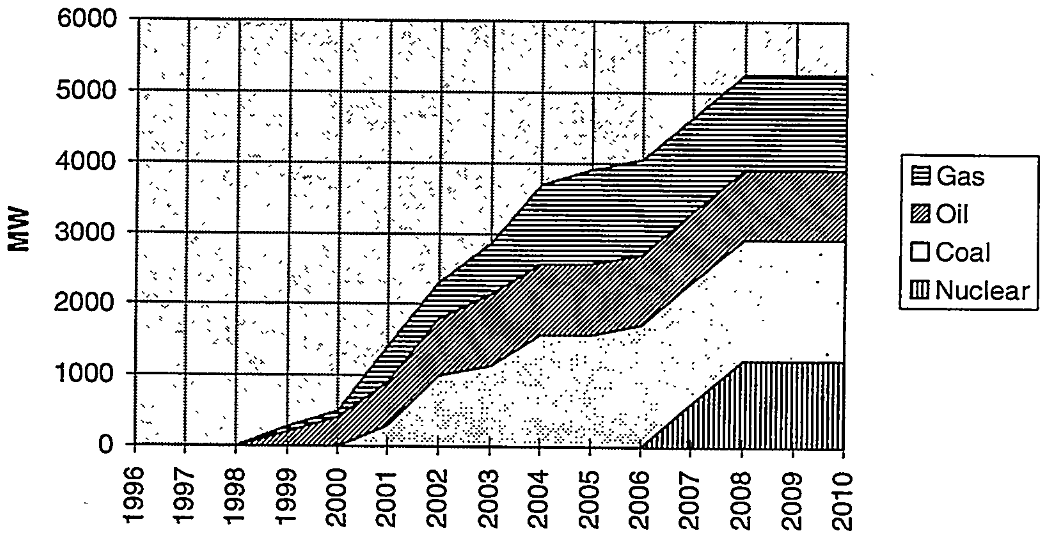
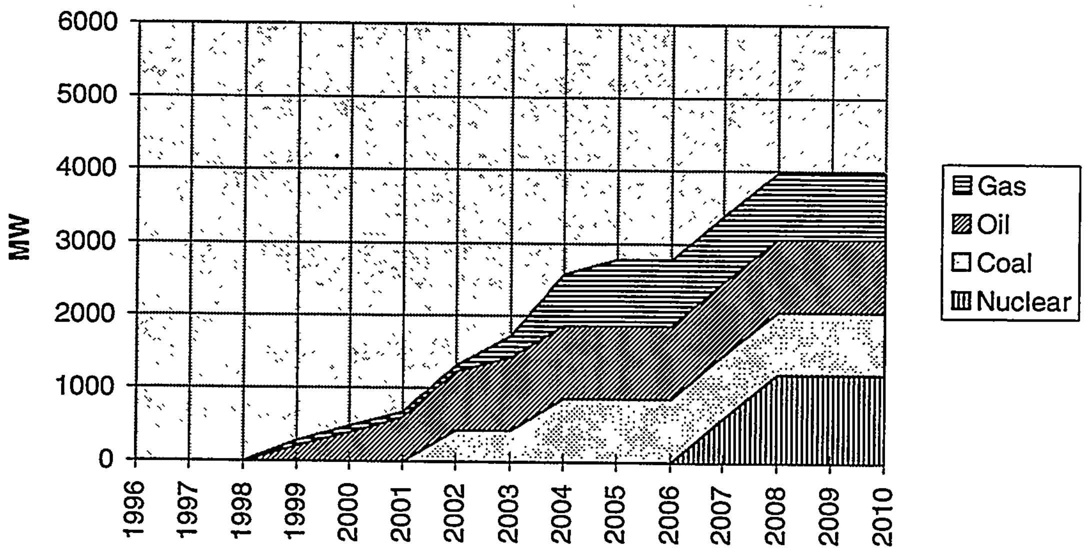


Figure 2.5: New capacities for scenarios D-F



Figures 2.6. through 2.11. contain the main results of the computer runs. They show the CO2, CO, and NOx emissions casused by the energy use, respectively. As far as CO2 emission is concerned, one can observe two big decreases in the cases when drastical retirements program is assumed: the first one is in 2001, the second one is in 2007 (see Figure 2.6.). In cases with no retirements, there is only one significant decrease, in 2007 (see Figure 2.7.). The same is true for the NOx emissions (see Figures 2.10. and 2.11). The decreases of CO2 and NOx emissions in 2001 are the result of the retirement of the old, not efficient coal fired power plants in the electrical sector (Figure 2.3.), while the second decrease in 2007 is the consequence of entering of the first new nuclear unit (Figures 2.4. and 2.5.). In case of CO emissions, almost the whole amount comes from the transportation sector, the share of the electricity sector is unsignificant - this is the reason, why no decreases can be observed.

Figure 2.6. CO2 emissions caused by energy use in the cases with retirements of power plants

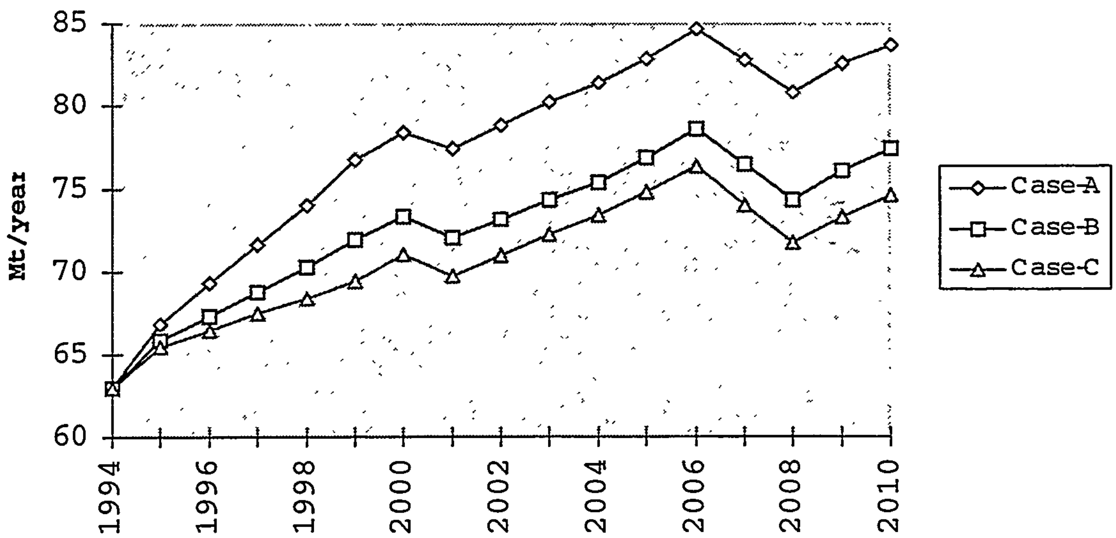


Figure 2.7. CO2 emissions cased by energy use in the cases without retirement of power plant

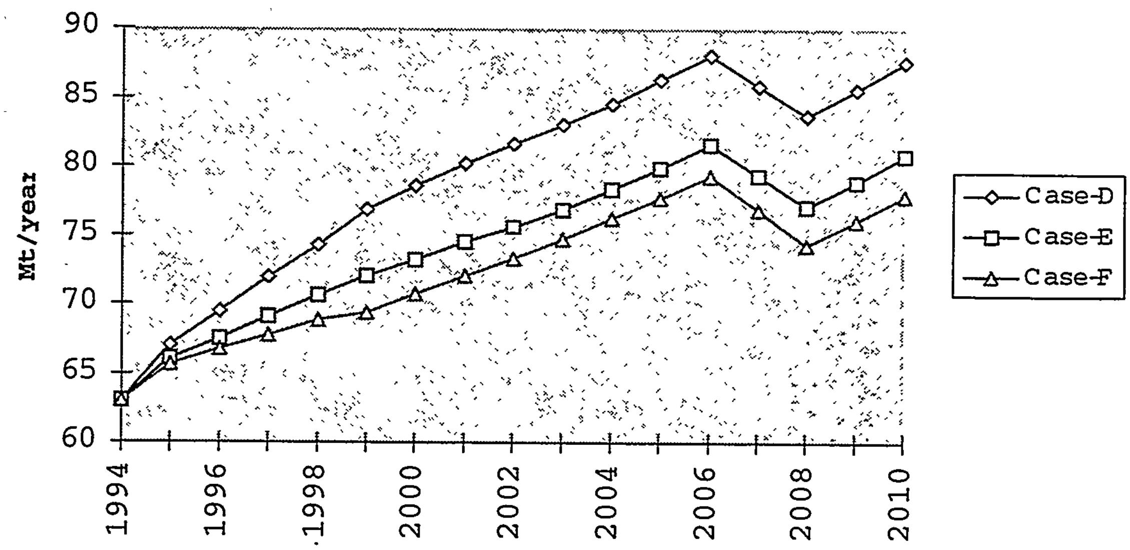


Figure 2.8. CO emissions caused by energy use in the cases with retirements of power plants

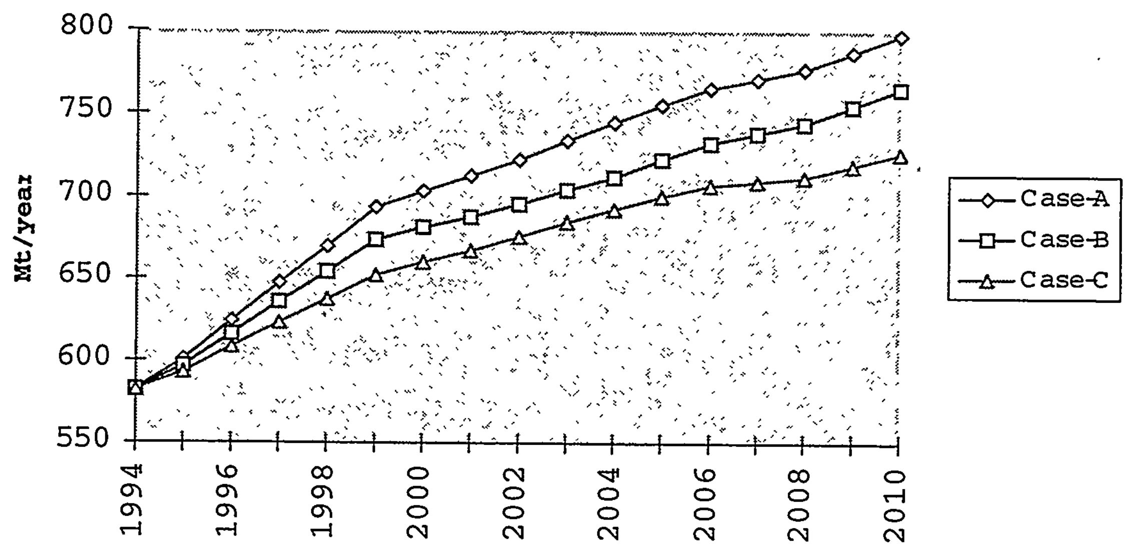


Figure 2.9. CO emissions cased by energy use in the cases without retirement of power plant

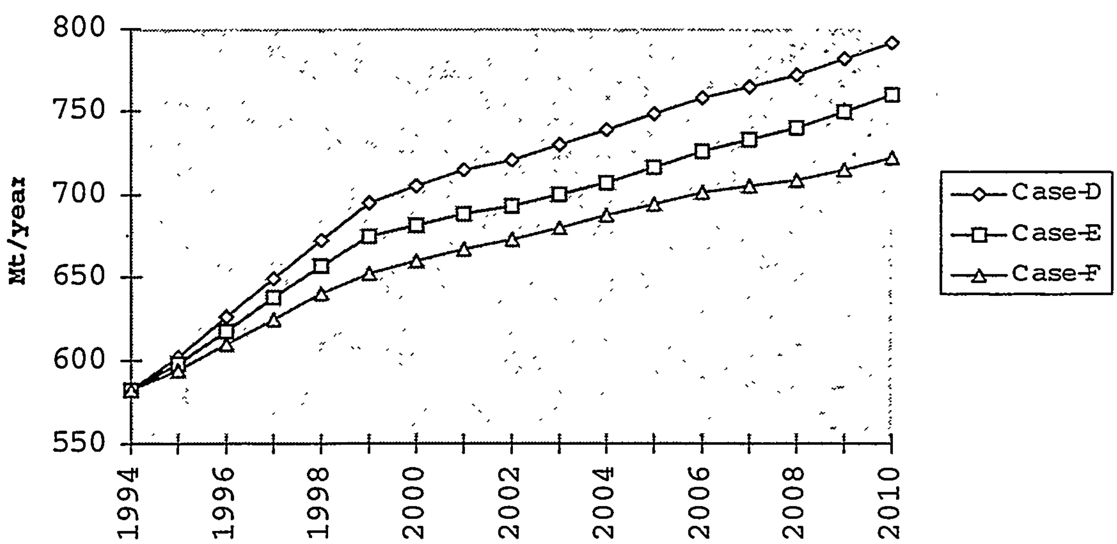


Figure 2.10. NOx emissions caused by energy use in the cases with retirements of power plants

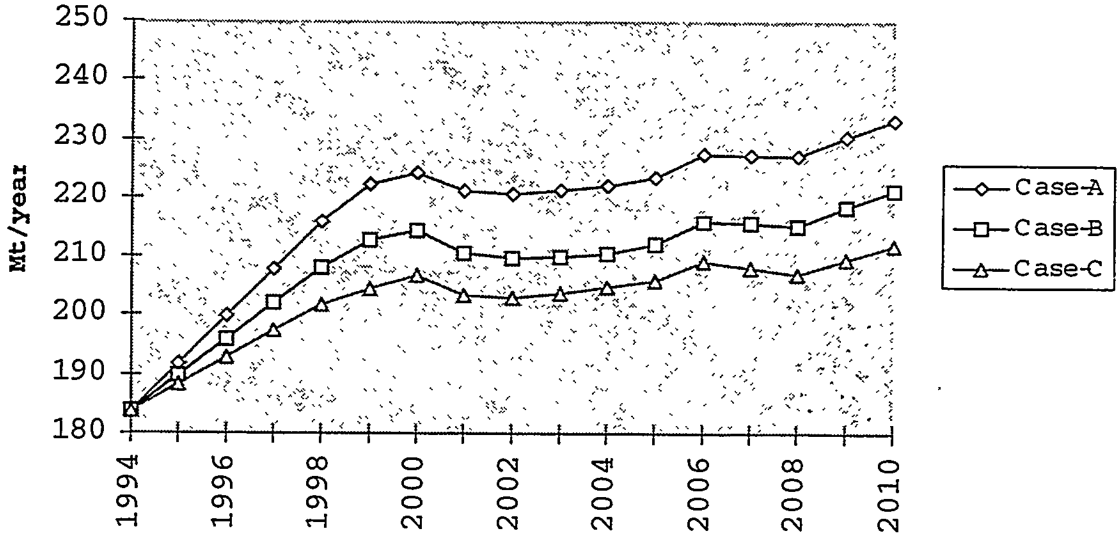
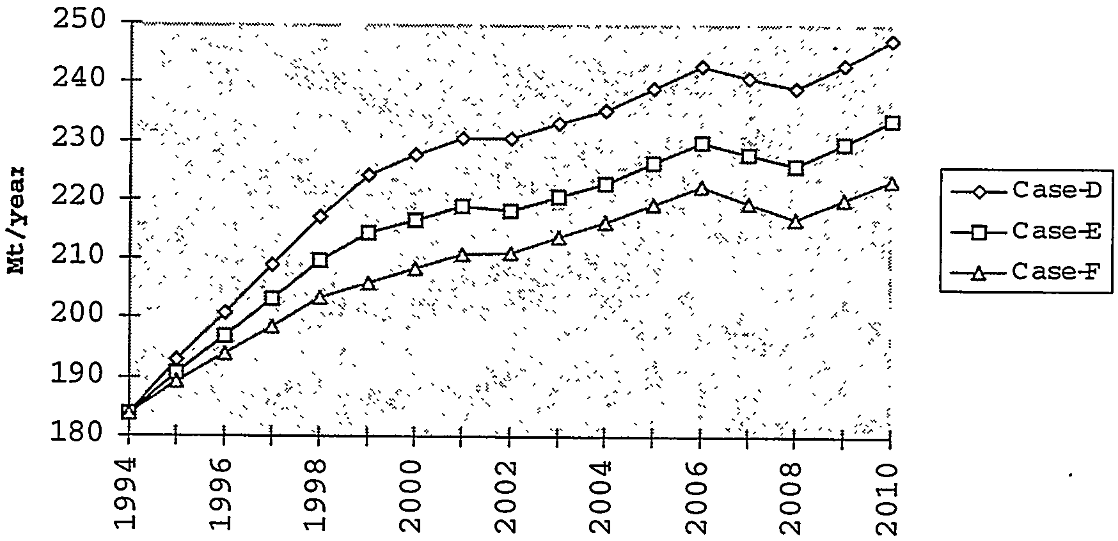


Figure 2.11. NOx emissions cased by energy use in the cases without retirement of power plant



At the examined demand levels, the mitigation scenario (Case B) results in 28.4 TG CO2 and 122.6 Gg NOx reduction in the examined period 1996-2010 compared to the baseline scenario.

The increase of greenhouse gas emissions from the energy sector cannot be avoided in the near future, even in the case of a minimum growth rate of demand. This will be a natural consequence of the expected economic decelopment after the deep recession of the late 80's which led to a profound political change in the region. Because of this expected increase of emissions, Hungary has chosen the period 1985-1987 as a base level for the implementation of the FCCC. The results of the inventory developed with the support of the U. S. Country Studies Program shows that the peak level of CO2 emission in 2006 will not reach the level of the base period. Primarily, the construction of a new nuclear plant may result in a relevant decrease after this year. It is expected that there will be no increase of any other greenhouse gas emissions after the economic recovery, i.e. after 2010.

We have also examined how the different carbon taxes would influence the greenhouse gas emissions of the Hungarian energy sector. For these calculations the model system ENPEP (Energy and Power Evaluation Program) and the model EFOM_ENV (Energy Flow Optimization Model) were applied. Three scenarios were taken into consideration as follows.

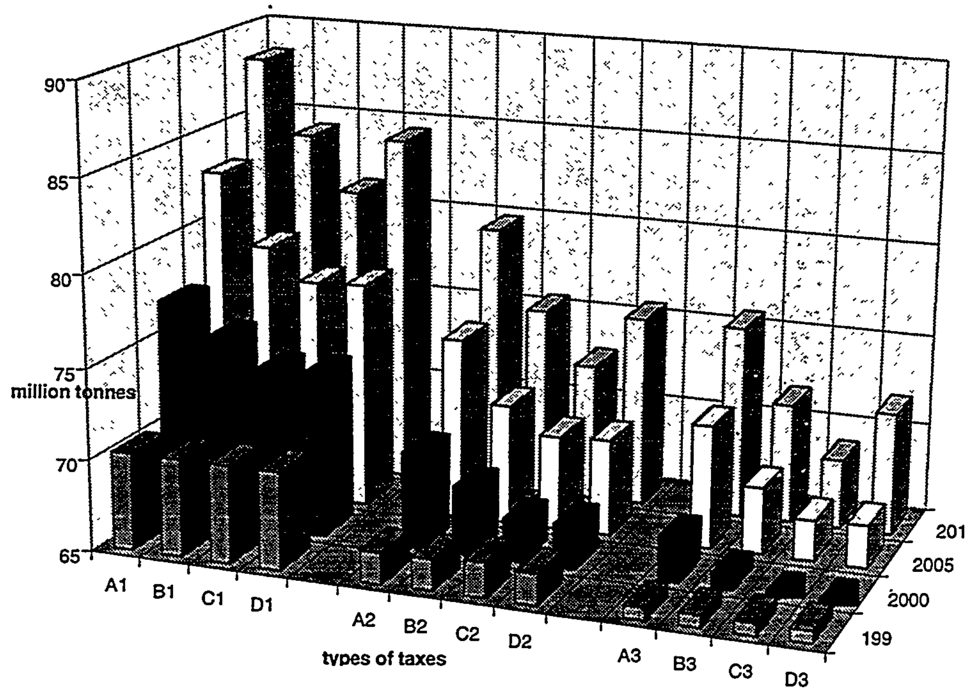
- Scenario I. This is the baseline scenario. It is supposed that GDP will begin to increase in the near future, i.e. before 2000.
- Scenario II. Different significant energy saving measures (see Table 2.2.) are added to the baseline scenario. These measures should be supported by the government.
- Scenario III. This is a pessimistic scenario. It is supposed that GDP will begin to increase only after 2000, and the level of the energy consumption in 2000 will not exceed that of 1995.

Four different cases of carbon taxation were examined.

- Case 1, without carbon tax on fossil fuels
- Case 2, where 50 USD/Mg C in 2000 and 100 USD/Mg C in 2010 is built in the prices of fossil fuels
- Case 3, where the measure of taxes are 100 USD/Mg C and 200 USD/Mg C in 2000 and in 2010, respectively
- Case 4, where 35 ECU/Mg C carbon tax and 0.7 ECU/GJ energy tax will be introduced for fossil fuels from 2000

According to our results, the introduction of the carbon tax for fossil fuels significantly decreases the coal consumption. It also decreases the rate of increase of hydrocarbons to a certain extent. In particular the use of gas increases less than that of oil products, since the supply of natural gas involves higher investment costs (extension of the pipeline system). It was found that there are practically no difference between the effects of Cases 2 and 4. However, these effects are significantly smaller than those of Case 3. The application of 100 and 200 USD/Mg C would result in a cca 6-8% CO2 reduction compared to the baseline scenario. At tthe same time, the 200 USD/Mg C might double the price of fossil fuels. This means that carbon taxes cannot be considered at the moment as a realistic mitigation option considering the economic and political situation of the country. Figure 2.12 presents the results for CO2 emissions in case of different carbon tax levels.

Figure 2.12. CO_2 emissions at different carbon tax levels and cases



3. Afforestation program

In the mitigation assessment, first, mitigation options were analysed. Based on the analysis, four scenarios of expanding carbon sinks by reforestation were developed. The possible benefits of other options - e.g., enhanced regeneration - were also analysed, but they were considered to be ineffective and, hence, rejected. Then, the Carbon Sequestration Model by Reforestation (CASMOR) was developed to describe the processes of a reforestation system, as well as to assess the rate of carbon seuqestration, and its costs and benefits. Finally, the results of running the model in the four scenarios were analysed. The CASMOR model used in assessing the rate of carbon seuqestration, as well as costs and benefits was designed by developing the respective submodel of Comprehensive Mitigation Analysis Processes (COMAP) to fit Hungarian conditions.

It is supposed in the CASMOR model that normal, professional forest management is carried out on the reforested land using three tree species groups. These groups represent the several - about 10 - possible tree species that could be planted complying wiht site, economic and social conditions in the country. A relatively slow-growing broadlived species group is characterized by Black Locust, a relatively fast-growing broadlived species group is characterized by Poplar, and the evergreens are modelled by Conifers. Any other combination could also be used. As far as the main processes, functions, interrelationships are concerned, we had to consider the following facts.

- Forest cover is increased by reforestations.
- Carbon assimilation by plants is the only process that increases sequestered carbon pools and reduces atmospheric carbon.
- Carbon pools in Baseline Scenario are also to grow in time, but slowly.
- Carbon pools in Mitigation Scenarios in CASMOR are modelled in a bit more detailed way than in COMAP.
- Carbon released in forestry operations may be small compared to the carbon fixed, yet, it is accounted for here to get a complete picture of the carbon cycle.
- The Stream of Costs and Benefits are very difficult to model, but the stream is better modelled if yearly costs and benefits are taken as they emerge rather than taking averages as in COMAP.

As it was mentioned above, the only option in Hungary to contribute to the reduction of air carbon to a considerable extent is reforesting large areas. Since forestry is fairly developed in Hungary, little could be achieved by, e.g., enhanced regeneration, agroforestry or urban and community forestry. Note that the term "reforestation" is used here in general to plant trees on bare lands, because most of the agricultural fields, bare lands or clearcut, but not yet regenerated areas used to be forested ares. "Afforestation", on the other hand, is used for all kinds of afforestations, including reforestation and regeneration. As compared to the size of the country and to the forest area, a large area of agricultural land could be reforested. This can, however, be done on the long run. Therefore, it is assumed that reforestations can be carried out by 2050. It is also assumed that the reforestation project could be started next year, i.e., in 1997.

The majority of the forests in Hungary are managed in a sustainable way. This means that protecting and maintaining existing stocks is done without extra effort. Thus, to speed up mitigation, expanding carbon sinks is necessary. The most important methods for this expanding are afforestation, and enhancing reforestation in clearcut forest compartments where reforestation is delayed for some reason. According to recent surveys, more than one million ha of former agricultural land awaits conversion. Most of this land used to be covered by forests before the intensive extension of arable land centuries ago. Roughly one half of this area is found in the lowland of the Eastern part of the country, the other half is scattered in the hilly parts of the Northern and Western parts.

After a large-scale privatisation program, a considerable part of this land is or will be owned by local farmers. It is generally in their interest to utilize their land profitably, which may mean that the timber grown in their forests is used in the farm itself. Many people are planning to develop a farm where agriculture and forestry are combined. However, afforestation could not be limited to smallholders' lands. There are large areas, too, that are owned by regional and local governments. In afforesting these lands, professional forestry companies would help. These companies would also help private landowners to assess site conditions, select appropriate tree species, provide the landowners with improved propagation material, and to prescribe and assist in technology. The long traditions of afforestation, many nurseries, the expertise of tending and other silvicultural work, as well as other elements of professional background of these forestry companies would ensure high efficiency in afforestation. Because of low wages and relatively high unemployment in the regions concerned, enough workers will be available for doing necessary field work. For mechanisable operations, good quality machines are at hand, too. The Hungarian Parliament has recently passed the new Forest Act. This will ensure the sustainable management of the new - and also of all other - forests in Hungary.

As for the sites of the land available for afforestation, they are usually of medium quality. About 80% of the afforestations would serve for timber production, and the function of most of the rest would be protection, mainly environment protection. Land for conversion could include several thousand ha of tree belt for arable land protection and channel and canal protection, roadside belt and also snowbelt. Because of site conditions, fast growing species can be planted on a large portion of the land to be converted. Preferable fast growing species include Black Locust (Robinia pseudoacacia), improved (Hybrid) poplars (Populus x euramericana), and conifers (Pinus silvestris and Pinus nigra). In addition to breeding, the latest achievements of research on silviculture and yield can also be used to optimize tree growth and, hence, maximal CO_2-sequestration.

Scenarios are developed from current trends, as well as from natural and technical potentials. The forest cover of the country is still below the European average. Hungary can meet only about 70% of her need for timber from the country's own forest resources. In addition, large areas abound where agriculture is not profitable any more. We would like to join the European Union, within which the potential of agricultural production has a substantial surplus. Because the market of agricultural products is saturated, agricultural production has - and increasingly will - become unprofitable on large areas. This has also resulted in high unemployment in agricultural regions.

All this prompted the government to launch a new afforestation program in 1991. The aim was to afforest 150 thousand ha by the year 2000. Contrary to the plan, which outlined that the yearly afforested area would increase by the time, it dropped from 6700 ha in 1991 to 2874 ha in 1994. Today, i.e., at the half of the original period, only 16% of the total 150 thousand ha has been afforested against the 50% planned. Because the reforestation rate dropped under three thousand ha by 1995, and by considering the currently difficult economic situation of the country, it may happen that not a single ha of new reforestation will be done for several years. For the most-likely-trend scenario, i.e., the baseline scenario, therefore, it is assumed that no reforestation will take place until 2050.

It is also likely that an afforestation of 3,000 ha per year will be done during the next 50 plus years. This will require effort of the country, but it can easily be done if politicians decide so, in which case no extra propaganda should be pursued. This will be taken as a mitigation scenario, namely, the likely-trend scenario (I).

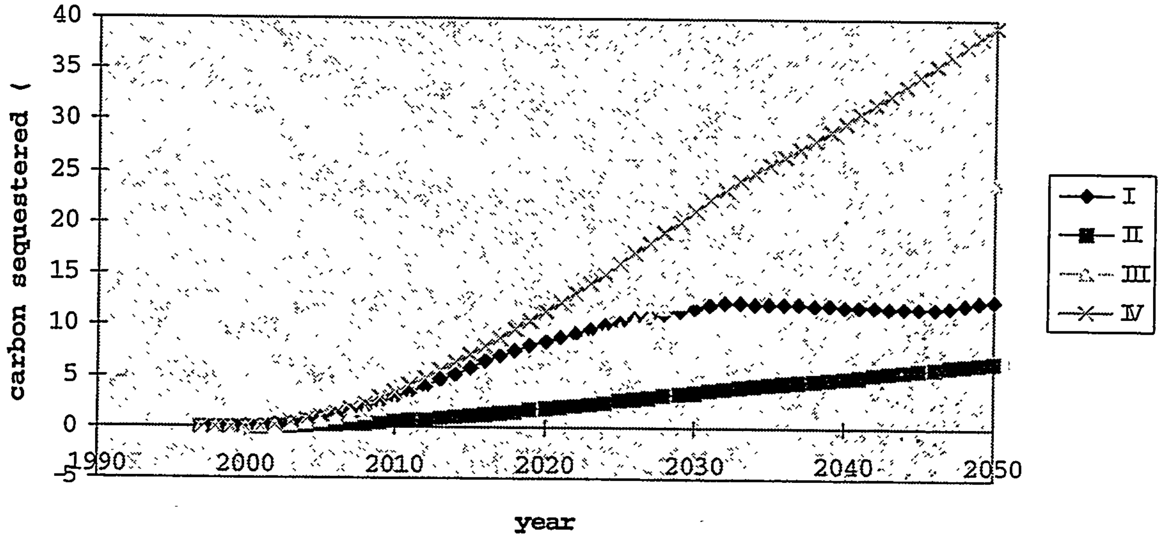
Although the momentum of the former afforestation programs has been hindered by the ailment and the transition of the economy, the conversion of the land from agriculture to forest must be speeded up. The country has great potentials for that. The three other mitigation scenarios were developed by analysing these potentials.

The second mitigation scenario, the programmatic scenario (II) that could be carried out is similar to the current afforestation program of the government (i.e., to make afforestations on 150 thousand ha in the next decade). That would require finding additional sources in the country, and some foreign aid, too. However, the program is already prepared by making fairly good assessment of the land available, its allocation and site conditions, as well as of the species to be planted. In this scenario we assume that the program is restarted and that 210,000 ha forest will be planted by 2010 (this is equal to a yearly reforestation of 15,000 ha).

The third mitigation scenario, the achieveable scenario (III) requires a yearly reforestation of 11,000 ha land by 2050. This would result in reforesting almost 600 thousand ha land. According to the latest analyses, this is the area the site of which can be regarded as suitable for forest management with acceptable benefits. However, the rate of reforestation is not comparable any more with the production capability of the country, so foreign aid is needed to help decision makers to engage in this program.

The fourth, and last, mitigation scenario, the technical potential scenario (IV), represents a reforestation of nearly 1 million ha land by the year 2050 at a rate of 18,000 ha per year. This program requires aid for the country. This is, however, the mostly preferred scenario because of its beneficial effects: it ensures the highest rate of C-sequestration, green cover on unused or marginal agricultural land, it creats the most job opportunities, it increases biodiversity to the greatest extent. Most data are taken from earlier measurements and correctly describe both natural processes and technological aspects. Figure 3.1 presents the carbon sequestration in Tg by scenarios.

Figure 3.1 Carbon sequestration by scenarios



4. VOC reduction program

The main target of the VOC Programme is to prepare a strategy consisting of a reduction plan and an implementation plan for VOC emissions in Hungary (DHV, 1995). Phase 1 of the project was completed in 1993. The result is a survey of the emissions of selected industries in Hungary. Phase 2 of the project resulted in a reduction plan for selected industries which are as follows: graphic industry, metal surface treatment industry, textile printing industry, painting processes (various industries), storage of chemical and oil products (chemical and oil industry), rubber and plastic industries.

The reduction plan indicates emission sources and summarizes the type of associated measures. In Phase 2 some workshops for the selected industries have been organized to achieve the goals of the reduction plan. The aim of the workshops is to reach consensus on the possible measures for the oil and chemical industry. The results are included in a list of (potential) measures for specific types of sources, as well as the special conditions and uncertainties of these measures. Conditions and uncertainties can be e.g. technical or economical or can be the competitive position relative to other countries. Furthermore, the indicative costs (e.g. in HUF per kg VOC) and the possibilities for financing measures became clearer in Phase 2 of the project.

There are several possibilities for the control of VOC emissions. Measures for the reduction of VOC emissions focus on products and/or process modifications (including maintenance and operational control) and on the retrofitting of existing plants. The following list gives a general outline of measures available which may be implemented either singly or in combination:

- Substitution of VOCs e.g. the use of water-based degreasing baths and paints, inks, glues or adhesives which are low in or do not contain VOCs,

- Reduction by best management practices such as good housekeeping, preventive maintenance programmes or by changes in processes such as closed systems during utilization, storage and distribution of low-boiling organic liquids,

- Recycling and/or recovery of collected VOCs by control techniques such as absorption, condensation and membrane processes; ideally, organic compounds can be reused on-site,

- Destruction of collected VOCs by control techniques such as thermal recatalytic incineration or biological treatment.

Some concrete possibilities with estimates of emission reduction and energy saving are listed in Table 4.1.

Table 4.1. VOC emission reduction options

Option	Description	Industrial sector	VOC-reduction (ton/yr)[a]	Energy saving (GJ/y)[a]
1	Recuperative incineration with heat recovery	printing industry chemical industry	200	3.600
2	Regenerative adsorption (active carbon) with reuse	printing industry chemical industry (refineries)	100	2.700
3	Decentral. point source ventilation	printing industry chemical industry	[b]	2.800
4	Water borne paints	painting processes	80	2.940
5	Floating roof (VOC with low vapour pressure)	chemical industry (refineries)	95	3.800

([a]VOC reduction and energy savings are indicated for one installation and/or one company; [b]this relates to an integrated measure in which the concentration is increased, flow is reduced but no emission reduction is achieved; a more cost-effective, end-of-pipe technique will be necessary)

The recent VOC emission reduction is due the economic decline (see Table 4.2.) and the autonomous and voluntary measures made by industry.

Table 4.2. The Hungarian VOC emission (Gg) in 1988 and 1990 (source DHV, 1993)

Source Category	**1988**	**1991**
Energy Production	1.0	1.0
Oil Industry (Mining, Storage, Refineries, etc.)	35.0	25.0
Traffic (incl. refueling)	90.5	72.5
Solvent Use	78.5	44.5
Total	**205.0**	**143.0**

In addition, the MERP issued a decree in 1995 on the control of hydrocarbon emissions resulting from storage of petrol and its distribution from terminals to service stations (stage-I measure) and its refueling to all motor vehicles at service stations (stage-II measure). In several cases, environmentally friendly investments by companies coincide with their business interests with even some savings realized (e.g. Hungarian Oil Co., printing industry).

5. Program of phase-out of ozone depleting substances

Hungary acceded to the Vienna Convention and the Montreal Protocol in 1989. The London Amendment to the Protocol was ratified by Hungary in November 1993 and the Copenhagen Amendment in June 1994.

The Hungarian Government enacted these international conventions into the national law and order by ministerial decrees. Decree No. 13/1992 (V.12.) of the Ministry for Environment and Regional Policy issued with the authorization of the government regulates the use of ozone depleting substances in full accordance with the London Amendment. The enforcement of the Copenhagen Amendment is ensured by the 22/1993 (VII.20) Decree of the Ministry for Environment and Regional Policy that replaced the previous decree.

The decree establishes deadlines for phasing out of the controlled substances in different fields of consumption, bans the establishment of new technology using the controlled substances, and establishes an authorization for their import. It also prescribes obligatory reporting about the use of controlled substances as well as penalties for violating the regulations. The prevailing decree establishes earlier deadlines compared to the deadlines of the Copenhagen Amendment in some fields of use since meeting them may cause difficulties for some ODS users. Table 5.1 shows the use of ODS's

Table 5.1. End use of ODS in Hungary (in Mg)

SUBSTANCES (metric tons)	1986	1989	1991	1992	1993	1994	1995
CFC-11	1483	1120	806	690	651	190	200
CFC-12	2087	2100	1544	1090	937	791	850
CFC-11/12	1620	1370	160				
CFC-113	160	160	120	90	62	31	50
CFC-114	10		30	10	10	8	
CFC-115					8		
All CFCs	5360	4750	2660	1880	1668	1020	1100
Halon 1211	446	425	255	150	54		
Halon 1301	7	15	20	20	10		
Halon 2402	2				1		
All Halons	455	440	275	170	65		
CTC (carbontetrachlorid)	700	630	320	200	124	70	70
MCF (methylchloroform)	570	780	580	447	290	250	150
MBr (methylbromide)			53	45	77	70	50

Hungary had not enough financial resources for the new ODS-free technologies and investments to be implemented by the Copenhagen Amendment until the end of 1995. Therefore, Hungary applied for a GEF grant to help its ODS phaseout activity. Work for the GEF support began in 1993 with the contribution of the World Bank as executing agency for the GEF. The main conditions for the GEF grant were as follows: prepare a country programme for phaseout of ODS with issues listed above; legislative measures for economic incentives of recycling of CFCs and halons; eligible projects for enterprises using substitutions for ODS's.

6. Discussion and conclusions

Four main programs have been discussed in this paper. For Hungary, the restructuring of the energy sector is crucial to fulfill the duties undertaken by signing and ratifying the Framework Convention on Climate Change. Since there are a lot of aged and unefficient power plants in the country, and the specific energy consumption is relatively high, both supply and demand side measures will contibute to the reduction of greenhouse gas emissions. The national energy saving program covers both supply and demand side measures. However, this program needs a lot of capital for investments. This may postpone the program considering the economic problems of the country. However, the electrical sector has been partly privatized and some of the nur owners have already undertaken new investments.

It is also difficult to forecast how the afforestation program will proceed in the future, since this program also needs a great amount of capital. It seems that 3000 ha/year can be taken even in the near future. It is generally expected that GDP will grow by 4-5 %/year after 2000. This would relevantly improve the efficiency of these programs.

The programs of VOC and ODS reduction have been successful, although these emissions have less importance from the viewpoint of climate change effect.

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ASSESSMENT OF GHG MITIGATION TECHNOLOGY MEASURES IN UKRAINE

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Ukraine, Kiev - 1996

1. INTRODUCTION

In June 1992 the representatives of 176 countries including Ukraine met in Rio de Janeiro at the UN Conference to coordinate its efforts in protecting and guarding the environment. Signature of the UN Framework Convention on Climate Change by around 150 countries indicates that climate change is potentially a major threat to the world's environment and economic development.

The project "Country Study on Climate Change in Ukraine" is coordinated by the Agency for Rational Energy Use and Ecology (ARENA-ECO) and supported by the US Country Studies Program Support for Climate Change Studies.

The aim of the project is to make the information related to climate change in Ukraine available for the world community by using the potential of Ukrainian research institutes for further concerted actions to solve the problem of climate change on the global scale.

The project consists of four elements:

- the development of the GHG Inventory in Ukraine;
- assessments of ecosystems vulnerability to climate change and adaptation options;
- mitigation options analysis;
- public education and outreach activities.

This paper contains the main results of the third element for the energy and non-energy sectors.

Main tasks of the third element were:

- to select, test and describe or develop the methodology for mitigation options assessment;
- to analyze the main sources of GHG emissions in Ukraine;
- to give the macro economic analysis of Ukrainian development and the development of main economical sectors - industry, energy, transport, residential, forestry and agriculture;
- to forecast GHG emissions for different scenarios of the economic development;
- to analyze the main measures to mitigate climate change.

2. METHODOLOGY

A deep crisis of Ukrainian economy considerably complicates the assessment of future GHG emissions. Today it is extremely difficult to define correctly the terms of economy stabilization, directions and rates of further economic development, the level of progressive technologies implementation, energy efficiency, etc.

Also it is impossible to use mathematical models and methodologies, used in the developed countries and earlier used at planning of the development of Ukrainian economy: the regressive analysis, production functions and input - output models.

According to above-mentioned a methodology, mathematical models and software were developed.

Accounting and iterative equilibrium models to forecast the development of economy, direct and indirect GHG emissions were used. Optimization models were applied to create mitigation scenarios and to estimate mitigation options.

The carrying out of investigations have included following stages.

1. Selecting and defining methodologies.
2. Developing the baseline scenarios for the period up to 2015.
3. Macro economic analysis.
4. Analysis of mitigation measures in all scenarios.
5. Estimation of GHG emissions in the long-term:
6. Developing the mitigation scenarios.
7. Recommendations and conclusions.

Within the framework of each scenario, the groups of the national experts elaborated the development of economy sectors and their basic output products, fuel combustion, and mitigation measures.

There were considered the following sectors and subsectors of economy.

1. Fuel & Energy Complex and its subsectors:
   - 1.1. Power & Heat Supply;
   - 1.2. Coal Industry;
   - 1.3. Oil & Gas Industry;
   - 1.4. Oil Refining.
2. Industry and its main subsectors:
   - 2.1. Metallurgy;
   - 2.2. Chemical Industry;
   - 2.3. Mechanical Engineering;
   - 2.4. Building Materials Industry;
   - 2.5. Food & Beverage Industry;
   - 2.6. Other Industrial Sectors.
3. Constructing Sector.
4. Agriculture.
5. Household and Services.
6. Transport.
7. Other Sectors of Economy.

Coal, natural gas, coalbed methane, residual fuel oil, diesel oil, other oil products were considered as primary fuels.

Alongside with it in a metallurgical sector coke and coke gas , and in a household sector coal briquettes and firewood were taken into account.

3. CURRENT UKRAINIAN ECONOMY, SOURCES AND LEVELS OF GHG EMISSIONS

3.1. General characteristic of economic situation

Ukraine is one of the largest countries in Europe, occupying the area of 603.7 thousand km^2, with the population (1990) - 51.8 million (Figure 1).

There is a favorable climate and fertile ground in the country. The economy of Ukraine, up to declaration of independence, was developing as a part of an economic complex of the USSR in conditions of a centralized management system and practically closed market. The structure and price levels for the goods and services sharply differed from world ones. The decision of local and global ecological problems was practically ignored.

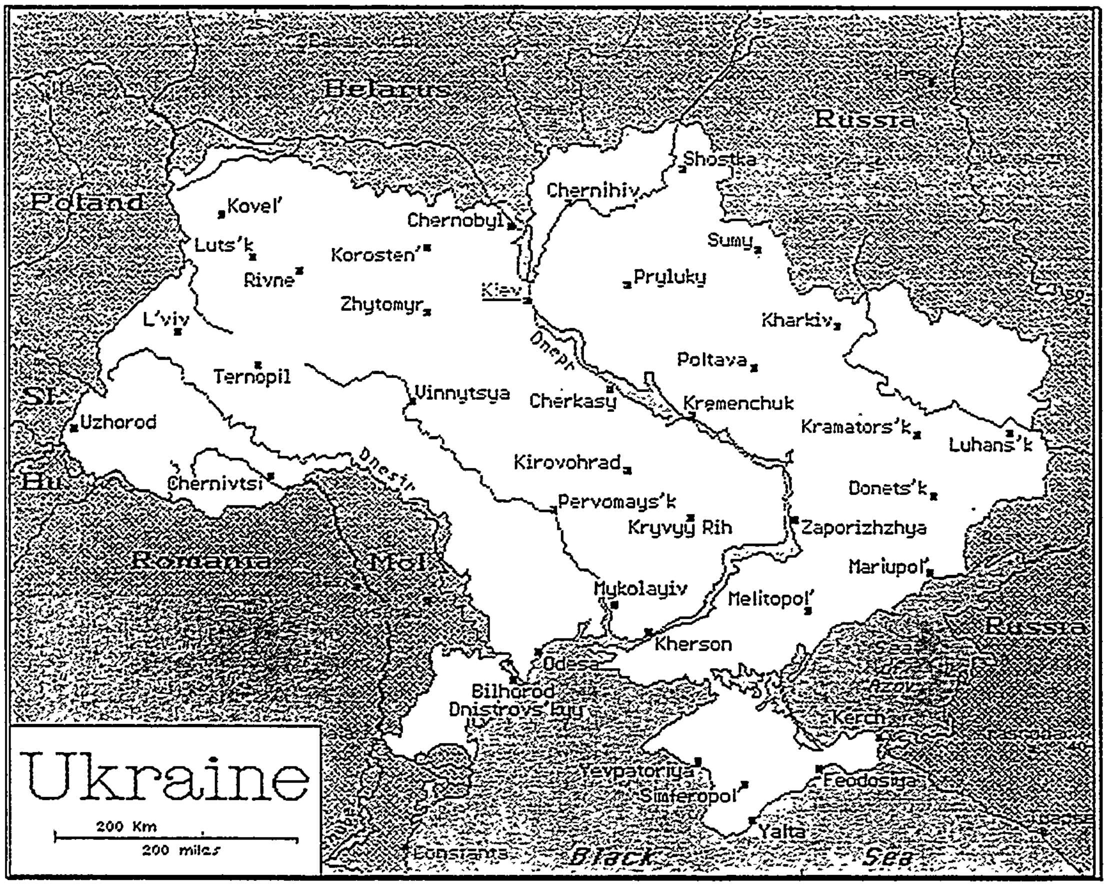

Figure 1. Map of Ukraine

As a result the development of heavy industry - fuel and energy (FEC) and mining-metallurgical (MMC) complexes. heavy mechanical engineering and agriculture was of priority importance.

In 1991 Ukraine has proclaimed the independence and proceeded to economic restructuring in a direction of the market development and democratic state construction. However. the transient period became very painful. and the country entered to the continuously deepening economic crisis.

The analysis of a situation change during 1991-1995 shows the constant strengthening of crisis phenomena - fall of output production, especially in industries of low energy consumption, and, as a consequence, decrease of GDP and growth of its energy intensity (Figure 2), increase of problems of payment for critical import of energy carriers, that causes negative balance of foreign trade balance and difficulties with energy supply of the country, and chronic growing the budget deficit.

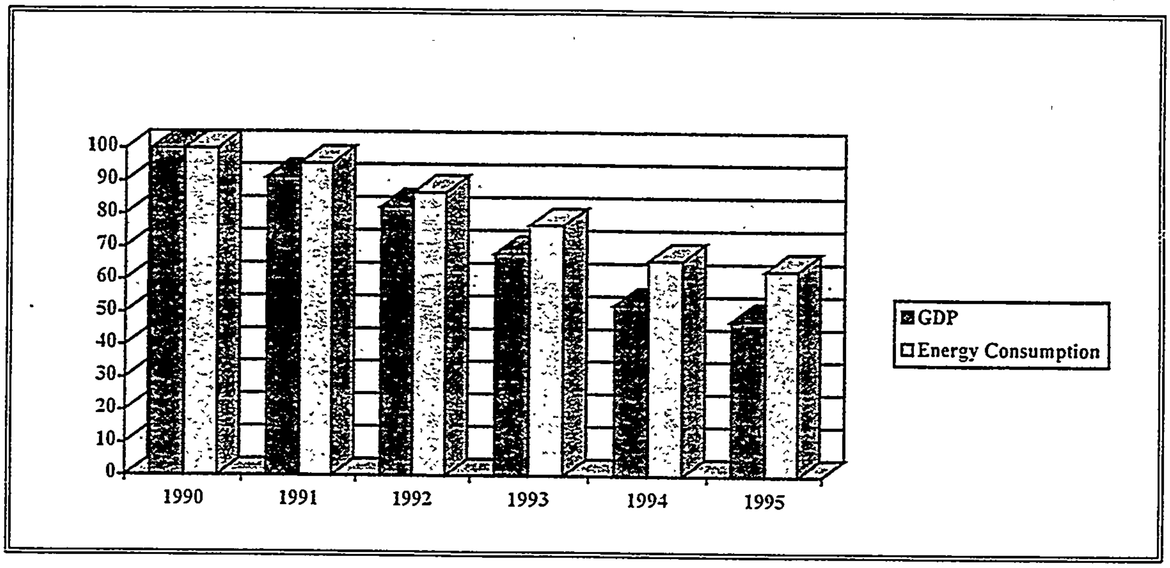

Figure 2. GDP and Energy Consumption trends, %

3.2. Sources and levels of GHG emissions in Ukraine

The assessments of GHG emissions have shown sharp decrease in the period 1990-1995, connected first of all with essential fall of production. So, fuel combustion and associated GHG emissions were reduced by about 40 % in 1995 relative to 1990 (Table 1). GHG emissions in industrial processes have decreased more than for 50 %.

Table 1. GHG emissions in 1990 and 1995 and its comparison, Tg

GHG/Sources	*1990*	*1995*
	Direct GHG	
CO_2, GWP factor -1	711.447	425.299
Fuel Combustion	662.632	402.394
Industrial processes	48.815	22.905
CH_4, GWP factor -22	10.115	7.150
N_2O, GWP factor -270	0.038	0.016
Total CE* emissions	***260.5708***	***161.8736***
	Indirect GHG	
CO	7.295	4.046
NOx	2.043	1.140
CxHy	1.007	0.471

* CE - carbon equivalent

4. MACRO ECONOMIC FORECAST

The assumptions of a national economy to overcome the crisis are connected with the following factors:

- stabilization and subsequent growth of production;
- privatization;
- stabilization of the legislation;
- improvements of taxation and currency policies;
- restoration of economic links with the CIS countries;
- help of the developed countries.

In Ukraine as a transitional country, where considerable economic and social change is expected over a nearest future, it can be quite difficult to select a single image of the future as more likely than another. Therefore three macro economic scenarios have been developed to reflect low, medium and high economic growth (Figure 3):

- the pessimistic baseline scenario;
- the baseline scenario;
- the optimistic baseline scenario.

The baseline scenario of the economy development is based on the state programs on development of energy, industry and energy saving. This scenario is not "business-as-usual', it include the adoption of technologies and practices that improve the efficiency of resource use and thereby reduce GHG emissions. Such defining a baseline scenario reflects the significant efforts of the Ukrainian Government to increase energy efficiency, to implement new technologies, to reduce energy losses, etc. For example, recently National Energy Program was adopted by Parliament. Therefore the baseline scenario should include a whole set of measures presented in such programs.

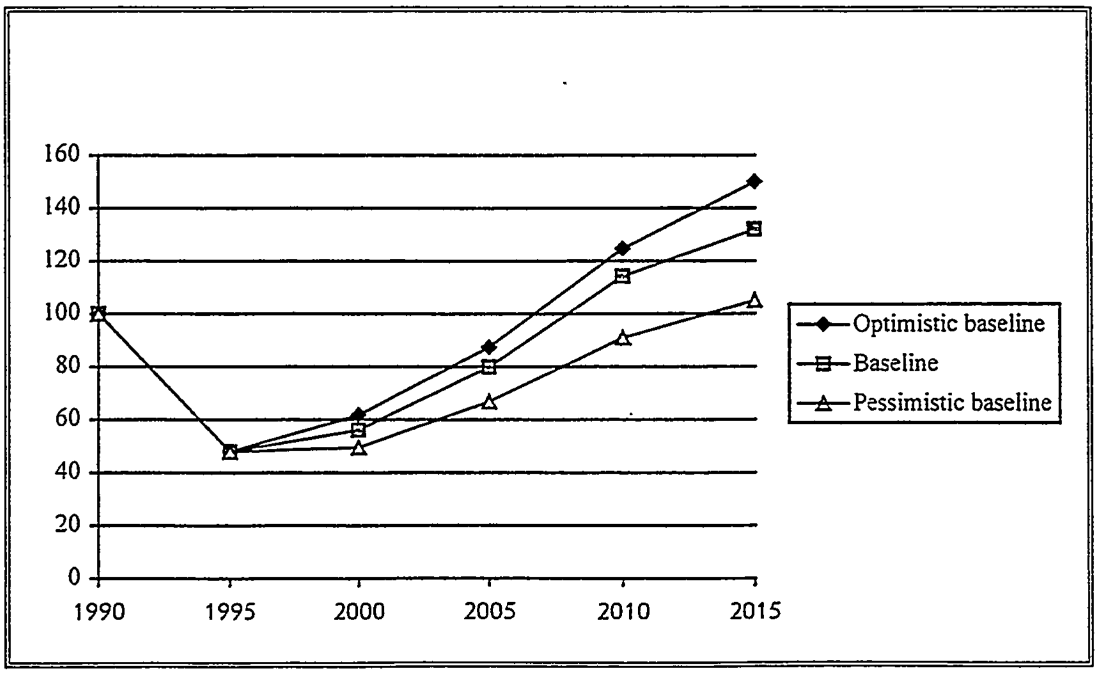

Figure 3. GDP growth

5. BASELINE SCENARIO

During the given period energy demand (Figure 4) become higher than 1990 levels after 2000, despite of energy saving measures including in baseline scenario. But significant growth of GDP (in baseline scenario 132% in 2015 relative to 1990) lead to reducing energy intensity (in optimistic baseline and baseline scenarios it will be lower in 2015 than 1990 levels). It is connected with implementation of above-mentioned Program, directed on the increase of energy effectiveness of the economy, including active energy saving policy and alternative energy sources.

Depending on the scenario of the economy development the levels of energy demand are much differed, however the tendency of decrease of energy intensity in the period after 2000 is typical for all the scenarios.

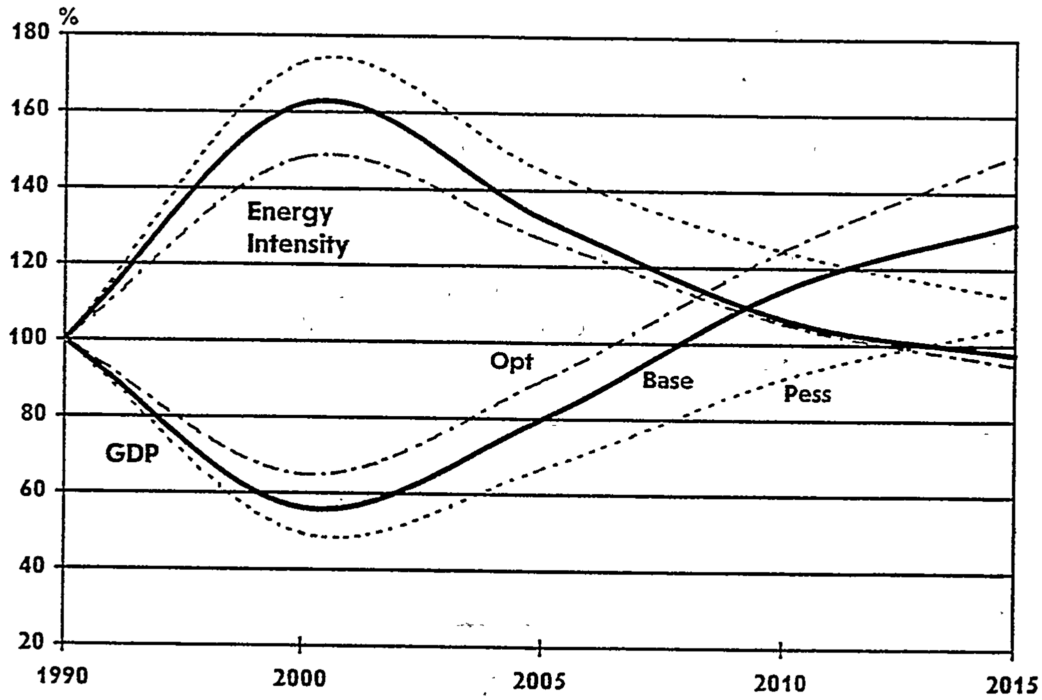

Figure 4. GDP and Energy Intensity Trends for Baseline Scenarios

In structure of fuel combustion (Figure 5), share of gas is increased in future due to the growth of its consumption in residential sector, in oil refining and as a motor fuel in transport.

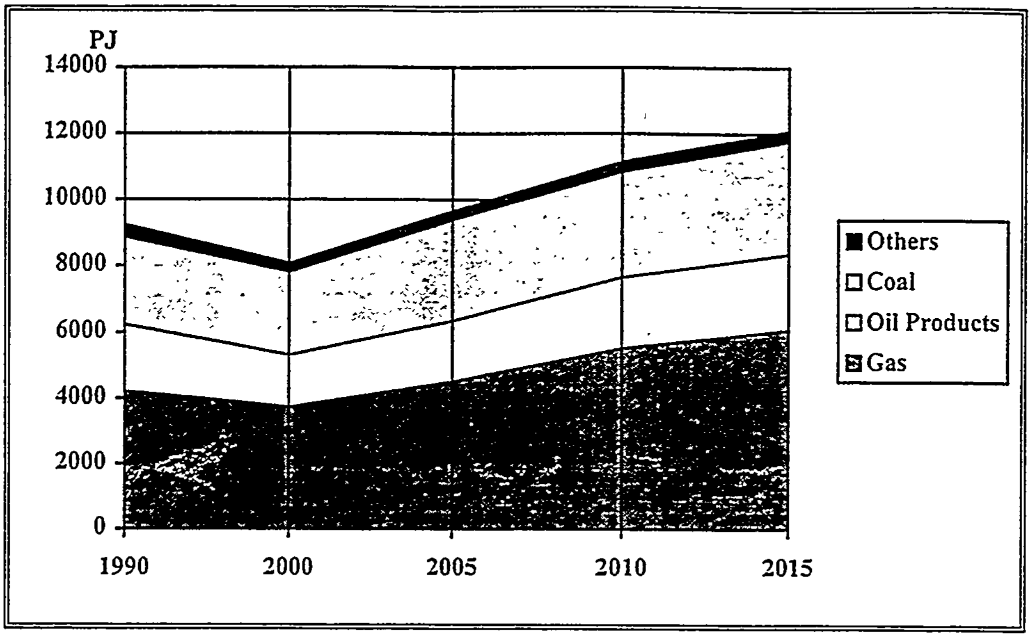

Figure 5. Fuel Combustion for baseline scenario

GHG emissions in baseline scenario (Table 2) in 2000 are lower than 1990 levels, therefore UN Framework Convention obligations will be fulfilled. But further GHG emissions will essentially exceed 1990 levels. Therefore there is obvious necessity to analyze mitigation options and to develop mitigation scenario.

Table 2. GHG emissions trends in baseline scenario

	1990	1995	2000	2005	2010	2015
		Direct GHG emissions				
CO_2, Tg	711.45	425.30	535.63	742.06	977.64	1109.46
CH_4, Tg	10.12	7.15	8.47	10.37	12.21	11.78
N_2O, Tg	0.04	0.02	0.04	0.05	0.07	0.08
CE, Tg	260.57	161.87	201.77	271.52	348.95	383.45
		CO_2 uptake in Forestry				
CO_2, Tg	-51.98	-64.89	-66.64	-68.55	-70.70	-72.78
		Total				
CE, Tg	246.35	144.17	183.55	252.83	329.67	363.60
		Indirect GHG emissions				
CO, Tg	7.30	4.05	6.03	7.77	10.23	11.56
NO_x, Tg	2.04	1.14	1.58	2.09	2.64	2.91
C_xH_y, Tg	1.01	0.47	0.85	1.15	1.55	1.82

6. ANALYSIS OF MITIGATION MEASURES

Main mitigation measures presented below were analyzed (Figure 6).

Policy instruments

State regulation of rational energy use in all sectors. including:

- legislation. supporting energy saving and environmental protection policies;
- bans and controls on inputs and emissions. equipment efficiency standards;

- fees, taxes, subsidies, prices, stimulating implementation of efficiency technologies and equipment;
- research, development and demonstration programs to improve and disseminate information;
- energy and environmental audit, R&D centers, information and personnel training centers, energy management at the enterprises, licensing requirements, patent rules, etc.;
- DSM;
- control devices for energy consumption.

This set of policies will stimulate energy effective and ecological development of Ukraine.

Restructuring of economy

A strong role of energy-intensive sectors (energy, mining-metallurgical complex, heavy mechanical engineering, etc.) will not be continued under conditions of market and low energy use sectors, services and agriculture are favourable.

Technological options

Implementation of energy effective technologies are the most important for reducing GHG emissions (Figure 7):

Cross-sectoral energy saving options: efficiency lighting equipment, motor drive systems improvement, more efficient combustion of bad quality fuels, improvement of the heat supply systems, utilization of secondary energy resources.

Sectoral energy saving options:

The most effective measures are follows:

Energy Supply: technological and efficiency improvements in power sector, high efficiency gas supply system, effective coal mining.

Metallurgy: improvements in coke making, recycling of technological processes of blast furnace, coke oven and converter gases, adoption of electric arc furnaces, decrease of output of the most energy intensive production.

Mechanical Engineering: efficiency technologies of metal processing, use of high quality raw materials.

Chemical industry: improvement of the technologies of ammonia, calcium soda and phosphoric fertilizers production.

Building materials industry: improvement of technological processes of cement, glass, brick, wall materials production.

Food industry: improvement of technological processes of sugar, spirit, vegetable oil production.

Constructing sector: improvement of technological processes of concrete production.

Agriculture: reduction of a share of energy intensive plants, improvement of post-harvest drying and storage, switch to low carbon energy sources etc.

Residential sector: switch to energy sources/equipment with low-carbon emissions, insulation for existing and new building shells, shift to more efficiency household equipment.

Transport: manage transport demand, improvement of vehicle technical efficiency, fuel switch, improve traffic flow.

Fuel substitution: It is necessary to increase share of nuclear fuel, renewable, secondary and non-traditional energy resources. Shift from coal and petroleum to natural gas, use of coalbed methane and biogas.

Reduction of losses in Gas Supply System.

Improvement of industrial processes.

Improvement of waste treatment.

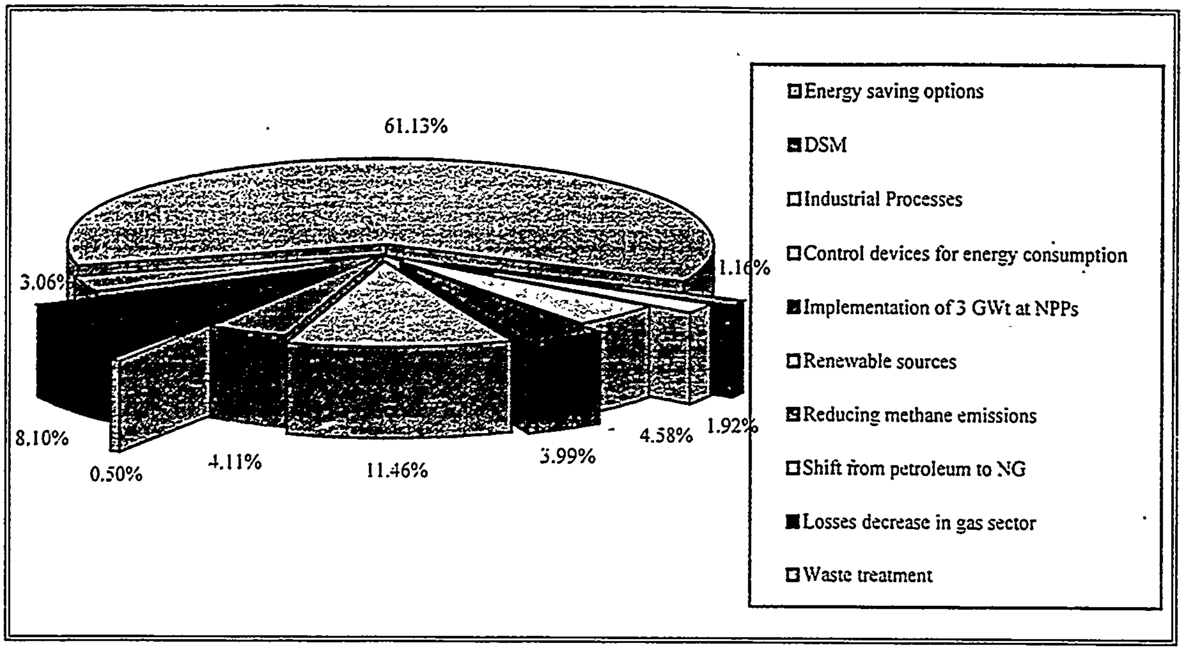

Figure 6. Mitigation options

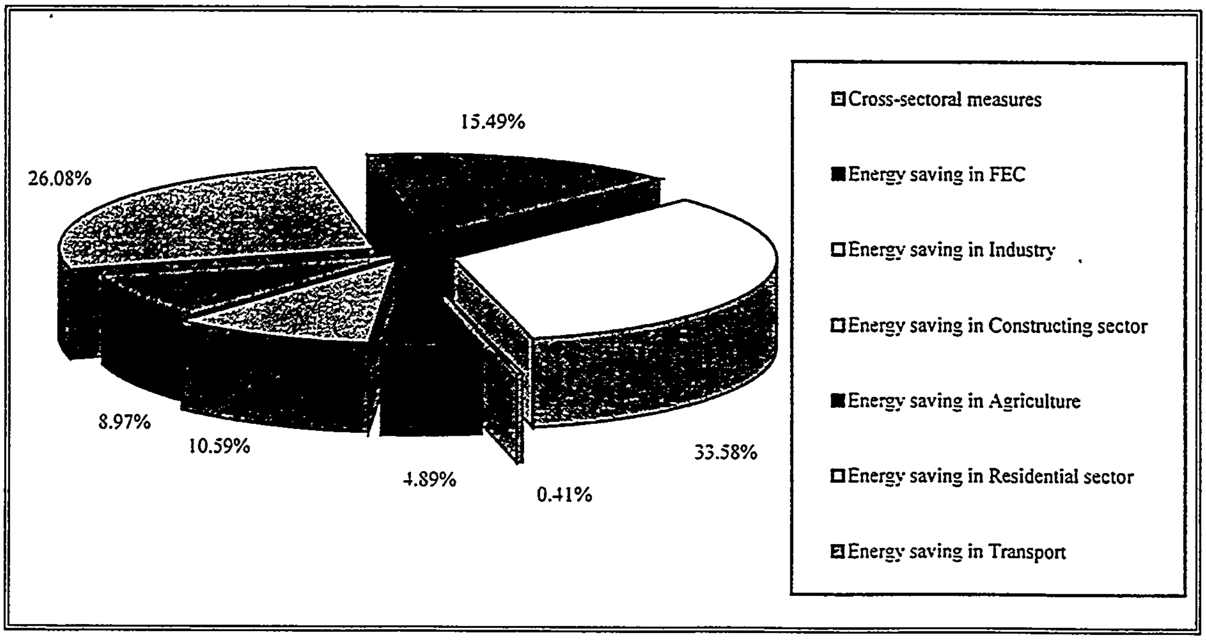

Figure 7. Energy saving mitigations options

An investment-efficiency analysis of GHG abatement have given a possibility to compare all these different options in an integrated procedure (Figure 8, Figure 9). An investment curves express the investments per unit of emission reduction as a function of quantity of GHG reduced. A horizontal line shows the average level of specific investments. The square of each block represents the total investments to corresponding option.

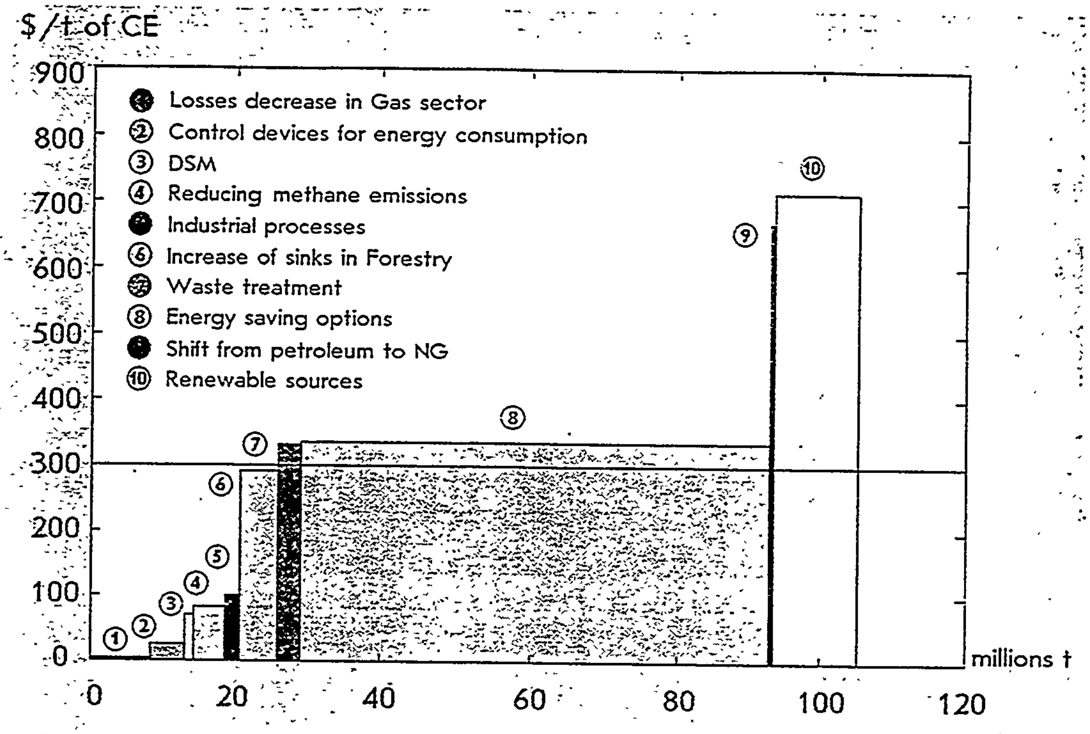

Figure 8. Investment curve

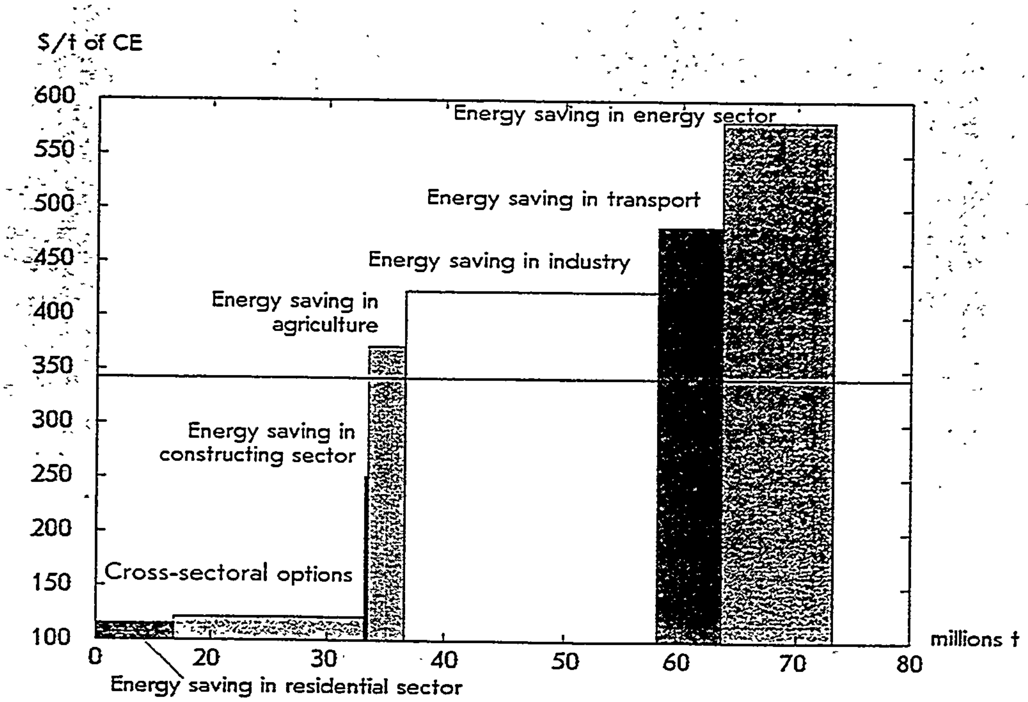

Figure 9. Investment curve

A package of above-mentioned measures was included into mitigation scenario.

7. MITIGATION SCENARIO

Realization of mitigation options will reduce the fossil fuel consumption by 3800-4000 PJ. Fuel combustion in mitigation scenario is shown at Figure 10.

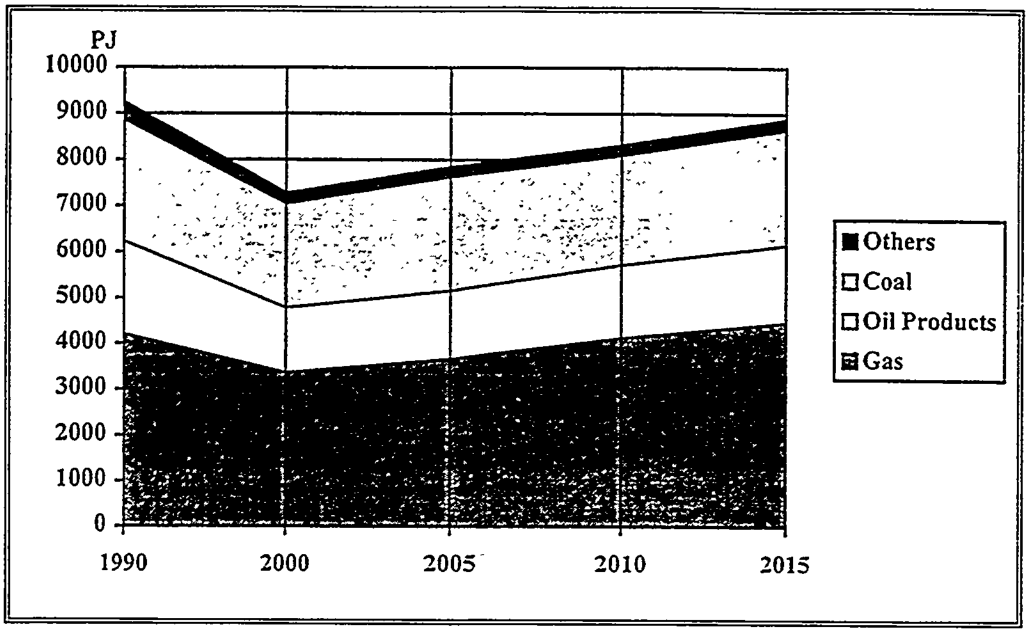

Figure 10. Fuel combustion for mitigation scenario

Energy demand and energy intensity will be essentially decreased relative to baseline scenario (Figure 11).

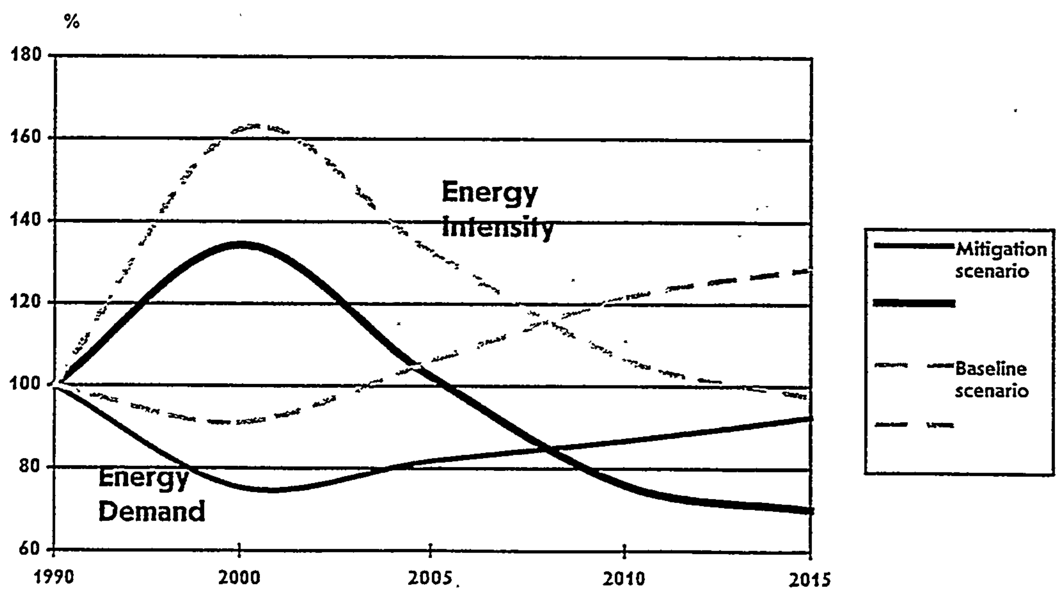

Figure 11. Comparison of baseline and mitigation scenario

Besides above-mentioned options a set of mitigation measures in forestry was included in mitigation scenario: forest protection and conservation, increased efficiency in forest management, harvesting, reforestation, agroforestry, etc. CO_2 uptakes will be increased by approximately 15 Tg in 2015 with the $1220 million additional investments.

The resulting GHG emissions and uptakes in a mitigation scenario are presented in Table 3 .

Table 3. Total GHG emissions and uptakes in mitigation scenario, Tg

	1990	1995	2000	2005	2010	2015
Direct GHG emissions						
CO_2	711.446	425.299	530.042	569.149	598.016	634.352
CH_4	10.115	7.150	8.383	7.951	7.467	6.738
N_2O	0.041	0.017	0.036	0.042	0.044	0.045
CE	260.570	161.873	199.668	208.254	213.449	219.242
Carbon dioxide sinks in forestry						
CO_2 uptake	-51.98	-64.88	-67.51	-71.66	-78.18	-87.29
Total						
CO_2	659.466	360.419	462.53	497.49	519.84	547.06
CE	246.350	144.17	181.26	188.71	192.13	195.19
Indirect GHG emissions						
CO	7.295	4.046	5.964	5.958	6.255	6.607
NO_x	2.043	1.140	1.564	1.605	1.613	1.666
C_xH_y	1.007	0.471	0.844	0.884	0.949	1.043

Investigations results allow to make an important conclusion that in a long-term period future GHG emissions will not exceed the 1990 levels in spite of essential GDP increase.

The comparative analysis of baseline and mitigation scenarios (Figure 12) indicate that direct GHG emissions will be reduced by more than 100 Tg in 2015 with the $30-35 billion investments.

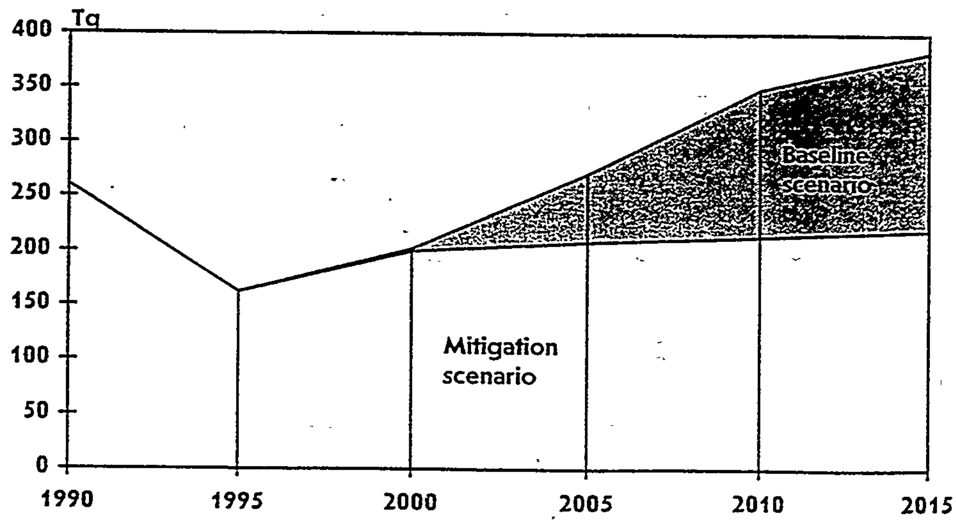

Figure 12. GHG Emissions Comparison of Baseline and Mitigation Scenarios

8. CONCLUSION

Such study in Ukraine is extremely important, because in the base year of 1990 it occupied the sixth place in the world on GHG emissions. Hence, the potential danger of GHG emissions on environment from the territory of Ukraine is rather great, and the measures on their reducing is necessary. A choice of 1990 as a basis for Ukraine is very indicative not only in connection with the fulfillment of obligations, accepted within the framework of the Convention, but also as it is a central point, after which fall of manufacturing production, inflation and crisis began. The transitional period has caused the basic difficulties in forecasting of the economy development and GHG emissions. In the main governmental documents, in particular in the National Energy Program, it is emphasized, that, taking into account incomplete definition of future development of economy, given measures should be specified annually, proceeding from the concrete conditions, specification of investment priorities and resource possibilities.

Investigation results will form the basis for the National Action Plan, directed to the mitigation of anthropogeneous impacts on the climate.

POTENTIAL OPTIONS TO REDUCE GHG EMISSIONS IN VENEZUELA

by

Nora Pereira, Yamil Bonduki, and Martha Perdomo

I. INTRODUCTION

The Government of Venezuela ratified the United Nations Framework Convention on Climate Change (UNFCCC) in December, 1994. The Convention requires all parties to develop and publish national inventories of anthropogenic greenhouse gas emissions (GHG) as well as national plans to reduce or control emissions, taking into account their common but differentiated responsabilities and their specific national and regional development priorities, objectives, and circumstances. Within this context, the Ministry of Environment and Renewable Natural Resources and the Ministry of Energy and Mines developed the «Venezuelan Case- Study to Address Climate Change».

The study was initiated in October 1993, with the financial and technical assistance of the Government of United States, through the U.S. Country Studies Program (USCSP), and the Global Environment Facility (GEF), through the United Nations Environment Programme (UNEP).

The main objectives of the Venezuelan Case-Study to Address Climate Change are, among others: i) develop a national inventory of anthropogenic emissions and removals of all greenhouse gases, ii) assess GHG mitigation options, and iii) formulate a national climate change action plan.

According to the national GHG emissions inventory [CVCC, 1995], the major sources of CO2 in Venezuela are energy combustion (56%) and deforestation (42%). Regarding CH4 emissions, the major sources are the energy sector (59%) (mainly from the fugitive emissions of the oil and gas production systems), and the agricultural sector (29%).

This paper, presents a summary of the technologies and practices that could be implemented in the country in order to contribute to both climate change mitigation and national development efforts. The selection of the sectors included in the mitigation options assessment was based on a detailed analysis that took into consideration the contribution of the main sources to national GHG emissions, the relevant natural and socio-economic characteristics of the country, the reduction potential, technologies for emission reduction, and local experience in related fields.

The mitigation analysis concentrates on options to reduce CO2 emissions generated from the energy sector and land use change. In the energy sector, the analysis was centered on the energy industry, the transportation sector and the manufacturing industry, since these three sectors jointly generate 94.4% of the CO2 emissions resulting from energy combustion.

For land use change, the mitigation options deals with the forestry sector, which includes two broad categories of sustainable forest practices: management and conservation of existing forest to reduce or avoid carbon emissions, and management for expanding forest cover and thus carbon storage in the country.

II. MITIGATION OPTIONS IN THE ENERGY SECTOR

Venezuela has diverse and abundant energy resources. The total volume of proven energy reserves in 1995 was 112.5 billion barrels of oil equivalent (BOE), where oil represented 63.8% of the total, natural gas 28.1%, hydroenergy 0.2% and coal 7.9%. The potential of renewable energies in Venezuela (including solar, wind, biomass, geothermal and mini-hydro energy), has been conservatively estimated in over 4 million BOE/day.

Oil production decrease from 1970 to the beginning of the 90's decade, due to a significant drop in crude oil and products exports, from 3,785 thousand BOE per day in 1970 to 2,352 thousand BOE per day in 1994, as a consequence of the OPEC strategy to control oil production. Exports share in total national production decrease from 95% to 78% during the 1970-1994 period.

Power generation capacity in the country increased from 2,677 MW in 1970, to 18,613 MW in 1994. The ratio of thermal to hydro capacity was 68/32 during the 70' decade to reach 24/76 in 1994 , mainly due to the completion of Guri hydropower plant. The country's population that had access to electricity services jumped from only 60% in 1970 to 90% in 1994.

The main changes in the structure of final energy consumption in the last 20 years were: (i) increasing of natural gas share in industrial consumption, rising from about 45% in 1970 to almost 52% in 1994, as a result of the basic industries growth, (ii) increasing of LPG share in household consumption from less than 10% in 1970 to almost 40% in 1994, and (iii) increasing of electricity share in total final consumption from 7.9% in 1970 to 14% in 1994 and from 26% in 1970 to almost 50% in 1994 in the household sector.

II.1 Methods and Instruments

The GHG mitigation assessment includes the selection of options and evaluation of their impacts on CO2 emissions and the energy system, including associated cost. An integrated study of the national energy supply and demand systems was carried out in order to identify, evaluate and compare possible mitigation options.

Two scenarios were considered, according to the Guidebook for Mitigation Assessments [Sathaye & Meyers, 1996]: i) A baseline scenario, consisting on a description of the plausible future of the Venezuelan energy system, where no specific actions to reduce GHG gas emissions will be taken; this scenario includes the adoption of enhanced technologies and actions to obtain a greater efficiency in the use of resources and ii) a mitigation scenario, which describes a similar future to that of the baseline scenario regarding the evolution of macroeconomic and social aspects, but assuming that efforts will be made as to the adoption of mitigation measures.

The assessment considered the following activities:

Development of a macroeconomic scenario; prospective of baseline energy demand using the LEAP model [SEI-B, 1993]; evaluation of the power system expansion, using the ELECTRIC module of the ENPEP model [ANL-EESD, 1994] and PLHITER models; construction and projection of the energy system's supply and demand network using the BALANCE module of the ENPEP model; estimate of the baseline scenario parameters; identification and assessment of potential mitigation options; impact assessment of several mitigation options with the BALANCE module; and identification of barriers and feasible mitigation options.

II.2 Baseline Scenario

Assumptions

The energy baseline scenario for 1990-2025 period was based on a macroeconomic scenario that assumes a sustained economic development, where the barriers that currently restrict the country's economic development will be overcome but without major structural changes taking place; the oil industry reduces its participation in the gross domestic product (GDP) from 28% in year 1990 to 24% in 2025, while the manufacture industry share increases from 15% to 17% in the same period, as a result of the aluminum and petrochemical industries development; a moderate decrease in the contribution of the service sector is also assumed. A reduction in population growth rate from 2.4 in 1990 to 2.1 in 2025, and a GDP growth of 4% per year between 1990 and 2025, are assumed.

In the sectoral energy demand scenarios, changes in energy use intensities are assumed as a result of improvements in the equipment efficiency, a better energy management, and changes in life style. A gradual increase in energy prices is set forth until they reach their opportunity cost (FOB export costs) in the case of oil fuels, or their marginal cost, in the case of natural gas and electricity.

The scenario assumes that there will be transformations in the energy system as a result of economic development, but no further efforts will be made to establish specific policies or measures to control or reduce greenhouse gas emissions.

Results

Primary energy production, 1000 million BOE in year 1990, would double by 2010 and would be 4.6 times higher by 2025. Table 1 shows that this high increase (4.4% annually), is basically due to fossil fuels production, basically encouraged by exports that grow at about 5% per year. Final consumption and fuel uses for electrical generation grow at lower rates, between 3.3% and 2.6% per year, respectively (Table 2).

In the baseline scenario hydroelectricity generation increases up to 88544 GWh by year 2011, remaining constant therafter thorugh the study period. After 2011, the demand increase is covered with natural gas thermal generation.

On the other hand, final energy consumption, 189 million BOE in 1990; would almost double by year 2010 and would almost triple by 2025. This represents a growth of 3.3% annually during the period, which is lower than the average growth assumed for the GDP (3.9%), and higher than population growth (2.2%). This means a reduction in the energy use intensity and an increase in per capita energy consumption. Final fossil fuel consumption grows at 3.3% interannually, while electricity consumption grows at 3.0%. Natural gas shows the highest growth (4.2% per year), which implies an important penetration of this fuel in consumption, by increasing its participation in the total final consumption from 33.0% in 1990, to 44% in year 2025. With respect to energy consumption by sectors, the industrial sector shows the highest growth, with an annual rate of 4%, followed by transportation (2.7%), and residential, services, and other sectors (1.6%).

These results show that under this scenario, there will be structural changes in energy consumption by sectors and by fuels, that could be summarized in a penetration of natural gas and a higher participation of the industrial sector in the final energy consumption.

Tables 3 show the estimates of C02 emissions generated by the energy sector activities, distributed by sectors and fuels. In general, it can be noticed that the emissions growth is somewhat lower than energy consumption, which is mostly due to a higher use of natural gas against liquid fuels that have a higher carbon content.

II.3 Mitigation Options Assessment

II.3.1 *Industrial Sector*

Steam Generation

Mitigation options are aimed at increasing the average efficiency of boiler and the use of fuel with lower carbon contents. Two mitigation options were considered for boilers which are operating in branches classified by the International Standard Industrial Classification of all Economic Activities (ISIC) as: (31) Foods, Beverages, and Tobacco; (35) Chemicals and Coal; and (37) Metallic Basic, which all together consume 82,4% of the energy used in steam generation. These options are: Boilers conversion from liquids fuels to natural gas and efficiency improvement of existing natural gas boilers through annual maintenance programs [Mantilla & Pereira].

In the baseline scenario, only the incorporation of new natural gas burning boilers is considered due to the steam increase requirements in this sector for the 1990-2025 study period, which slightly increases the average efficiency of these equipments.

OPTION 1: Boilers Conversion from Liquid Fuels to Natural Gas

This option basically deals with the substitution of the burner and the installation of pressure regulators and automatic valves. Efficiency of the converted natural gas boiler reaches 85%. Implementation of this option is assumed to begin on year 2000 and finish by 2005, when all liquid fuel boilers would have been replaced. Table 4 shows the investment and operation costs involved in the application of this mitigation option. Table 5 summarizes energy savings, CO2 emissions reduction and the cost for the final user. Although the option involves costs through the modification of boilers, the final result provides economical benefits.

OPTION 2: Natural Gas Boilers Maintenance Program

Combustion adjustment is one of the measures that allows boiler efficiency to increase. This adjustment consists in obtaining a correct oxygen-fuel mixture in order to have a complete combustion, according to the type of burner used. In addition, maintenance program includes: elimination of steam leaks and sealing of oxygen chamber, cleaning fireside boiler tube, proper refractors repairs, adjustment and proper burners cleaning, adequate inspection of control and safety devices.

Implementation of this option is assumed to begin in 2000, initially on 20% of existing boilers, and will be progressively extended up to year 2004, when all the boilers would have been covered. This option will only be adopted in branches 31 and 35 where the natural gas boilers efficiency is low.

The operating and maintenance costs for each year, necessary to implement this option, as well as the new boilers efficiencies as assumed for this mitigation measure are shown in Table 6. Table 7 shows results related to energy savings, C02 emissions reduction and the final user costs.

Direct Heat

In 1990, the metallic basic industries (branch 37) registered a consumption of 41% of the total energy in the manufacture industry and 50% of direct heat consumption for these industries [García & Pereira, 1996].

The steel and aluminum industries consume almost the total energy for direct heat in branch 37. Two mitigation options were formulated for these industries: Changes in iron mineral reduction and combustion efficiencies improvement in natural gas furnaces for foundry and lamination.

The baseline scenario considers a tendency behavior in the development of the steel and aluminum industries under the following assumptions: energy demand for using direct heat will increase at an interannual rate of 4.2%, there will be no actions concerning relevant changes in processes, and there will be some improvement in energy efficiencies due to the renewal and introduction of new equipment.

OPTION 3: Changes in Direct Reduction of Iron Ore

Table 8 presents the characteristics of available technology in the Venezuelan steel industry. The "H&L" and "Midrex" technologies are the most important regarding capacity and production; however when analyzing their specific consumptions of natural gas per Ton of production, a significant difference could be observed (4.86 BOE/Ton and 2.04 BOE/Ton). This difference is due to: (1) the actual value of the "H&L" technology is more than double the theoretical value (2,1 BOE/Ton) and (2) the "H&L" is the oldest reduction technology and did not fully achieve the designed production levels. Thus, CO2 emissions reduction could be obtained through energy efficiency improvement of the "H&L" technology or a conversion or substitution process to more efficient technologies. Furthermore, the Midrex technology could also be improved.

This mitigation option was developed under the assumption that efficiency for the "H&L" technology will improve from 43% by year 2000 to 73% by 2025 and will be maintained in 80% for the "MIDREX" technology. Technological changes from "H&L" to "MIDREX" are assumed to take place in years 2005 and 2010, while improvement of "MIDREX" will occur by 2015, with investments of M$ 200, M$ 255, and M$ 280, respectively. Table 9 presents energy savings, C02 emissions reduction and the final user costs obtained for this option.

It is important to bear in mind that only between 20% and 30% of the gas used in direct reduction furnaces is consumed as fuel for direct heat, the rest is used as process gas (feedstock use). The results obtained considered only natural gas used as fuel for direct heat, which represents part of the potential of energy savings and emissions reduction. If saving of process gas were included, the emissions reduction potential would be higher, and thus mitigation costs per Ton of C02 might be considerably reduced.

OPTION 4: Combustion Efficiency Improvement in Natural Gas Furnaces

In this mitigation option, a typical furnace with its own characteristics was considered taking as a basis, reheating lamination furnaces of steel products and furnaces for aluminum alloys. The designed thermal efficiency of furnaces was found to be low.

The main assumptions are: energy efficiency increases from 42% by year 2000 to 70% by 2025; increase of yearly operation and maintenance costs of 20$/BOE by year 2000; and investments of M$ 0.4 by 2010. Table 10 presents energy savings, C02 emissions reduction and final user costs.

II.3.2 ***Transportation Sector***

As explained in [Segnini & Pereira, 1996], big cities in Venezuela have high vehicle densities and especially, low fuel efficiency, mainly due to fleet age, poor maintenance, and high traffic volume. In order to accelerate an improvement of fuel efficiency in the transport sector, the Venezuelan government is developing an ambitious plan, focussing the effort initially, on the public transport fleet.

Three mitigation options were assessed in detail: switching to more larger capacity vehicles, less private vehicles share, and switching from gasoline to natural gas vehicles.

The baseline scenario considers a road vehicle fleet of 2.7 million units in 1990, where passenger vehicles represents 81%, and freight vehicles 19%. Average road transportation demand growth rate for 1990-2025 period is assumed to be 3.4% per year for both passenger and freight. Regarding the demand structure evolution, private vehicles represented 33% of the total passenger demand in 1990 and it is assumed to grow at an average rate of 4% yearly, reaching 97,000 pass-Km by 2025, which represents 40% of passenger demand. Public transportation share is assumed to decrease from 63% in 1990 to 56% by 2025. In this segment, small buses decreased from 25% in 1990 to 22% by 2025. Railroad share maintains a small percentage of about 3.5%. Regarding freight transportation, it maintains almost a constant structure along the period 1990-2025, where light 2 axle trucks share is about 7.%, heavy 2 axle trucks 14%, 3 axle 43%, and 4 axle trucks 36%.

OPTION 5: Switching to Larger Capacity Vehicles

This option considers the switching of public transportation from small buses to large buses. Also, a switching of light duty trucks to heavier trucks is assumed.

The main assumptions are: private and public transport shares in total passenger transportation demand are the same as the baseline scenario. Share of public transportation presents the following changes: small buses tend to disappear by 2010; medium buses 1990-2025 growth rate per year change slightly from 3.03% in the baseline case to 2.85% for this option; and large buses share increases from 23% in 1995 to 35% in 2025.

On the other hand, two axle light duty vehicles share in freight transportation demand, decreases from 8% in 1990 to 1.6% in 2025, while in the baseline scenario its share was almost constant; and heavy duty freight share increases in 5.5% yearly along the period; in baseline case it is constant. Table 11 presents energy savings, CO_2 emissions reduction, and mitigation costs for the transportation system.

OPTION 6: Less Private Vehicle Share

Private vehicles share in transportation demand (pass-km) decreases in relation to baseline scenario, while large buses share increases according to the following assumptions: private vehicles share is maintained in 34%; annual growth during the 1990-2025 period is 3.5%, compared to 4% in the baseline scenario; and large buses share increases from 23% in 1990 to 28% in 2025, which represents an annual growth of 4% against 3.3% in the baseline scenario. Table 12 presents energy savings, CO_2 emissions reduction, and mitigation costs for the transportation system..

OPTION 7: Switching Gasoline to Natural Gas Vehicles (NGV)

The Venezuelan government has initiated a promotion plan to switch gasoline by natural gas in public transportation, taking into account that the gas price is significantly lower than gasoline. The plan includes subsidies for motor conversion.

The assumptions for this case are the following: public transport demand is the same as in the baseline scenario; conversion to natural gas until year 2000 will be 10000 small buses, 15000 medium buses, 10000 taxis, and 25000 light duty trucks; public transportation demand by year 2000 (NGV), will be 7,073 passenger-Km and 16,042 passenger-Km by 2025; assuming that all new public transportation demand will be satisfied by natural gas. Energy intensity is the same in both gasoline and natural gas vehicles. Table 13 presents energy savings, CO2 emissions reduction, and mitigation costs for the transportation system.

II.3.3 *Electricity Generation*

In the baseline scenario hydroelectricity generation increases up to 88544 GWh by year 2011, remaining constant therafter thorugh the study period. After 2011, the demand increase is covered with natural gas thermal generation. Consequently, an increase in hydroelectrical generation capacity would contribute to CO2 emission reduction. To this effect, Venezuela has an economically usable hydroelectrical potential in the High Caroni and Caura rivers estimated in 10000 MW of capacity and 65000 GWh/year of medium energy [Jimenez, 1996] . Currently, feasibility studies to develop this potential have been carried out, but without enough cost data to perform a complete mitigation assessment; however, an expansion case study of the power system that only included the Tayucay project was carried out.

OPTION 8: Increase of Hydroelectrical Capacity with Tayucay Plant

Projects characteristics are as follows: capacity of 3000 MW; annual energy of 15300 GWh; 6 units of 500 MW each; beginning of operation by year 2012; and cost of 2130 $/KW.

The development of Tayucay plant would imply an investment cost increase of about 700M$ and an operating and maintenance costs decrease of 72M$. Table 14 presents energy savings, CO2 emissions reduction, and mitigation costs.

II.4 Analysis of Mitigation Options Results

The results for each mitigation option are summarized in Table 15. The most effective options correspond to the transportation sector, in terms of both contribution to emissions reduction and costs. For the three transportation options considered the cost were negative, which means that their application would provide benefits for the national energy system.

Regarding the manufacture industry options, boilers conversion from liquid fuels to natural gas also reflects negative costs, but to a considerably lower extent than those for the transportation sector; likewise, the emissions reduction is also considerably lower in comparison with the rest of the options. Efficiency improvement of natural gas boilers that present close to zero cost, is more effective in reducing emissions than boilers conversion but not in terms of unit cost.

From the options showing a positive cost, efficiency improvement of natural gas furnaces presents the lowest total cost but is not very effective in reducing emissions. Therefore, it has a high unit cost that is very close to that of the option dealing with changes in the iron reduction process, which requires higher investments.

The increase in hydro power generation is the alternative with the highest total cost but it is very effective in reducing emissions; compared to direct heat options, unit cost is less that half.

Figure 1 shows the "discrete step" curve where the cost and the extent of the emissions reduction of each alternative are presented.

These options were analyzed separately but neither the interdependency that may exist between them nor the effects that they may have in the energy system if they were jointly analyzed, have been assessed. However, it should be noted that they are highly independent actions, except for those in the transportation sector, which may require a few adjustments in order to apply them together. In spite of these limitations, and the small number of analyzed options, cost curves were built in order to have some global results for the energy system. Table 16 shows the estimated series for average and incremental costs while and Figure 2 shows the corresponding curves.

III. MITIGATION OPTIONS IN THE FOREST SECTOR

III.1 Forest Clearing and Greenhouse Gas Emissions

According to the last comprehensive study of vegetation cover in Venezuela, the forested area of the country in 1980 was roughly 57 million hectares [MARNR, 1982], which represents more than 60% of the national territory. About 75% of this forested land is classified as closed forests and more than 70% is located in the southern region of the country, where the Amazonian Basin is also located.

Agriculture and pasture activities, as well as other development projects, have affected large areas of forest in the country. Logging is not considered to be a major cause of deforestation because wood production is based on a few species and trees are harvested selectively. However, logging leads indirectly to deforestation as the forest areas are opened up through road construction and are, consequently, subject to further intrusion by agricultural colonists.

The annual rate of forest clearing in Venezuela has not been consistently documented. Rough estimates have provided a wide range of annual forest clearing, from less than 300,000 ha/yr [Catalán, 1993] up to 600,000 ha/yr [FAO, 1993]. For the greenhouse gas emissions inventory, [CVCC, 1995], the average deforestation area was estimated to be approximately

517,000 ha/year during the last decade.

Forest clearing accounts for about 44% of national CO_2 emissions (carbon emitted from disturbed forest soils is not included in this estimate). Biomass burning that occurs in conjunction with changes in land use is also an important contributor to trace gas emissions. Biomass burning accounts for approximately 5% of methane, 26% of nitrous oxides, 6% of nitrogen oxides, and 34% of carbon monoxide [CVCC, 1995].

III.2 Mitigation Options Analysis

In this study, the mitigation analysis for the forest sector deals with the options that have been traditionally considered priority government programs to manage, enhance and protect the country´s forest resources. These options are: natural forest protection and management, establishment of industrial and small-scale plantations, and development of agroforestry systems.

The mitigation assessment was based on the following steps: i) construction of a baseline scenario to determine possible trends of carbon emissions from forest clearing: ii) assessment of carbon storage in pilot forestry projects and associated costs; iii) construction of mitigation scenarios to assess Venezuela´s potential for storing carbon, based on forest practices; and v) identification of main barriers for options implementation.

III.2.1 Baseline Scenario

The baseline for carbon dioxide emissions from land use change in Venezuela was developed using several assumptions regarding i) carbon emissions from forest conversion and ii) carbon sequestration and conservation in forest plantations and managed natural forest. The assumptions mainly deals with rough estimates of the rate at which lands will be converted from and to forest use. Estimates of carbon emissions and sequestration are based on the IPCC/OECD methodology for national greenhouse gas emissions inventory.

Annual cleared area is assumed to drop between 30% and 40% towards 2025. as a result of new policies implementation to control and reduce degradation of natural forests. On the other hand, the country is going through an important economic crisis that might already be affecting the process of land use change. Government subsidies for agricultural activities have been drastically reduced while high inflation rates have considerably increased the cost of developing new agricultural lands and have produced an important reduction in wood consumption and production. It has been assumed that these trends could produce an additional 20% reduction in the base year's deforested area.

Thus, annually cleared area in 1990-2025 period is expected to decrease steadily. From an average of 517,000 ha/yr, deforestation in the country will drop to 232,000 ha/yr by 2025, which implies a deforestation rate reduction of one third as compared to the 1990´s figure. The total forest area of the country will then be reduced from an estimate of 51.8 millions ha in 1990 to 38.1 millions ha in 2022.

Carbon dioxide emissions from forest clearing (excluding those from disturbed forest soils) will then reach about 54,000 Gg by 2025, a significant reduction with respect to the base year (84,790 Gg). Emissions do not decrease in the same proportion as deforestation does because average biomass density of cleared forests was estimated to increase from 115 tons of dry matter per ha (t dm/ha) to 160 t dm/ha, based on the assumption that a great fraction of forest clearing will occur in areas less affected by human intervention.

Regarding carbon sequestration, the scenario assumes that annually planted area will be comparable to the average planted during 1970-90 period (20,000 ha/yr) while the area of managed natural forest for sustainable wood production is estimated to double the average of the previous period, reaching about 14,000 ha/yr, as a result of ongoing government policies to encourage the adoption of sustainable forest practices and improve harvesting control. Based on these assumptions, annual carbon dioxide sequestration has been estimated to be 11,000 Gg by 2025.

Net carbon dioxide emissions will then reach about 43,000 Gg, which represents a decline of approximately 45% with respect to the base year (79,260 Gg). In addition to lower deforestation rates, the increase of the forest managed area is responsible for reduction of net carbon dioxide emissions in this scenario.

III.2.2 Carbon Storage in Forestry Projects

Two different forest projects, an industrial plantation (Uverito) and a managed protected area (Ticoporo Reserve), are used here as case studies in order to extrapolate this local experience to a broader context that includes carbon emissions reduction and sequestration. Project selection was based on the following main criteria: a) should be considered successfully or with high implementation potential, b) applicable on larger scale in the country, c) based on sustainable forestry practices, and d) should cover a wide range of possible mitigation options.

Carbon sequestration potential and associated costs were evaluated for both the Uverito Plantations and the Ticoporo Reserve in order to assess the value of these projects as mitigation options. This analysis is briefly summarized below [for details see Bonduki and Swisher, 1995]. The information and data used for developing the case studies were obtained from the Corporacion Venezolana de Guayana [CVG, 1993] and the Venezuelan Forest Service [Seforven, 1993]. The carbon stock accounting method is from [Swisher, 1991]. The costs and carbon storage results for each project type are summarized in Table 17.

III.2.3 Mitigation Scenarios

The results of carbon storage densities and associated costs of the case studies are used to determine the amount of carbon that might be stored in the country through the implementation of similar forestry options under two different scenarios: a technical potential scenario and a constrained scenario. In both cases, the following mitigation options are included: forest protection, forest management in small areas, forest management in large areas, small scale forest plantations, industrial plantations, and agroforestry systems.

The technical scenario is based on estimates of the amount of land technically suitable for the development of mitigation options, without considering socioeconomic, legal, and other limitations. However, the potential land areas that could theoretically be fully allocated for mitigation options development were adjusted in order to avoid overestimation of carbon sequestration potential. Consequently, the results of this scenario might be considered a rather conservative upper limit to the amount of potential carbon storage through the adoption of proposed options. In this scenario, the mitigation analysis was carried out only for year 2025.

Estimates of available land for each mitigation options relied mainly on i) some studies that have characterized potential land use of the country, based only on physical parameters [MARNR, 1982, and 1991], and ii) on assumptions made on the amount of lands that could be allocated for mitigation options development, based mainly on technical considerations. For the options that deal with forest protection and management, potentially available areas were also analyzed within the context of the baseline scenario in order to assess the amount of forest that could be subject to sustainable management practices. Thus, the total amount of land potentially available for mitigation options implementation has been estimated to be about 19.7 million hectares while total carbon storage reaches 1,437 MtC (Table 18). Based on the results of average unit mitigation costs from the two case studies, total investment cost for this scenario has been estimated to be about US$ 13.7 billion.

The constrained scenario tries to provide a more realistic picture of the country´s potential to store carbon, since, as acknowledge in the literature, socioeconomic factors may limit the actual availability of land for the purpose of storing carbon [Sathaye and Meyers, 1995]. However, given the difficulties in assessing the influence of economic, institutional, legal, demographic, and cultural factors on present and future land-use decisions. estimates of the land area that could actually be allocated for each mitigation option was based mainly on rough projections of a feasible development of the forestry sector in Venezuela by 2025. Thus, the total land area in this scenario represents less than 50% (about 9 million ha) of the total suitable land estimated in the technical scenario. Total carbon storage in this mitigation scenario reaches 695 MtC by 2025 (Table 19).

Based on the results of average unit mitigation costs from the two case studies, total investment cost for this scenario has been estimated to be about US$ 5.7 billion.

III.3 Analysis of Mitigation Options Results

This general analysis of mitigation options in the forest sector shows that there is a considerable potential in Venezuela for reducing CO_2 emissions through the adoption of sustainable forest practices, especially by slowing the rate of forest loss and degradation. Maintenance of already existing biomass in natural forests should then be the first priority of forest measures to reduce the amount of carbon released to the atmosphere. More importantly, forestry projects designed within the context of climate change issues basically deal with deforestation, which is a significant environmental problem in Venezuela.

Based on the two case studies and the mitigation scenarios, forest protection and management of native forest represent the two options with the highest carbon conservation potential and the lowest carbon unit cost. Expansion of the forest cover through the development of intensive forest plantations also presents a high potential to offset carbon emissions in the country.

IV. BARRIERS TO MITIGATION OPTIONS IMPLEMENTATION

In the energy sector, low energy prices represent the main barrier to any mitigation program. In spite of the last energy price increase, oil products and natural gas prices are still below the exportation FOB value and the marginal costs, respectively. Thus, energy still maintains a low share of the users cost structure and does not incentivate investments in energy use improvement programs.

Even with the future price increases assumed in the baseline scenario, other types of measures will be needed to promote and encourage these programs since, in general, the users have other priorities and, in many cases, more attractive investments opportunities. Also, in most cases, the users lack the knowledge on how to achieve a rational energy consumption and the associated benefits. The measures should then be oriented at developing education and training programs, energy auditing, adequate financial mechanisms, and equipment standars.

Another important limitation to mitigation strategies implementation is the lack of institutional capacity and legal instruments for developing the mitigation measures. Venezuela lacks adequate institutional arrangements to deal with energy demand management.

In the forest sector, stopping or drastically reducing deforestation, through the application of effective measures to protect native forests, may appear to be a rather simple and high-impact alternative for offsetting greenhouse gas emissions. However, the primary causes of forest clearing in Venezuela are not related to forest activities and, consequently, the definition of feasible mitigation options will depend upon a good understanding of other economic sectors and how they account for land-use change. Land tenure, rural poverty, political interests, and weak implementation of land-use planning instruments and environmental laws are considered to be key limitations to any effort dealing with forest conservation efforts.

On the other hand, forest plantations might be considered more applicable in the longer run due to the higher costs involved in the development of this type of project. Land tenure, economic factors, and lack of incentives represent some of the most important barriers to the development of forest plantation and agroforestry systems in the country.

Community participation, local benefits, institutional capacity and competence as well as the involvement of non-government organizations are other relevant issues that need to be addressed in an assessment of forestry projects for offsetting carbon emissions in Venezuela. Given the social issues involved in the land-use change processes that have characterized Venezuela, a closer analysis of the main constraints and opportunities for the implementation of mitigation options will have to consider non-carbon benefits as the key component of such initiatives.

Political decisions to implement mitigation programs and the allocation of financial resources for programs promotion and development are other important factors for both the energy and forest sector since any mitigation initiative, regardless of the associated economic benefits, requires adequate financing and human resources for planning and implementation.

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November, 1996.

FIGURE 1
DISCRETE STEP CO2 - REDUCTION COST CURVE

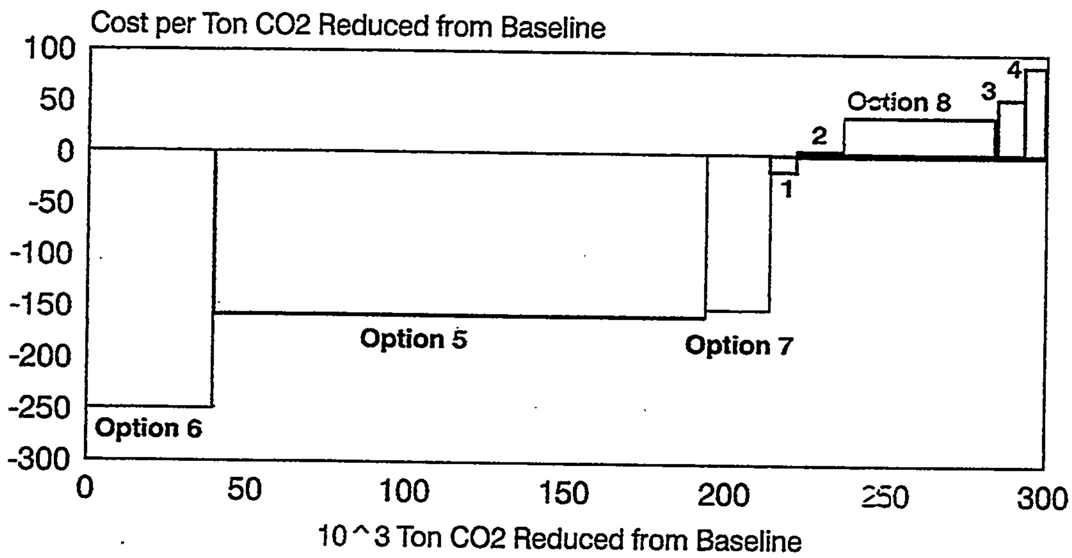

FIGURE 2
INCREMENTAL AND AVERAGE COST CURVES

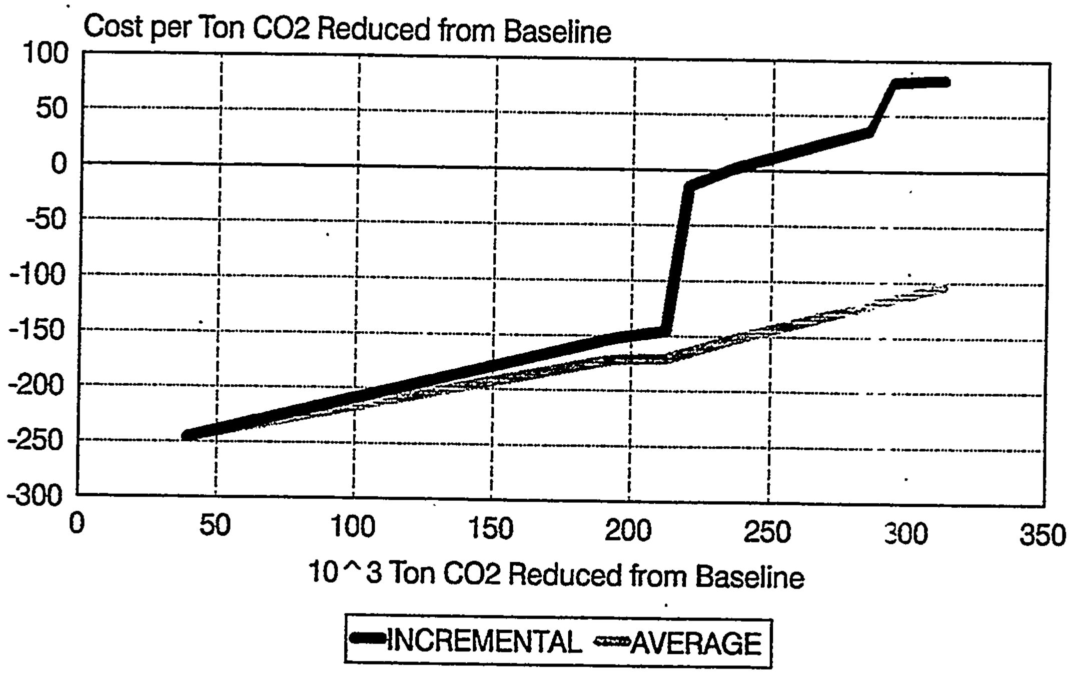

TABLE 1. BASELINE SCENARIO - PRIMARY ENERGY PRODUCTION (10^3 BOE)

YEARS	1990	1995	2000	2005	2010	[illegible]	2020	2025
CRUDE OIL	834126	1005187	1230066	1509317	1872833	[illegible]	2925804	3662565
NATURAL GAS	132975	160245	196095	240613	298564	[illegible]	466427	583881
COAL	11188	16900	26195	41119	65106	[illegible]	165800	265769
HYDROENERGY	22264	35624	42450	49386	51094	[illegible]	50582	53221
TOTAL	1000553	1217956	1494806	1840435	2287597	[illegible]	3608613	4565436

TABLE 2. BASELINE SCENARIO - FOSSIL FUELS USES (10^3 BOE)

YEARS	1990	1995	2000	2005	2010	[illegible]	2020	2025
EXPORTS	718941	889732	1108915	1387752	1743383	[illegible]	2785910	3518514
FINAL CONSUMPTION	188523	220203	252327	290749	342178	[illegible]	490869	587240.3
ELECTRICITY GEN.	53184	17719	15116	16998	40167	[illegible]	98520	130141
TOTAL	960648	1127654	1376358	1695499	2125728	[illegible]	3375299	4235895

TABLE 3. BASELINE SCENARIO - CO2 EMISSIONS (10^3 [illegible])

FINAL CONSUMPTION								
YEARS	1990	1995	2000	2005	2010	[illegible]	2020	2025
BY SECTORS								
INDUSTRY	24818	30110	36174	43780	53306	[illegible]	79826	94600
TRANSPOT	29180	33001	35945	38832	44142	[illegible]	61658	73216
RESIDENTIAL	4272	4674	4973	5444	5866	[illegible]	7048	7449
TOTAL	58269	67785	77091	88056	103315	[illegible]	148532	175265
BY FUELS								
OIL	38347	43064	46731	50700	57347	[illegible]	78853	89741
NATURAL GAS	18951	23695	29285	36229	44785	[illegible]	68362	84126
COAL &COKE	972	1026	1076	1128	1183	[illegible]	1317	1398
ELECTRICITY	0	0	0	0	0	[illegible]	0	0
BIOMASS	0	0	0	0	0	[illegible]	0	0
TOTAL	58269	67785	77091	88056	103315	[illegible]	148532	175265
ELECTRICITY GENERATION								
YEARS	1990	1995	2000	2005	2010	[illegible]	2020	2025
DIESEL	972	0	0	0	0	[illegible]	0	0
RESIDUAL	5411	0	0	0	0	[illegible]	0	0
GAS NATURAL	13182	6007	5196	5906	14079	[illegible]	33075	43659
TOTAL	19565	6007	5196	5906	14079	[illegible]	33075	43659

TABLE 4. INVESTMENTS AND CHARACTERISTICS OF BOILERS CONVERSION FROM LIQUID FUEL TO NATURAL GAS

Industrial Branch	Power HP	Investment 10^3 $/Plant	O&M Cost $/BOE	Efficiency %	Capacity 10^3 BOE/year
31	250	10.03	0.23	85	5.54
35	150	9.43	0.38	85	3.32
37	150	9.43	0.38	85	3.32

TABLE 5. DIFFERENCES BETWEEN BOILERS CONVERSION MITIGATION OPTION AND BASELINE SCENARIO

Year	2000	2005	2010	2015	2020	2025
Energy Consumption for Steam Generation (10^3 BOE)						
Baseline	24531	29013	34325	40863	48587	57706
Energy Saving	101	498	458	463	1764	1835
CO2 Emissions (10^3 Ton)						
Baseline	7921	9318	11019	13109	15608	18646
CO2 Reduction	71	333	303	309	327	386
Final User Costs (10^6 $)						
Baseline	166	192	263	313	438	525
Increase	-3.8	-19.7	-17.3	-18.5	-19.5	-24.6

TABLE 6. OPERATING AND MAINTENANCE COSTS AND BOILERS EFFICIENCY IMPROVEMENT

Industrial Branch	Year	2000	2001	2002	2003	2004	2005-2025
31	O & M Costs $/BOE	0.15	0.16	0.18	0.19	0.20	0.20
	Efficiency %	78	79	80	81	82	82
35	O & M Costs $/BOE	0.21	0.22	0.24	0.25	0.27	0.27
	Efficiency %	78	79	80	81	82	82

TABLE 7. DIFFERENCES BETWEEN NATURAL GAS BOILERS MAINTENANCE PROGRAM MITIGATION OPTION AND BASELINE SCENARIO

Year	2000	2005	2010	2015	2020	2025
Energy Consumption for Steam Generation (10^3 BOE)						
Baseline	21089	24838	29270	34742	41177	48733
Energy Saving	228	1325	1604	1928	2309	2759
CO2 Emissions (10^3 Ton)						
Baseline	6751	7901	9303	11030	13091	15598
CO2 Reduction	76	447	543	656	787	944
Final User Costs (10^6 $)						
Baseline	135.4	154.4	211.5	249.8	350.9	419.5
Increase	-1.0	-6.0	-9.5	-11.8	17.7	-21.5

TABLE 8. DIRECT REDUCTION IRON TECHNOLOGIES IN VENEZUELAN STEEL INDUSTRY

TECHNOLOGY	"H&L"	"MIDREX"	"AREX"	"FIOR"	"FINMET"
Product	DRI	DRI	DRI	HBI	HBI
Capacity 10^3 Ton/year	2,163.00	1,630.00	450.00	400.00	1,000.00
Production 10^3 Ton/year	1,172.00	1,615.00		404.00	
Present State	Operation	Operation	Project	Operation	Project
Input	Lump/Pellets	Lump/Pellets	Lump/Pellets	Fine	Fine
Furnace Type	Reducing Shaft Batching Process	Reducing Shaft Continuous Process	Reducing Shaft Continuous Process	Fluid Bed Continuous	Fluid Bed Continuous
Gas Treatment	Reforming	Reforming	Auto Reforming	Reforming	Reforming
Pressure	5 Bar	Atmospheric	Atmospheric	10 Bar	10 Bar
SPECIFIC ENERGY CONSUMPTION					
Natural Gas BOE/Ton	4.86 (1)	2.04 (1)	1.86 (2)	3.01 (2)	3.17 (2)
Electricity BOE/Ton	0.08 (1)	0.06 (1)	0.05 (2)	0.12 (2)	0.09 (2)

(1) Actual Values
(2) Theorical Values

TABLE 9. DIFFERENCES BETWEEN DIRECT REDUCTION IRON MITIGATION OPTION AND BASELINE SCENARIO

	1990	2000	2005	2010	2015	2020
ENERGY CONSUMPTION (10^3 BOE)						
Branch 37 (Baseline)	11830	17325	21104	25544	31195	36632
Process (Baseline)	3881	5923	7305	9003	11088	13095
Energy Saving (Mitigation-Baseline)	0	278	752	2387	3131	3698
% / Branch 37	0%	1.6%	3.6%	9.3%	10%	10%
% / Reduction Process	0%	4.7%	10.3%	26.5%	28.2%	28.2%
CO2 EMISSIONS (10^3 Ton)						
Branch 37 (Baseline)	2840	3928	4684	5542	6665	7745
Process (Baseline)	1302	1987	2451	3020	3720	4393
Reduction (Mitigation-Baseline)	0	93	252	801	1050	1241
% / Branch 37	0%	2.4%	5.4%	14.5%	15.8%	16%
% / Reduction	0%	4.7%	10.3%	26.5%	28.2%	28.2%
USER COSTS (Million $) (CNV 1990)						
Branch 37 (Baseline)	972	1541	1803	2151	2556	3623
Process (Baseline)	82	118	139	172	202	276
Reduction (Mitigation-Baseline)	0	17	46	86	129	138
% / Branch 37	0%	1.1%	2.6%	4.0%	5.0%	3.8%
% / User Process	0%	14.4%	33.1%	50.0%	63.9%	50.0%

CNV: Current Net Value

TABLE 10. DIFFERENCES BETWEEN FURNACES USING NATURAL GAS MITIGATION OPTION AND BASELINE SCENARIO

	1990	2000	2005	2010	2015	2020
ENERGY CONSUMPTION (10^3 BOE)						
Branch 37 (Baseline)	11830	17325	21104	25544	31195	36632
Furnaces (Baseline)	1586	2374	2959	3511	4353	5164
Energy Saving (Mitigation-Baseline)	0	158	197	1135	1406	1669
% / Branch 37	0%	0.9%	0.9%	4.4%	4.5%	4.6%
% / Furnaces	0%	6.7%	6.7%	32.3%	32.3%	32.3%
CO2 EMISSIONS (10^3 Ton)						
Branch 37 (Baseline)	2840	3928	4684	5542	6665	7745
Furnaces (Baseline)	532	796	993	1178	1460	1732
Reduction (Mitigation-Baseline)	0	53	66	381	472	560
% / Branch 37	0%	1.3%	1.4%	6.9%	7.1%	7.2%
% / Furnaces	0%	6.7%	6.7%	32.3%	32.3%	32.3%
USER COSTS (Million $) (CNV 1990)						
Branch 37 (Baseline)	972	1541	1803	2151	2556	3623
Furnaces (Baseline)	40	58	69	84	99	138
Reduction (Mitigation-Baseline)	0	17	20	21	25	27
% / Branch 37	0%	1.1%	1.1%	1.0%	1.0%	0.7%
% / User Furnaces	0%	29.5%	29.0%	25.0%	25.0%	19.5%

TABLE 11. DIFFERENCES BETWEEN SWITCHING TO MORE EFFICIENT VEHICLES TYPES MITIGATION OPTION AND BASELINE SCENARIO

	1995	2000	2005	2010	2015	2020
FUEL CONSUMPTION (Thousand BOE)						
Baseline Case	74906	81335	87536	99378	117019	134263
Difference (Mitigation-Baseline)	-962	-3904	-9383	-12971	-15990	-18651
Reduction (%)	1.3	4.8	10.7	13.0	13.7	13.9
CO2 EMISSIONS (Thousand Ton)						
Baseline Case	31378	34073	36666	41621	49012	56326
Difference (Mitigation-Baseline)	-394	-1598	-3840	-5312	-6556	-7654
Reduction (%)	1.2	4.7	10.5	12.8	13.4	13.6
COSTS (Million $)						
Baseline Case	5301	7388	9348	11815	14652	16321
Difference (Mitigation-Baseline)	-57	-312	-784	-1115	-1428	-1617
Reduction (%)	1.0	4.2	8.4	9.4	9.7	9.9

TABLE 12. DIFFERENCES BETWEEN LESS PRIVATE VEHICLES SHARE MITIGATION OPTION AND BASELINE SCENARIO

	1995	2000	2005	2010	2015	2020
FUEL CONSUMPTION (Thousand BOE)						
Baseline Case	74906	81335	87536	99378	117019	134263
Difference (Mitigation-Baseline)	-407	-974	-1754	-2804	-4207	-5644
Reduction (%)	0.5	1.2	2	2.8	3.6	4.2
CO2 EMISSIONS (Thousand Ton)						
Baseline Case	31378	34073	36666	41621	49012	56326
Difference (Mitigation-Baseline)	-168	-402	-723	-1156	-1734	-2327
Reduction (%)	0.5	1.2	2.0	2.8	3.5	4.1
COSTS (Million $)						
Baseline Case	5301	7388	9348	11815	14652	16321
Difference (Mitigation-Baseline)	-42	-111	-209	-345	-531	-684
Reduction (%)	0.8	1.5	2.2	2.9	3.6	4.2

TABLE 13. DIFFERENCES BETWEEN SWITCHING GASOLINE TO NATURAL GAS VEHICLES MITIGATION OPTION AND BASELINE SCENARIO

	1995	2000	2005	2010	2015	2020
FUEL CONSUMPTION (Thousand BOE)						
Baseline Case	74906	81335	87536	99378	117019	134263
Difference (Mitigation-Baseline)	109	493	415	241	285	296
Reduction (%)	-0.2	-0.6	-0.5	-0.2	-0.2	-0.2
CO2 EMISSIONS (Thousand Ton)						
Baseline Case	31378	34073	36666	41621	49012	56326
Difference (Mitigation-Baseline)	0.5	-127	-423	-839	-1228	-1228
Reduction (%)	-0.002	0.4	1.2	2.0	2.5	2.2
COSTS (Million $)						
Baseline Case	5301	7388	9348	11815	14652	16321
Difference (Mitigation-Baseline)	-15	-129	-229	-300	-445	-438
Reduction (%)	0.3	1.7	2.4	2.5	3.0	2.7

TABLE 14. DIFFERENCES BETWEEN TAYUCAY PLANT MITIGATION OPTICN AND BASELINE SCENARIO

	1990	1995	2000	2005	2012	2016	2020	2026
ENERGY CONSUMPTION (10^3 BOE)								
BASELINE	53184	17719	15116	16998	[illegible]	64318	98690	130141
SAVING	0	0	0	0	-[illegible]779	-11337	-10118	-10686
%	0	0	0	0	-12	-18	-10	-8
CO2 EMISSION (10^3 TON)								
BASELINE	19565	5944	5071	5702	[illegible]719	21677	33075	43669
REDUCTION	0	0	0	0	-[illegible]539	-3803	-3394	-3585
%	0	0	0	0	-12	-18	-10	-8
COST								
BASELINE	452	330	339	397	[illegible]82	521	618	707
INCREASE	0	0	0	0	[illegible]13	111	129	145
%	0	0	0	0	23	21	21	20

TABLE 15. SUMMARY RESULTS ACCUMULATED (1990-2025)

MITIGATION OPTIONS		ENERGY SAVING 10^3 BOE	CO2 REDUCTION 10^3TON	TOTAL COST M$	UNIT COST $/TON CO2	% CO2 REDUCTION/ BASELINE
MANUFACTURE INDUSTRY						
STEAM GENERATION						
CASE 1	BOILERS CONVERSION	11602	7847	-120	-15.3	0.21
CASE 2	NAT. GAS BOILERS	45137	15340	10	0.64	0.41
DIRET HEAT						
CASE3	IRON REDUCTION	57829	19400	1593	82	0.52
CASE4	NAT. GAS FURNACES	25828	8665	692	80	0.23
TRASNPORTATION						
CASE 5	SWITCHING MODES	372000	153000	-23613	-154	4.07
CASE 6	LESS PRIVATE SHARE	96000	39600	-9695	-246	1.05
CASE 7	SWITCHING TO NGV	-10000	20000	-3000	-146	0.53
ELECTRICITY GENERATION						
CASE 8	TAYUCAY PROJECT	144850	48594	1742	36	1.29
	TOTAL		312446	-3239[illegible]		8.31
			BASELINE CO2 EMISSIONS			3757950

TABLE 16. MITIGATION COSTS

Mitigation Case	CO2 Reduction 10^3 TON	Incremental Cost $/CO2 TON	Total Cost M$	Average Cost $/CO2 TON
6	39600	-246	-9695	-245
5	192600	-154	-33308	-173
7	212600	-146	-36308	-171
1	220447	-15	-36428	-165
2	235787	1	-36418	-154
8	284381	36	-34676	-122
3	293046	80	-33984	-116
4	312446	82	-32391	-104

TABLE 17
CARBON STORAGE AND ASSOCIATED COSTS BY PROJECT CATEGORY

PROJECT TYPE	LAND AREA (10^3 ha.)	CARBON STORAGE DENSITY (tC/ha)	TOTAL CARBON STORAGE (MtC)	COST $/ha	COST $/tC
PLANTATION	24	52	1.3	905	17
AGROFORESTRY	26	27	0.7	550	20
FOREST RESERVE	22	94	2.1	375	4
MANAGED FOREST	100	75	7.5	700	9
TOTAL	172	248	12	2530	10

TABLE 18
POTENTIAL FOREST MITIGATION OPTIONS AND CARBON STORAGE IN VENEZUELA. YEAR 2025
TECHNICAL SCENARIO

MITIGATION OPTION	POTENTIAL AREA (10^3 ha)	CARBON STORAGE DENSITY (tC/ha)	TOTAL POTENCIAL CARBON STORAGE MtC	UNIT COST $/tC
PROTECTED AREAS	4000	94	376	4
FOREST MANAGEMENT SMALL AREAS	600-1000	75	45-75	9
FOREST MANAGEMENT LARGE AREAS	9000	75	675	9
SMALL SCALE PLANTATION	310-470	52	16-24	17
LARGE SCALE PLANTATIONS	4500	62	279	17
AGROFORESTRY SYSTEMS	1000	27	27	20
TOTAL	19690	-	1437	-

TABLE 19
CARBON STORAGE POTENTIAL IN VENEZUELAN FOREST
UNDER THE CONSTRAINED SCENARIO (2000-2025)

	AREA (10^3 ha)				CARBON STORAGE (MtC)			
MITIGATION OPTION	2000	2005	2015	2025	2000	2005	2015	2025
PROTECTED AREAS	400	1100	1700	2300	37.6	103.4	159.8	216.2
FOREST MANAGEMENT SMALL AREAS	25	105	225	375	1.9	7.9	16.9	28.1
FOREST MANAGEMENT LARGE AREAS	1200	2800	3900	5200	90.0	210.0	292.5	390.0
SMALL SCALE-PLANTATIONS	15	30	110	225	0.8	1.6	5.8	11.7
LARGE SCALE-PLANTATIONS	35	105	450	700	2.2	6.5	27.9	43.4
AGROFORESTRY SYSTEMS	10	25	80	210	0.3	0.7	2.2	5.7

CEEST
The Centre for Energy, Environment, Science and Technology

Greenhouse Gases Mitigation Options and Strategies for Tanzania

By: Prof. M.J. Mwandosya
and
Hubert E. Meena

November, 1996

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1. Introduction

Tanzania became a party to the United Nations Framework on Climate Change (UNFCCC) when she ratified the Convention in March, 1996. Now that Tanzania and other developing countries are Parties to the UNFCCC, compliance with its provisions is mandatory. The legal requirements therefore provide a basis for our participation in climate change studies and policy formulation.

All parties to the Convention are required by Article 4.1 of the United Nations Convention on Climate Change (UNFCCC) to develop, periodically update, publish and make available national inventories of anthropogenic emissions and removal of greenhouse gases that are not controlled by the Montreal Protocol.

Article 4.2 of the UNFCCC further requires Parties to the Convention to take their common but differentiated responsibilities and their specific national and regional development priorities into account with the objective to formulate, implement, publish and regularly update national and where appropriate, regional programmes containing measures to mitigate climate change. This study on possible options for the mitigation of greenhouse gases in Tanzania is a preliminary effort towards the fulfilment of the obligation.

The UNFCCC also provides for a multilateral financing mechanism for funding `incremental costs' of implementing measures leading to the mitigation of greenhouse gas emissions and adaptation to climate change. Decision on whether or not such measures need to be implemented requires a detailed study of the options based on some reference scenario for a particular sector and the economy as a whole.

2. Source and Sinks of Greenhouse Gases in Tanzania

In order to fulfil our obligations under the UNFCCC and have a meaningful mitigation assessment, identification and quantification of anthropogenic sources of atmospheric emissions of greenhouse gases in the country was undertaken. In this respect, the study on Anthropogenic Emissions by Source and Removals by Sink of GHGs in Tanzania was done with the main objective of increasing the quantity and quality of base-line data available in order to further scientific understanding of the relationship of greenhouse gas emissions to climate change. Furthermore, the study facilitated identification of nation's policy and technological options that could reduce the level of emissions in the country.

The inventory has been implemented using the International Panel on Climate Change (IPCC)/Organisation for Economic Co-operation and Development (OECD) methodology. The inventory work was the result of collaborative efforts among a number of governmental and non-governmental institutions and organisations. The study was funded by the Global Environment Facility (GEF) through the United Nation Environment Programme (UNEP), and the International Development Research Centre (IDRC) through its assistance to CEEST for a comparative study of greenhouse gas emissions of Tanzania and Zimbabwe. Table 1 is a summary of preliminary results of the emissions of greenhouse gases in Tanzania in 1990.

Table 1: Summary of Greenhouse Gas Emissions and Removals 1990 (Gg)

Sources and Sinks	CO_2	CH_4	CO	N_2O	NOx
SOLID WASTE MANAGEMENT Solid waste management	47.60	24.46			
Municipal Waste Management		2.20			
Industrial Waste Management		19.75			
Total Gg	47.60	46.42	0.00	0.00	0.00
ENERGY INDUSTRY AND TRANSPORT Natural Gases	0.34				
Coal	0.12	1.68			
Thermal Power Generation	73.12	5.28	645.90	1.80	880.90
Traditional Biomass Fuel		266.98	3358.8	2.33	38.83
Cottage Industry		0.02	13.24		0.36
Stationary Combustion in Industry Sector	1158.41	0.02	6.32		2.72
Mobile Combustion in Transport Sector	1424.17	0.41	47.71	0.03	14.41
Total Gg	2,656	274.39	4072.0	4.1627	937.22
AGRICULTURE AND LIVESTOCK Rice Cultivation		95.85			
Agricultural Crop Residue Burning		297.09	953.16	0.57	13.50
Nitrogenous Fertiliser Uses				0.12	
Enteric Fermentation		488.05			
Domestic Animal Wastes		26.17			
Total Gg		907.16	953.16	0.692	13.5
LAND USE AND FORESTRY Forest Clearing for Permanent Agricultural Land	733.30	9.32	81.56	0.06	1.51
Grassland Conversion for Agricultural Land	15375.00				
Abandoned Managed Land	-5309.00				
Accessible Natural Forests	55675.00				
Shifting Cultivation	4021.00	2.68	23.42	0.02	0.43
Man-made Flooded Lands		0.04			
Savannah Burning		63.00	1662.	2.00	21.00
Total Gg	70495.30	75.04	1766.9	2.08	22.94
INDUSTRIAL PROCESSES Cement Production	343.83				
Pulp and Paper Production	5.79				
Total Gg	349.62	0	0	0	0
Grand Total (Gg)	97,961	1,734	6792.1	6.9347	973.66

source: (2)

Note: Blank means not applicable

3. Technological and Other Options for the Mitigation of GHG Emissions

The country study on Technological and Other Options for the Mitigation of Greenhouse Gases in Tanzania was carried out by CEEST with a support from the Germany Development Co-operation (GTZ). The study examined the long term development scenario for Tanzania including macroeconomic assessment as the basis for developing mitigation options and strategy(1). Furthermore, sectoral analyses of mitigation scenarios and technologies for the relevant sectors, namely, the energy, industrial, transport, forestry and land use and agriculture were made. Ranking of the mitigation options based on the multicriteria assessment method was carried out. The study has attempted, for each option analysed, to determine the costs and benefits of each option. Where information on costs could be quantified, cost curves have been drawn.

3.1. Tasks and methods

Specific tasks which have been performed under this study included among others, identifying technologies that are associated with GHG emissions for various sectors; identifying technical possibilities of minimising GHG emissions; identifying the best and new environmentally benign technologies available for Tanzania including its specific reduction potential and its cost; investigating various options for GHG abatement including retrofitting, emissions reductions on equipment; exploring the link between energy efficiency, mitigation of GHG emissions and costs; proposing technology, strategies and policy options to mitigate the emissions of GHG based on abatement cost curve; recommending possible targets for GHG mitigation or stabilisation particularly in the national energy policy

These tasks were conducted under the following categories: (1)

- the energy sector, covering energy forecast and energy supply analysis, demand side analysis covering energy efficiency in industries etc., energy pricing and cost curves analysis;
- the household and commercial sector, covering demand side analysis;
- industrial sector, covering industrial process, specifically cement and pulp and paper production;
- the transportation sector, covering demand side analysis and energy efficiency;
- the agricultural sector, covering efficiency in agricultural practices and livestock feeding;
- the forestry sector, covering land use and forestry, land tenure, afforestation and reforestation;
- multicriteria assessment of the mitigation options.

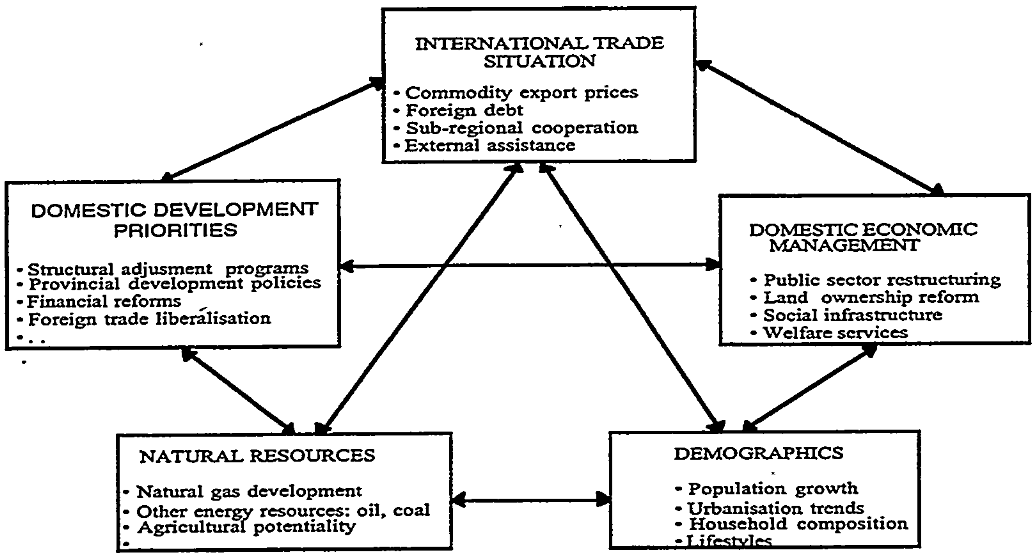
The approach of the Tanzania Country Study follows the methodological guideline developed by the UNEP Collaborating Centre on Energy and Environment (UCCEE), in the context of the UNEP project on GHG Abatement Costing Studies.(1)

3.2. Mitigation scenarios in the macroeconomic context

3.2.1. Factors influencing long term development

The main scenarios are built in the context of the Tanzania's economic development structures. Development constraints in the baseline development trend are considered in building up the mitigation scenarios. Fig. 1 shows factors influencing long term development of Tanzania.

Fig. 1: Factors Influencing Long Term Development of Tanzania



Tanzania's economy, like most developing countries economies, has a strong dependence on a number of factors including external factors. How these factors will evolve in the future is a complex question. For the purposes of scenario construction two types of trends concerning the external environment can be assumed:

- the improvement of terms of trade, favourable conditions for debt servicing, and increasing flows of external assistance are essential conditions for a successful materialisation of a balanced growth type scenario; while

- periodical fluctuations in the terms of trade as well as the short-term and temporarily rescheduling arrangements for debt servicing are more compatible with accelerated structural reforms scenario.

In the context of long term development trend, a combination of the structural reforms and the balanced growth scenarios resulting into a composite development scenario is more relevant for Tanzania. This scenario also incorporates the regional co-operation aspect, because of its complementarity to the current economic development trend of the country.

3.2.2. Composite scenario for Tanzania's economic development

From the standpoint of GHG mitigation analysis what is important in the context of long-term scenarios is the behaviour of socio-economic sectors. Decisions about which mitigation options should be pursued in the future depend on the constraints and opportunities that sectoral development offer to the diffusion of different technologies. Therefore, the development characteristics of economic sectors define the potential space for the successful implementation of mitigation strategies.

The most likely scenario for the long-term development of Tanzania can be characterized by the predominance of structural reforms in the short-term, followed by a more balanced growth strategy in the long-term. The regional co-operation scenario includes the inter country co-operation initiatives like the East African Community, and the Southern African Development Community (SADC).

The co-operation aspect comes about from the fact that GHG mitigation can not be addressed in isolation from the national development objectives and goals. This is because in most cases economic development is associated with technological development, and economic co-operation is associated with technology transfer.

With the composite scenario an annual rate of increase in GDP of 4.7% is estimated for the period 1990-2020. GDP per capita is expected to double. Agriculture output will greatly increase, but its share in the total product is expected to fall from 47% in 1990 to around 36% in 2020. The share of manufacturing and construction and electricity sectors is expected to increase from 14% to 23%.

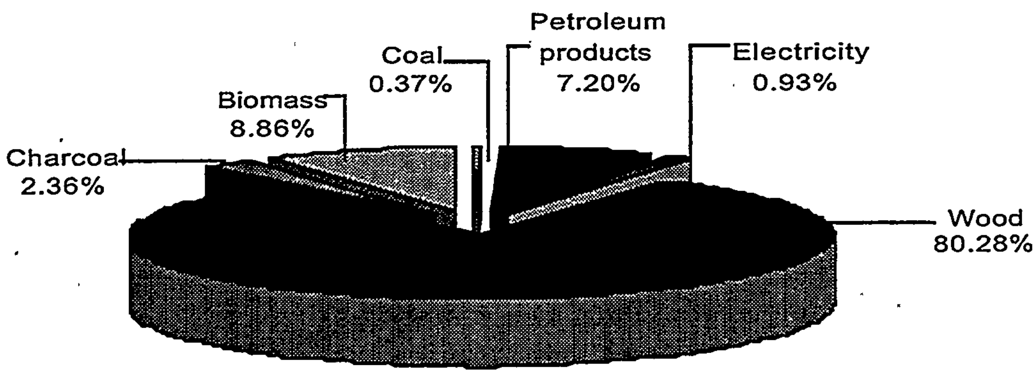
The analysis of the economic growth is made in the context of economic sectors. The structure of the economic sectors in respect of Tanzania's economic analysis is as follows:

- The energy sector, which is a key determinant of development in other sectors.
- The agricultural and livestock sector, which is the "backbone" of the economy, providing food and exports.
- The industrial sector, which is the potential future "backbone" of the economy.
- The forestry and lands sectors, which are the providers of resources.
- The service sector, which directs the use of resources

3.3. Energy sector

The analysis of the energy sector involved analysis of the structure of energy supply, that is the energy balance, which are inputs in forecasting future trends. The energy balance of 1990 and the associated emissions was taken as the base case. Figure 2 shows the energy situation of the country. From the energy balance, projections for reference and case were made on the basis of the current energy policy and master plan and Long Range Energy Planning (LEAP). On the basis of the technological requirements for GHG reduction a mitigation scenario was therefore developed.

Fig. 2: Net energy supply by fuel



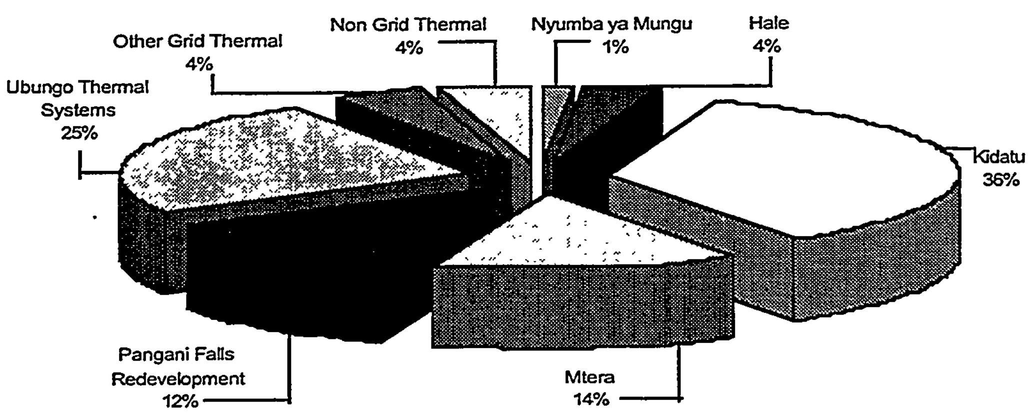
3.3.1. Reference scenario for energy production

The reference scenario for the energy sector is based on the National Energy Master Plan. The sector development trend is based on the existing policies and strategies. The energy demand projections are based on the historical consumption trends of fuels. The average annual growth rate of demand for each fuel has been determined.

3.3.2. Power generation

The present power system is composed of isolated plants and the interconnected grid. The bulk of the isolated system consists of thermal power plants powered by reciprocating diesel engines. Total installed capacity of the isolated power plants in 1990 was 32.82 MW generating about 64.3 GWh per year. Most of these plants are old and in dire need of spare parts to make them operational. Figure 3 shows the current power generation capacity of the country. Note that the non grid thermal station consist of 4% of the total installed capacity and the grid thermal consist of 29% of the total installed capacity. The rest are Hydtro power stations connected to the grid system. The current total capacity is 544MW of which 379MW is hydro and 165MW is themal.

Fig. 3: **Electricity generation installations**



3.3.3. Mitigation options in power generation

In the power sub-sector a number of technological options exist which can reduce emissions of greenhouse gases. These include efficiency improvement of present installed equipment, retrofitting of thermal power plants to improve combustion efficiencies, retiring the present less efficient thermal power plants in favour of more efficient power plants or hydro power plants and demand side management.

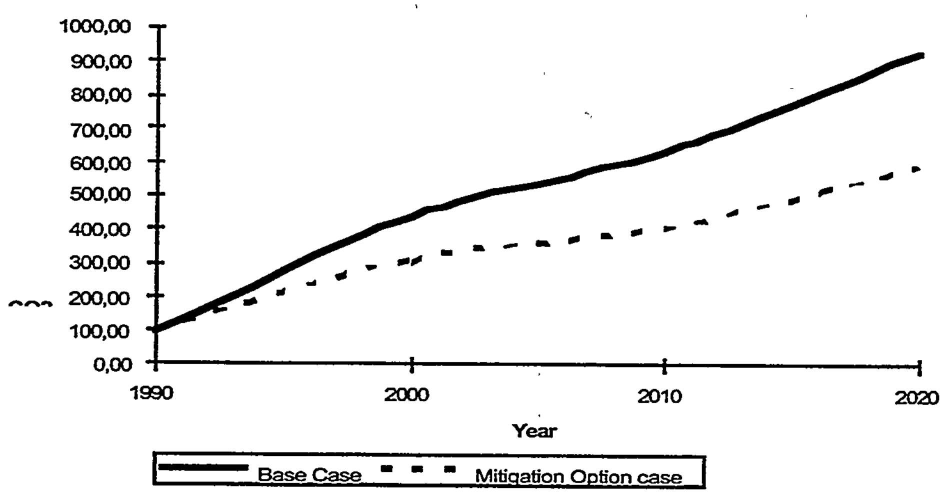
For thermal power plants in the interconnected system, three main options exist for mitigating greenhouse gas emissions:-

- upgrading the thermal power plants to be installed in the future from the planned simple cycle power plants to combined cycle power plants;
- opting for all hydro generation in future investment in new plants; and
- power sharing with neighbouring states.

The last two options will afford 100% reduction of greenhouse gas emissions whereas the first option will afford some reduction of the emissions. The likelihood of the last two options being implemented during the planning horizon is small because of cost and time implication.

Fig 4 shows a comparison of emissions of CO_2 between the baseline and mitigation scenarios for power generation.

Fig. 4 : CO_2 emissions in baseline and mitigation scenarios for power generation



3.3.4. Other mitigation options for the energy sector

Other mitigation options for the energy sector include energy efficiency in end uses, like households and industries, fuel switch to natural gas, and development of clean energy sources including solar, wind, mini hydro and biomass.

3.3.5. Mitigation cost curve for the energy sector

The unit cost of introducing technologies in the energy sector forms the basis of ranking the various options in the GHG mitigation analysis. Costs are defined to represent the real costs and benefits to society in energy production and utilisation. The costs of various technologies have been levelized using the discount rate of 12%. This discount rate reflects the capital constraint facing the country. Both the investment and the operation and maintenance cost for these technologies were considered. For energy efficiency technologies the fuel cost implications have also considered using the fuel price projections.

The data for the cost curves were developed using the analysis shown in Table 2. Each GHG reducing technology was analysed in terms of its reduction capacity, penetration possibilities and costs.

Table 2: Analysis of Technologies, Their Reduction Capacity and Costs

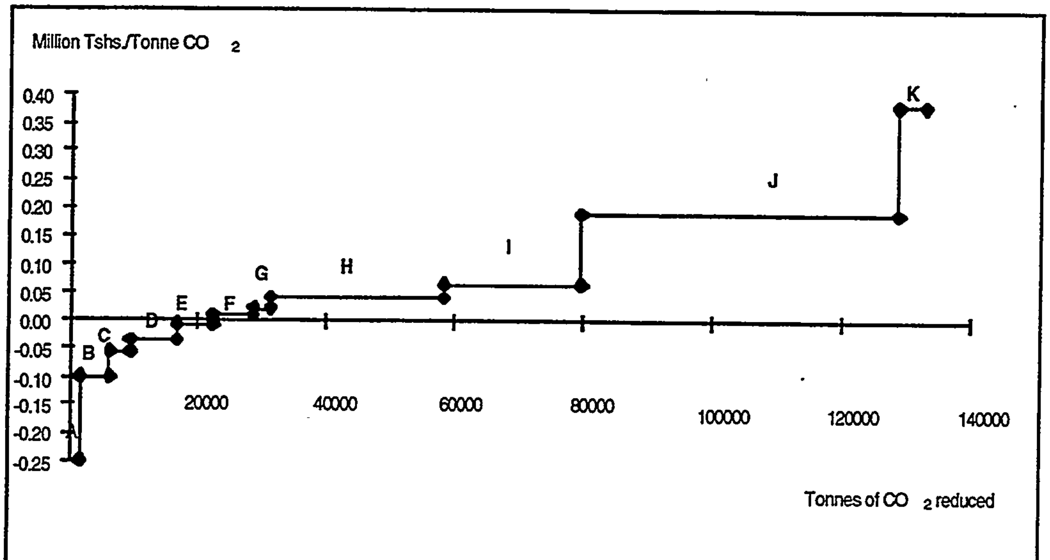
GHG Reduction option	Mill. Tshs./ tonne CO_2	Unit Type and size	Energy Type Saved	Emission Reduction tonne/ unit CO_2	Reduction in 1995 tonnes CO_2	Reduction in 2020 tonnes CO_2
Efficient Boilers	-0.24971	1 Boiler	diesel/coal	0.358815	358.815	1794.075
Efficient Lighting	-0.10102	1000 Bulbs	el-diesel	0.036971	1109.139	4658.386
Power Factor Correction	-0.05668	1 MVAR	el-diesel	0.644016	128.8033	3220.082
Efficient Motors	-0.03605	1 kW	el-diesel	3.567676	3567.676	7135.351
Efficient Furnaces	-0.00629	1 Furnace	diesel/coal	5.633929	2816.965	5633.929
Combined Cycle Turbines	0.009756	1 kW	diesel	0.027446	2744.563	6243.881
Biogas for Rural Households	0.020645	1 digester	wood/el-diesel	0.628532	3142.658	2514.126
Biogas from Landfills	0.040312	1 Landfill	el-diesel	6801.907	6801.907	27207.63
Hydro Power	0.067551	1 kW	diesel	0.09396	5637.586	21375.85
Solar Power	0.189491	1 kW	diesel	1.225298	1225.298	49011.91
Natural Gas Turbines	0.380981	1 kW	el-diesel	0.02125	1699.966	4249.914

source: (3)

The Cost curve relates the quantity of GHG which can be reduced to the cost per unit GHG reduction. These curves makes it possible to identify the least cost options for GHG reduction.

The cost curve for the energy sector, in Figure 5 shows that introduction of efficient boilers, efficient lighting, power factor correction, efficient motors, and efficient furnaces are "no-regret" (negative cost) options. Most industries in Tanzania need to take energy efficient measures to increase productivity and decrease energy costs. The total benefits are worth the investment costs.

Fig. 5: Cost curves for the energy sector in Tanzania



KEY:
A= Efficient lighting
B= Power factor correction
C= Efficient motors
D= Efficient boilers
E= Efficient furnaces
F= Combined cycle turbines
G= Biogas for rural households
H= Biogas from landfills
I= Hydro power
J= Solar power
K= Natural gas turbines

3.4. Industrial sector

Industry is an important sector in the economy of Tanzania. Export earnings in the industrial sector for the last four years have averaged 20% of total foreign exchange earnings. In this regard the sector, ranks second to agriculture. Furthermore, the industrial sector is an important employer, accounting for 18% of total wage employment. It is the largest single source of urban employment. The sector facilitates and contributes significantly to technical progress in other sectors of the economy and has strong backward and forward linkages.

The emissions inventory identified the cement and pulp and paper industries as being significant contributors to GHG emissions. In this study therefore options for the reduction of emissions for these two industries have been considered. Feasible options in the cement industry include:- installation of an automatic control system which reduces the amount of fuel used and improves production efficiency; installation of a CO_2 recovery system, (CO_2 can be sold for other industrial applications) fuel switching from fuel oil to natural gas; recovery of waste heat; and production of blended cements such as pozzolanic cements, blast furnace slag portland cements.

In the pulp and paper industry the options analysed include:- optimization of the recovery boiler which reduces the amount lime needed and uses less energy; recovery of CO_2 from calcination by absorption of CO_2 which reduces most of the CO_2 and uses existing installations; and lastly afforestation which apart from maintaining the CO_2 sink also provides raw material for the pulp and paper production.

3.5. Transport sector

The transport sector contributes 5.6% to GDP and accounts for 16% of total public expenditures. One of the main reasons for the large share is that the government, through parastatals, owns most of the transport infrastructure, i.e. roads, railways, airports, harbours, as well as inland waterways. Except for the railway, users of transport infrastructure own the operating equipment such as motor vehicles, cycles, ships, boats etc.

Like elsewhere in developing countries the objective of the sector on Tanzania is to provide efficient domestic and international transport services, to maximize both foreign and local revenue generation in the transport sector, and to minimize transport related environmental hazards.

The mitigation options considered include the improvement of the Dar es Salaam city road network; introduction of CNG fuelled motor vehicles; and introduction of city train (metro) in Dar es Salaam city. The options are focused on Dar es Salaam city alone because almost half of gasoil and gasoline sales in the county are made in this city.

3.6. Forestry and land-use

Forests in Tanzania can be classified into unproductive, productive, protected and community forests. Forests provide biomass energy for households, protect important watersheds for hydropower dams, conserve soil from erosion, and significantly provide employment opportunities. Forest management is guided by the forestry policy and legislation.

The greenhouse gas mitigation in the forestry and land use sector is based on two options: management of the existing land-based carbon stock, and expansion of land-based carbon sinks. In order to decide which mitigation measures are most suitable, land-based products supply is matched with the capacity of the land to meet the demand. Mitigation of GHG emission requires improvement of existing land-use management, enhancement of land-use productivity, and measures to halt deforestation. The aim here is to maintain the existing stands of aboveground biomass by exercising protection and conservation measures, encouraging non-wood bioenergy, and practising intensive agricultural management. These options result in more carbon storage in vegetation and soil.

In line with management of land-based carbon stock and expansion of land-based carbon sinks, options identified for Tanzania include: afforestation, reforestation, agroforestry and urban tree planting.

3.7. Agriculture and livestock sector

The economy of Tanzania hinges on the agricultural sector. The sector employs about 84% of the employed population and contributes about 61% of both GDP (at current prices) and merchandised exports. Traditional cash crops include coffee, cotton, sisal, tobacco, tea, cashewnuts and pyrethrum. Food crops production dominates the sector, totalling 55% of agricultural GDP, with livestock accounting for 30%. Food crops include maize, paddy, wheat, sorghum, millet, cassava, beans, sweet potatoes and bananas. Except for years of uncertain rainfall, Tanzania is largely self-sufficient in food production. There is a herd of more than 13 million cattle, 8 million goats, and 5 million sheep, which play an important economic and social role in the economy. An estimated 90% of households keep livestock of some kind mainly for subsistence, but also for sale and social purposes. Cattle are particularly important for providing food, draft power, manure and cash income.

The potential cultivable land is estimated at 40 million hectares, of which only 8.8 million hectares are under cultivation. About 1.2 million hectares are suitable for irrigation but only 0.15 million hectares are under irrigation, about 2/3 of this under paddy. The potential grazing land is estimated at 63 million hectares, of which about 26 million hectares are currently under grazing. The main grazing areas are found in the semi-arid parts of the country where large numbers of livestock are concentrated.

3.7.1. Mitigation options for methane emissions from rice cultivation

For paddy cultivation the National Irrigation Development Plan (NIDP) objectives are to fulfil the national sufficiency in rice production by the year 2000. The demand forecast for the year 2000 is in the range of 735,000 - 805,000 tones, representing paddy production of 1,132,000 - 1,240,000 tonnes(4).

The NIDP suggests that the development efforts should be focused on small scale farmers for whom (in contrast with state farms) foreign exchange elements of production costs are minimal.

In order to reduce the cost and disruption in the existing national plan, any mitigation option for reducing methane emissions should complement the existing NIDP. Three areas of management have been identified as possible options to mitigate methane emissions: irrigation water management; nutrient management; and improved cultivar use.

3.7.2. Mitigation options for livestock husbandry

The National Livestock Development Program (NLDP) to the year 2000 summarizes its main objectives as increased output from the livestock sector. This is envisaged to be achieved primarily through increased productivity and secondarily through increased livestock population (5). In order to meet the program objectives there also will be redistribution of the commercial sector ruminant population from places of over population to under-utilized areas.

IPCC estimates that improved nutrition through supplementation of natural feed and other strategies can reduce methane emissions between 10% and 25%(6). The quality and quantity of feed available for the ruminants in the traditional sector depends on the agro-climatic conditions.

Mitigation options for livestock sector include improved nutrition by use of better pastures, feed supplementation and reduction in stock numbers. Another option is improved nutrition through increased feed digestibility through mechanical processing of feed and chemical processing of the feed. Third option is improved breeding where output per animal is enhanced.

3.8. Barriers to diffusion of mitigation technologies

Market imperfections and institutional barriers have been identified as the main causes of lack of successful diffusion and implementation of technological innovations. In Tanzania besides the financial constraints other barriers to technological development include:

(i) distorted prices and limited competitive pressures; and

(ii) weakness of structures for generating and managing technical change in response to price signals and competitive environment. This weakness has the following important features:

- limited human and organisational resources needed to plan and manage the environment and operations involved in the use of technologies;
- low technological capability to operate and maintain reasonable efficiency levels. In many situations technologies are operated at sub-optimal levels and usually below the design levels and standards of efficiency.
- lack of a system of innovation that would allow maintaining or increasing high efficiency levels through incremental technical and organisational changes.
- weakness of the service-supplier network which means that the operation of technologies stals when some spare parts or after-sale service are lacking.

In this context, continuing with the existing patterns of technology use into the future, while seeking to accelerate the introduction of new and emerging technologies, will contribute little to alleviate the growth of GHG associated with their use. Most of the GHG mitigation options to raise the efficiency in energy use focus on narrowly defined categories of technology which appear to be concerned on achieving one-off step of efficiency improvement. However, little attention is paid to the problem of reverting to past practices of inefficiency or creating a basis for self-sustaining paths in the future.

Some developing countries' experience with technological innovations shows a rather dismal record. In Tanzania, projects and programmes focusing on the implementation and development of new and renewable energy technologies offer a good example. An evaluation carried out in 1990 (7) showed that popularisation and extension of these technologies has faced a number of constraints including:-

(i) *lack of funds*: a number of windmills have stopped operating due to lack of spare parts;
(ii) *lack of routine maintenance:* has led to breakdown of a number of windmills and biogas units;
(iii) *high costs of investment:* in some cases successful demonstration has not been followed by successful extension because of the high investment cost of units such as windmills and, biogas plants and photovoltaics;
(iv) *social problems:* an example is the case of a biogas plant stopped working due to vandalism-school cows which used to provide biomass were stolen;
(v) *technical assessment problems:* water pumping systems have stopped working due to lack of underground water;
(vi) *perception problem:* a biogas plant for a school was abandoned because electricity has been connected to the school;
(vii) *lack of people's participation* right from initiation to implementation of projects;
(viii) *negative attitudes* where in some cases the sponsors were unwilling to teach the beneficiaries how to operate the plant because they did not believe they could not grasp 'sophisticated' technology.

This experience acquires special relevance in the present circumstances, where the global warming issue has brought again into discussion the massive deployment of those technologies.

If past and current failures are to be avoided, the relevance of a technology has to be evaluated in wider context within which:

- skills and know-how for its operation; and
- knowledge, experience and expertise needed for generating and managing technical change are critical factors.

3.9 Multicriteria assessment of mitigation options in Tanzania

Due to the complex interaction of social, economic and scientific factors in the mitigation analysis, multicriteria analysis was undertaken. This assessment involved weighing the various mitigation options against a number of criteria, including the sustainability of the mitigation options, acceptability of the technologies, significance of the mitigation options, and the second order effects of the mitigation options.

Ranking of the mitigation options was first carried out by, definition and evaluation of sectoral priorities. Criteria weights and composite weights were determined using the microcomputer based software Expert choice. The judgement is arrived at by answering a series of questions through an iterative dialogue, and numerical values are assigned to them. To construct an absolute intensity of priority scale for both sectors and criteria the importance ranks are broken down as shown in Figure 5. Inconsistency of judgements was measured and tracked using the features of the Expert choice software. Figure 5 represents the hierarchy constructed for the multicriteria assessment.

Fig 5: hierarchical structure of the multicriteria assessment

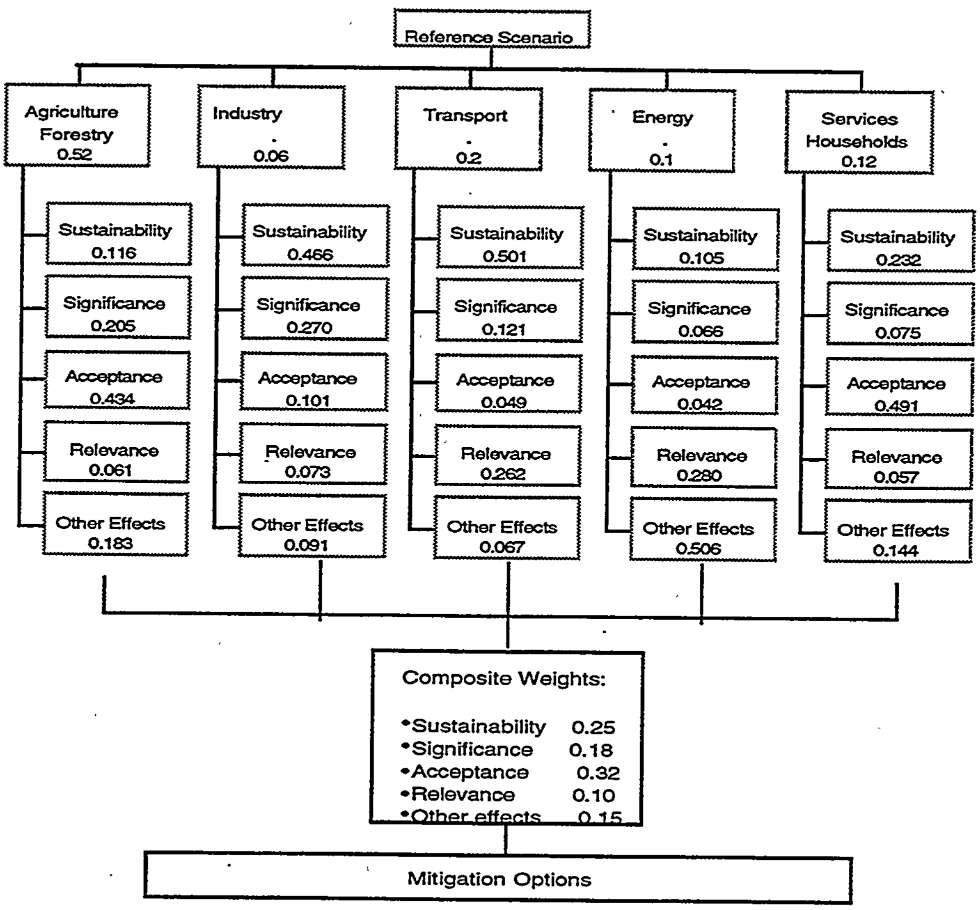
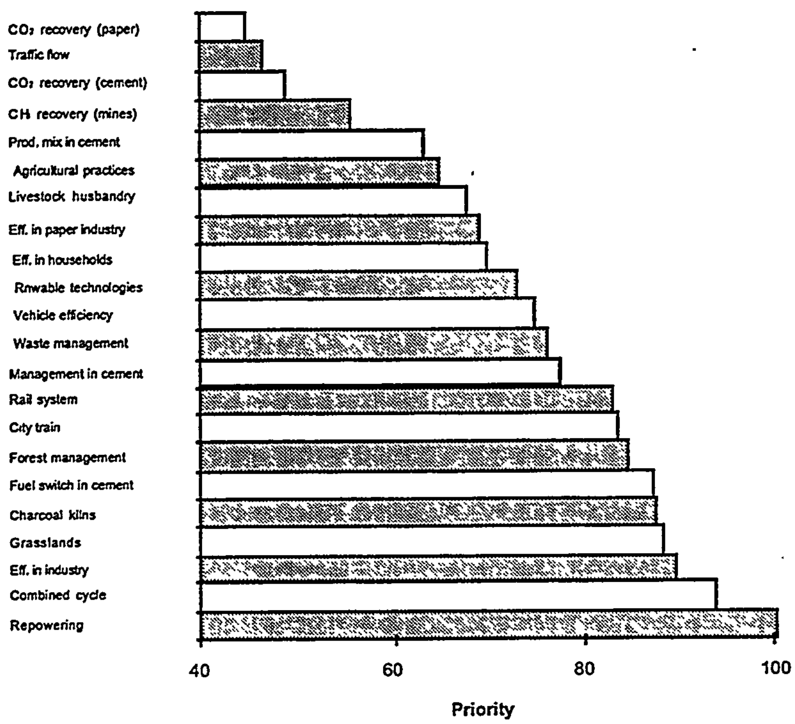


Figure 6 shows the ranking of the proposed options after the application of perfomance ratings (the results have been normalised as percentage of the maximum score). The ranking obtained here reflects the values, opinions and judgements used for this exercise.

Fig. 6 Ranking of mitigation options



4.0. Some Concluding Remarks

Since mitigation analysis has to incorporate technological developments and efficiency in production, it is intended to link these with scenarios in national development plans, as well as the national sectoral policies. It is also intended to develop National Action Plan on Climate Change on the basis of these findings, as well as facilitating evolution of implementable projects or programmes to facilitate GHG mitigation. Furthermore, since one of the development scenarios for Tanzania involves regional collaboration, there is a need to study the impact of regional collaboration on development of Tanzania as well as seeking avenues of implementing mitigation options through regional collaboration and technology transfer.

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STRATEGIES TO ADDRESS CLIMATE CHANGE IN CENTRAL AND EASTERN EUROPEAN COUNTRIES

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I. Introduction

1. The paper presents analyses based on information mainly from the National Communications of nine Central and Eastern European countries that are undertaking radical transition from centrally planned to market driven economies (EIT)[1]. It is designed primarily to provide an overview of the policies and measures to address climate change that have been implemented, or under implementation or planned.

2. In order to better understand the objective of policies and measures and the way they have been implemented in EIT countries the analysis has been supplemented by a review of the national circumstances and overall policy contexts in EIT countries that are relevant to climate change policies and measures problems. Therefore, these issues will be discussed in the paper along with analysis of mitigation policies and measures by sector.

II. National circumstances

3. In all EIT countries, the transition to free market economies has been characterized by deep economic crisis, the collapse of traditional foreign markets, decrease of domestic consumption and industrial output resulting in a drastic drops in gross domestic product (GDP) **(fig.1)**. An important consequence of this process for climate change was the

[1]This paper has been prepared mainly on the basis of the information included in the National Communications of nine countries in the process of transition from centrally planned to market economies, including Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Poland, Romania, the Russian Federation and Slovakia that belong to Annex I Parties to the United Nations Framework Convention on Climate Change

decrease in the level of greenhouse gas emissions (GHG) in a proportion to the drop in economic activity. For example, in Poland GDP dropped about 20% in 1988-1991 period, while CO_2 emissions diminished by 22 % for the same period.

4. Another important characteristic of the EIT countries was the high proportion of industrial output in the economy that resulted in high energy intensity of the economy and as a consequence in high energy consumption per unit GDP production. This affected the level of GHG emissions and the choice of the most appropriate, efficient and cost-effective policies and measures to mitigate climate change.

5. EIT countries emphasized that major structural changes in the economies particularly within the industrial sector had taken place during the economic recession (**fig. 2**), that resulted in decreasing the share if industry in GDP on account of services. In this regard the economic pattern of EIT countries is getting closer to those of OECD countries. An important consequence of this was the GHG emissions reduction during the crisis driven not only by total economic collapse, but also by structural changes of economy. Most of the EIT countries experienced economic growth in the last few years. It is important to note that the economic and industrial recovery in Poland started in 1992 by 2.56% growth, while CO_2 emissions continued to decrease by at least 1% in the same period, that is believed to be a very important indicator of the effect of structural changes.

6. In the National Communications some of the EIT countries, such as Hungary, Slovakia, Estonia and Bulgaria expressed concern about scarce indigenous energy resources and the high share of energy imports, while in other countries such as Poland, the Czech Republic and Bulgaria energy resources were mainly fossil fuel based with high carbon content. In general fossil fuel component prevail in the structure of primary energy supply (**fig. 3**). This is why it was difficult to implement mitigation measures targeting substantial change in the primary energy supply structure.

7. Despite that EIT countries traditionally had relatively high industry's share in GDP and the high energy intensity of industrial output only few of them are among the world's largest GHG emitters (**fig. 4**). They were characterized by a high energy related CO_2 emissions per unit GDP, while energy-related CO_2 emissions per capita was within the range of OECD member countries - 12 tonnes CO_2 and OECD-Europe member-countries - 8 tonnes, although some countries, such as Estonia, the Russian Federation and the Czech Republic were above this level (**fig. 5 and 6**).

III. Climate change policy in the overall policy context

8. Pursuant to Article 4.6, EIT countries that belong to Annex I group of FCCC Parties have a certain degree of flexibility in choosing the reference year in order to enhance the ability of these Parties to address climate change issues. Four of the Parties used the provisions of this article and considerable emphasis was given in their communications to choose a reference year different from 1990. Bulgaria and Poland had chosen a 1988, Romania had chosen 1989, while Hungary chose the period 1985-1987 rather than a single year. The years that had been chosen as reference corresponded to the highest level of economic activity and GHG emissions in the countries before the crisis. Four of the Parties, Slovakia, Czech Republic, Russian Federation and Latvia, chose 1990 as base year. One Party, Estonia, did not provide specific information on this issue.

9. Most of the Parties, including Bulgaria, Poland, Russian Federation and Slovakia had interpreted provisions of Article 4.2(b) as a binding target and clearly expressed their commitment to return the level of emissions in year 2000 to their 1990 level. In addition.

10. From an overall policy point of view climate change was not a key concern in EIT countries. Rebuilding infrastructure and the economy was reported as the key policy focus in EIT countries in the transition period with priority given to privatization and establishment of capital markets in the situation of shortage of foreign investment. Solving urgent social problems such as unemployment, health care and impoverishment was considered an integral part this process.

11. Even within the environmental policy agenda EIT countries stressed on issues with higher priority than climate change which needed to be solved in the near term, such as air pollution and transboundary pollution. Because of this, many EIT countries recognized that climate change policy had to be integrated into the country's overall national economic, energy and environmental strategy in order for it to have stronger impetus.

12. In general, EIT countries implemented policy instruments and measures which were cost-effective, technically and politically feasible, and would lead to more efficient use of energy and raw materials, enhance the competitiveness of industrial production, or improve air quality and living standards (quality of houses and apartments).

IV. Policies and measures to limit anthropogenic emissions and protect and enhance sinks and reservoirs of greenhouse gases

13. Pursuant to Article 12.2 of FCCC all EIT countries had communicated mitigation policies and measures that had been adopted to implement Article 4.2(a) and 4.2(b).

Identification of mitigation policies and measures was the key element of the National Communications, not only because of the importance for the Annex I Parties to meet the stabilization target, but also because policies and measures were an important link between other issues reported in the National Communications, such as inventory and projections of GHG emissions.

14. Data on 259 policies and measures for nine EIT countries was compiled in the data base, with the policies and measures categorized by country, sector, gas and type of policy instrument, including economic instruments, regulation and guidelines, voluntary agreements and actions or information, education and training.

15. In implementing climate change policy, EIT countries applied a wide range of policy instruments similar to those implemented by Annex II Parties. These included economic instruments and incentives, regulations and guidelines, information, education and training, and research. Voluntary agreements, although reported in a few cases, had not been widely used. The most often used instruments were economic instruments that accounted for 60% of the cases..

16. The overall emission profile of EIT countries did not differ from that of Annex II Parties. CO_2 is the main GHG that accounted for 72% of the total anthropogenic emissions expresses by their 1994 global warming potential, excluding land-use change and forestry, followed by methane (20%) and nitrous oxide (8%) (**fig. 7**). Fuel combustion was the largest CO_2 source with most emissions coming from energy and transformation industries (57%), residential, commercial and institutional (16%), industry as energy end-use (13%), transport (11%) and others (3%) (**fig. 8**). Therefore, the majority of measures targeted CO_2 emissions in the sectors where fuel combustion occures. Policies and measures that addressed emissions of methane and nitrous oxide were analyzed in industrial processes, agriculture and waste management sectors (**fig 9**).

1. Energy and transformation industries

21. The energy and transformation sector was characterized with the largest share of CO_2 emissions from fuel combustion (about 57%), small amounts of N_2O emissions (about 1.9%) and CH_4 emissions (about 0.3%) in EIT countries in 1990. Within the sector the major part of CO_2 emissions was from electricity production. The total number of measures reported in the National Communications within this sector, representing over 30% of all policies and measures mainly targeting CO_2 from energy combustion.

22. All EIT countries emphasized the importance of the liberalization of energy prices, the removal of subsidies and convergence of indigenous energy prices with international ones as important elements of their climate change policy and as fundamental steps toward decreasing the energy intensity of the economy and improving the competitiveness of industrial production. This policy would create, among others, incentives for both energy savings in all sectors of the economy, and accelerated penetration of environmentally-friendly technologies, such as renewable technologies.

23. Upgrading of the overall regulatory framework and legislation, including regulation and legislation in the energy sector was reported by EIT countries as an important element in the gradual harmonization of legislation and norms with those of EU member countries. It was reported that the new regulations were expected to give strong impetus to the overall efficiency of the energy sector by creating economic incentives, institutional and financial mechanisms (Czech Republic, Slovakia, Estonia, Bulgaria).

24. The trend of harmonizing environmental legislation and regulation in EIT countries was reported in the communications of almost all the Parties, including Poland, the Czech Republic, Slovakia, Hungary, Bulgaria and Romania. Although, greenhouse gases were not included in the environmental regulation in most of EIT Parties, this regulation promoted the decommissioning of old coal-fired plants, fuel switching to natural gas, the use of renewable of energy and implementation of new technologies.

25. All EIT Parties acknowledged renewable energy, including solar, wind, biofuels and hydro resources as the most environmentally-friendly option for GHG mitigation, and 6% of total measures were reported on renewables. However, most of EITs emphasized that the technical and market potential of this option is still very limited with an exception of traditional renewable energy such as hydro energy.

26. Most of the countries had estimated high potential for energy savings in energy supply. Some of them, including Hungary, Poland, Bulgaria, and the Russian Federation, had communicated quantitative evaluations of this potential on the energy supply side which varied substantially among countries, reaching a highest level of about 15% of the total primary energy supply in the Russian Federation. A mix of policy instruments has been implemented, or planned such as abolishing energy subsidies, new regulations and the establishment of special energy efficency.

27. EIT Parties emphasized that almost half of the energy saving potential and significant greenhouse gas emission reduction could be achieved by implementing some relatively inexpensive measures, such as improving energy control and management practice, and

also by implementing new standards on energy equipment. In reporting of policies and measures it was indicated that first steps in this direction had already been made and planning concepts such as Integrated Resource Planning (IRP) and Demand Side management (DSM) were just beginning to be implemented in the most of EIT countries.

28. Five EIT countries, Bulgaria, Hungary, Poland, Czech Republic and the Russian Federation, identified significant technical and market potential for new technologies, particularly in the energy sector, such as natural gas combined cycle, co-generation and fluidized bed combustion. EIT Parties considered the new technologies as one of the most cost-effective mitigation approaches, but in order to implement them it would be necessary to overcome major barriers such as the shortage of new domestic and foreign investment opportunities.

29. Another very effective mitigation policiy reported by EIT Parties is increasing the share of natural gas. However, only the Russian Federation reported plans for significant increase of the natural gas share in the primary energy balance from 41.4% in 1990 to 49-51% in 2000. The Czech Republic has presented several projects and programs for fuel switching and extension of natural gas supply networks. Bulgaria has set forth a program for natural gas supply to the households that is expected to increase the share of natural gas in Bulgaria primary energy supply. Other countries did not consider this option probably due to the lack of investment opportunities, access to natural gas supply or energy security reasons.

30. Four EIT Parties, Russia, Bulgaria, Czech Republic and Slovakia, had considered nuclear energy as an option to mitigate greenhouse gas emissions. In general efectiveness of this measure was reported to be high, but countries express concern about nuclear safety issues and the political acceptability of nuclear energy.

2. Industry

32. Industry accounted for 13% of energy related CO_2 emissions, and less than 1% of the total CH_4 and N_2O emissions in EIT Parties in 1990. About 7% of the total policies and measures implemented by the EIT Parties targeted industrial energy end-use and CO_2 emissions.

33. With a very few exceptions, measures within the industrial sector were implemented by economic instruments. These included energy price liberalization, tax relief on new technology development, energy audits , establishing a special funds or other economic incentives promoted by Governments. In many cases the energy efficiency measures

implemented in this sector were reported to be cost-effective. For example, Slovak Government allocated 100 million. Slovak crown for program and support for energy saving in industry, that resulted in 2.3 PJ energy saved, that is about 1% of the final energy consumption in 1993 at a cost of energy saved less than the subsidies for heat.

34. Substantial reductions in CO_2 emissions were expected from improvement of existing manufacturing technologies, implementation of state-of-the art manufacturing technologies and energy saving measures implemented within the industrial sector in all EIT countries. Most Parties have identify high potential for energy conservation within the industrial sector, including Russian Federation - 5,480-6390 PJ, Bulgaria - 44 PJ, and Hungary - 12,5 PJ. Poland reported on 507 Gg CO_2 already saved by improving of specific manufacturing technologies.

3. Residential, commercial and institutional

35. The share of CO2 emissions from residential, commercial and institutional sector in EIT Parties in 1990 varied substantially from country to country within the range of 9% - 23%. All EIT Parties had reported policies and measures in this sector and about 21% of the total number of policies and measures reported in the national communications were in this sector. All the policies and measures in this sector targeted CO2 emissions, although many of them would reduce other greenhouse gases emissions as well.

36. All Parties recognized the positive impact of the liberalization of energy prices on the energy consumption pattern in this sector. Although energy prices to households remain subsidized in most EITs, subsidies will be reduced only gradually to avoid social problems. The Czech Republic and Bulgaria emphasized the importance of the new energy legislation and institutional building at national and regional level in promoting energy efficiency. All other policies and measures identified by the Parties were aimed at issues as energy efficiency improvement in the building sector (Czeck, Poland, Bulgaria, Slovakia), increase and upgrade the heat supply system (russia, Poland, Latvia, Bulgaria, Czeck), efficiency improvement in appliances and behavioral change (Czeck, Bulgaria, Slovakia). A broad mix of instruments have been applied in this sector, including tax exemption, subsidies, partial refund of interest from loans, energy efficiency demonstration projects, regulations and guidelines, information, education and public awareness. Among them information, education and public awareness are expected to play an important role in this sector in changing consumer behavior toward more energy efficient consumption patterns.

4. Transportation

43. Transport emissions on EIT countries accounted for 11% of energy related CO_2 emissions, less than 0.3% of the total CH_4 and 1.9% of the total N_2O emissions in EIT Parties in 1990. Although this shares are about two times smaller than in Annex II Parties, this sector is expected to grow very fast as a result of changes in the economic system, social and behavioral patterns. EIT countries recognized that to limit this growth, the establishment and implementation of consistent policies and measures is urgently needed. For example, the Czech Republic reported combined measures in transport that are expected to stabilize emissions from this sector at the 1990 level in the period 1998-2000, while without measures the emissions would increase by 14% over the same period. Most of the EIT Parties identified a variety of policies and measures in transportation and in total 16% of all measures addressed this sector.

44. Transportation measures in EIT Parties aimed primarily to conserve and extend, at the extent possible, the use of public transport, to increase fuel efficiency, to optimize transportation flows, and to improve the air quality. Measures in this sector targeted primarily CO_2, although in most cases they reduce N_2O and precursors as well. In this sector regulations and guidelines prevail as an implementation instrument, followed by taxes and subsidies, while information and rising the public awareness were rare. All countries recognized the role of liberalization of fuel prices as important tool to prevent the rapid growth of fuel consumption and emissions from the sector.

45. Most of the EIT Parties, Czech Republic, Slovakia, Latvia, Hungary and Bulgaria, reported measures to optimize the national transportation infrastructure by giving preferences to the railway and, in relevant cases to water transport and measures to strengthen the role of public transport in cities by improving city infrastructure and making public transport convenient for passengers.

46. Since few EIT Parties are vehicle producers, the key focus with regard to improving transportation fuel efficiency is behavior change, for example strict speed limits to promote efficient driving, and mandatory maintenance and annual check ups of vehicles and import duties and taxes to promote the use of smaller and more environmentally friendly cars.

47. Six Parties, Bulgaria, Czech Republic, Slovakia, Hungary, Poland and Latvia, had presented estimates of the effects of measures to limit the growth of transportation emissions. Only Latvia expected the level of emissions from the transportation sector in 2000 to be 6-25% less that in 1990, while all other EIT Parties that provided estimates on

transportation sector expected growth of emissions in this sector unless additional measures are implemented.

5. Fugitive emissions

49. Although the contribution of this sector to the total CH_4 emissions was high (68.2%), EIT Parties reported a few measures aimed to decrease fugitive methane emissions. Slovakia recognized reducing the leakage from the natural gas distribution system as an important measure since leakages are the largest source of methane in the energy sector. Russian Federation and Poland reported projects for coal-bed methane utilization, but they are at the very early stage of implementation.

6. Industrial processes

50. Only two Parties provided information on policies and measures to reduce emissions from industrial processes. Hungary reported a comprehensive program to reduce VOC emissions from industry and the Czech Republic have implemented eco-labelling to reduce NMVOC emissions.

7. Agriculture

51. The agricultural sector accounted for about 19% of CH_4 emissions (mainly from livestock), 30% of N_2O emissions (mainly from fertilizer application) and less than 1% of CO_2 emissions (mainly from combustion activities). Six EIT Parties, Bulgaria, Slovak Republic, Latvia, Poland, Hungary and Czech Republic, had reported measures in this sector. About 6% of the total policies and measures addressed this sector. Most of the measures were implemented through regulations and guidelines, financial support, training and rising the public awareness.

52. Four EIT Parties, Slovakia, Bulgaria, Poland and Latvia reported measures aimed to reduce N_2O emissions from agriculture. The most common approach was to introduce new norms for fertilizer application as an element of the process of harmonization of EIT Parties norms with EU standards. Two EIT Parties, Slovakia and Latvia, reported guidelines and training for farmers to improve management practices aimed to reduce CH_4 emissions from agriculture.

53. Significant potential for CO_2 reduction from combustion in agriculture was pointed out by the Parties that identified measures in the agriculture, especially if biomass is used as a substitute for fossil fuels. Two countries, Czech Republic and Hungary provided

measures to support more extensive use of biomass and to increase public awareness of this problem.

8. Land use change and forestry

56. Land-use change and forestry was reported as net sink by seven EIT Parties, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Russian Federation and Slovak Republic. Six of them, Bulgaria, Hungary, Poland, Latvia, Russian Federation and Slovak Republic, communicated measures to enhance forest sink capacity that accounted for 8% of total measures. Enhancing forest sink capacity was seen by most EIT countries as a priority for greenhouse gas mitigation policy.

57. Five EIT Parties, Bulgaria, Hungary, Poland, Slovakia and Russian Federation, provided details on their policy for afforestation focusing on improving forestry management practice, including gradual change of coniferous plantations unable to resist to the global warming, improving the forest age structure, increasing forest density and to prevent forests from fire.

58. Some EIT Parties (Russian Federation, Slovakia and Bulgaria) noted that an important issue in formulating forestry mitigation options is linking it to forestry adaptation policy. If not, these options might fail to succeed due to the process of global warming.

9. Waste management

60. The waste management accounted for 12% of CH_4 emissions in EIT Parties. Five of EIT Parties, Bulgaria, Czech Republic, Latvia, Poland and Slovakia, presented information, policies and measures in this sector that accounted for 6% of total policies and measures.

61. Most of the countries provided information on improving waste management practices, but they also have made steps toward separate collection of waste, projects on a waste incineration plants, upgrading legislation on waste management and established a waste management departments.

D. Measures implemented in international cooperation

61. Several activities were reported as successful in the field of international cooperation, including participation of the countries in the US Country Study Program on Climate Change and projects on bileteral basis. All EIT Parties that have reported participated in the US Country Study Program on Climate Change working mainly on GHG inventory,

mitigation policies and measures as well as on adaptation. This program not only provided the countries with methodologies, software and training, but also created significant opportunities for exchange of information on analytical techniques and technologies, approaches and results among the countries themselves.

IV. Summary conclusions

66. All nine EIT Parties have provided description of mitigation policies and measures. While the policies and measures targeted primarily CO_2 emissions, Bulgaria, Slovak Republic, Romania, Poland and Latvia addressed all greenhouse gases, Hungary, Czech Republic and Russian Federation gave the information on CO_2 and CH_4.

67. Most of the Parties, Bulgaria, Hungary, Poland, Czech Republic, Russian Federation, Latvia and Slovakia followed the guidelines in presenting their policy and measures in the national communications. However, the presentation of information varied substantially from country to country and within each country from measure to measure. For most policies and measures there was a lack of information on the status of implementation, the effect of individual measures and monitoring progress, while another part of the measures was just mentioned.

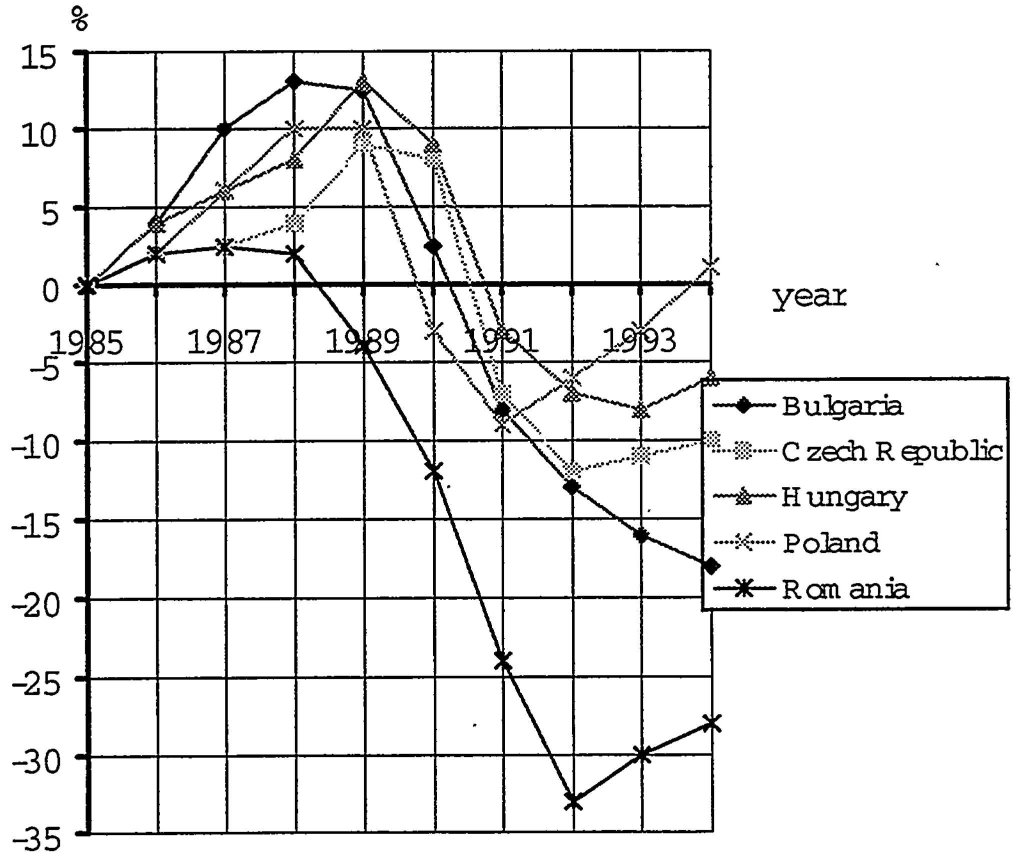
68. Most of the policies and measures implemented by EIT countries were cost-effective and no-regret measures, because it was considered very difficult to allocate additional financial resources for climate change in a situation of deep economic crisis and lack of foreign investment. This approach is consistent with the guidelines which state that the actions to mitigate climate change do not need to have as a primary objective the limitation of greenhouse gas emission

69. Fossil fuel combustion was the major source of greenhouse gas emissions for EIT Parties and within this source the share of emissions from the energy and transformation sector was predominant. Most of the policies and measures that were reported addressed this sector. Policy objectives for this sector included increasing efficiency of energy supply by implementing new technologies, increasing the share of renewables and natural gas, promoting energy efficiency, improving management practices, maintaining the share of nuclear energy in the electricity supply and upgrading centralized heat supply systems. Increasing efficiency in energy end use sectors, including residential, commercial, industrial and transportation was the area where the highest potential for energy saving and GHG mitigation was identified and many measures implemented.

70. EIT Parties recognized transportation sector as the most rapid growing sector and a broad range of policy instruments such as taxes, subsidies, improving guidelines and infrastructure projects have been implemented in this sector. The main aim was to maintain to the extent possible, the existing share of public transport. The other sectors, industrial processes, agriculture and waste management, was given much less attention.

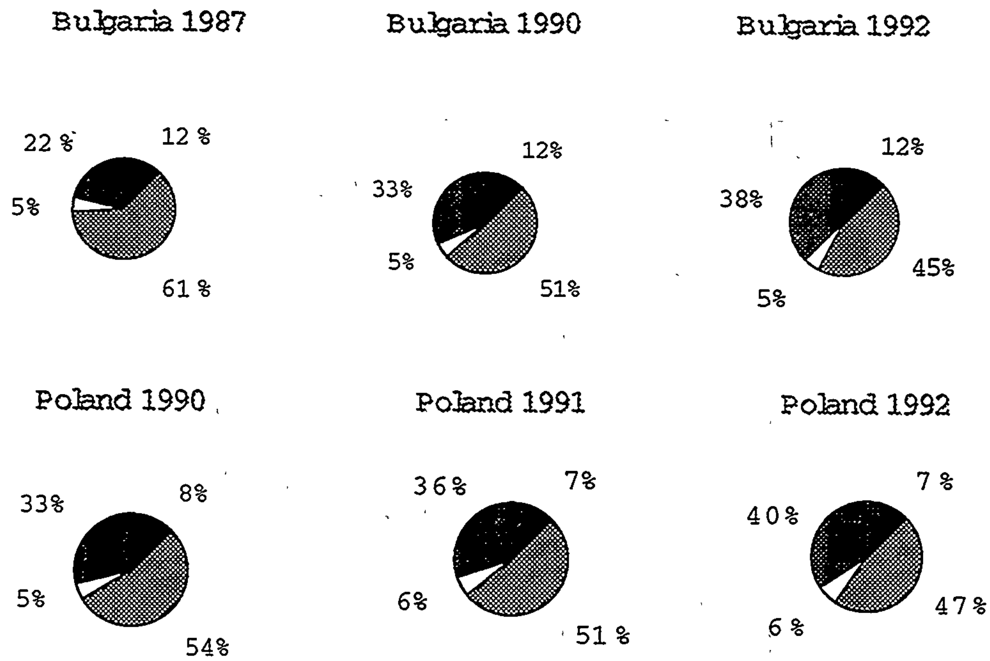
71.Enhancing sink capacity was considered as an important mitigation measure in most of the communications of EIT Parties. Countries reported options for substantial improvement of forestry management practices and afforestation, including a series of pilot projects.

Figure 1. GDP indexes for selected EIT countries (in constant prices).



Source: World Bank

Fig.2. GDP Structure of OECD, Bulgaria and Poland



Source: World Bank

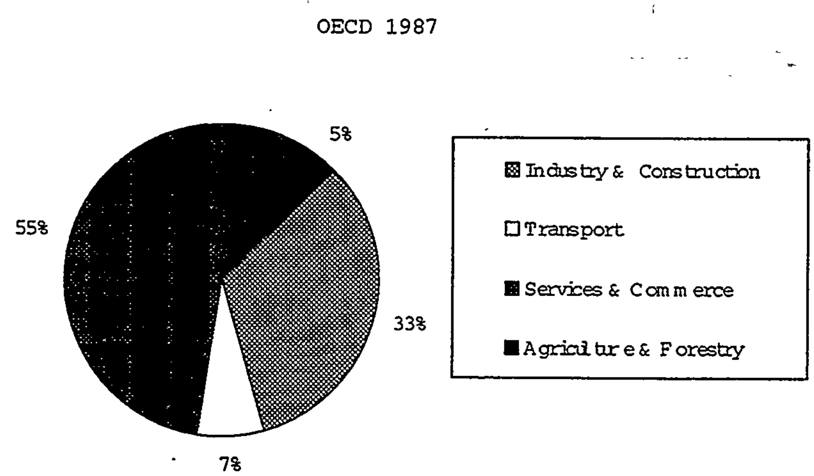
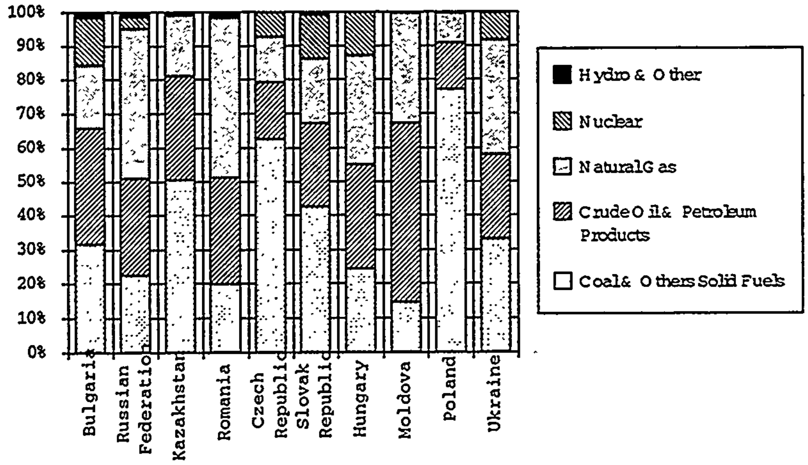
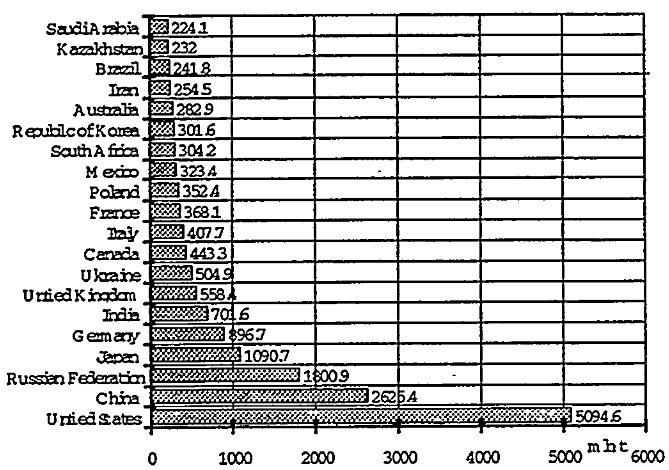


Fig. 3 Structure of primary energy supply by EIT countries (1993)



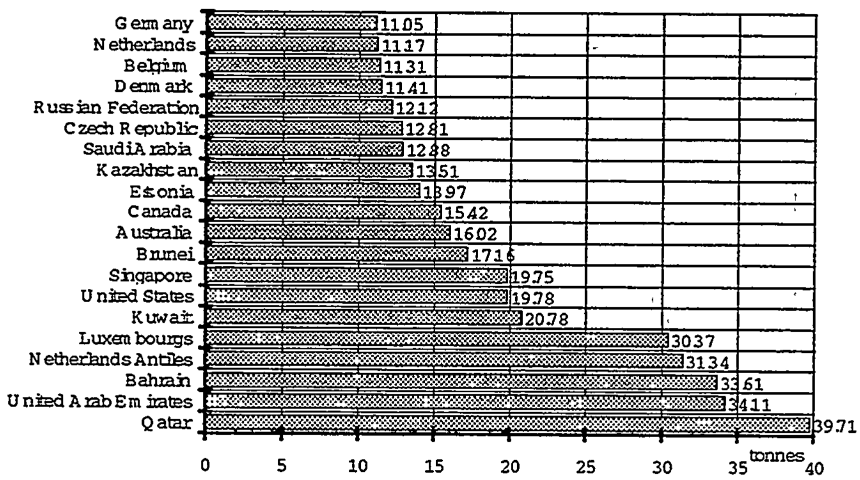
Source: IEA Statistic

Fig.4 World's largest emitters of energy-related CO_2 (1993)



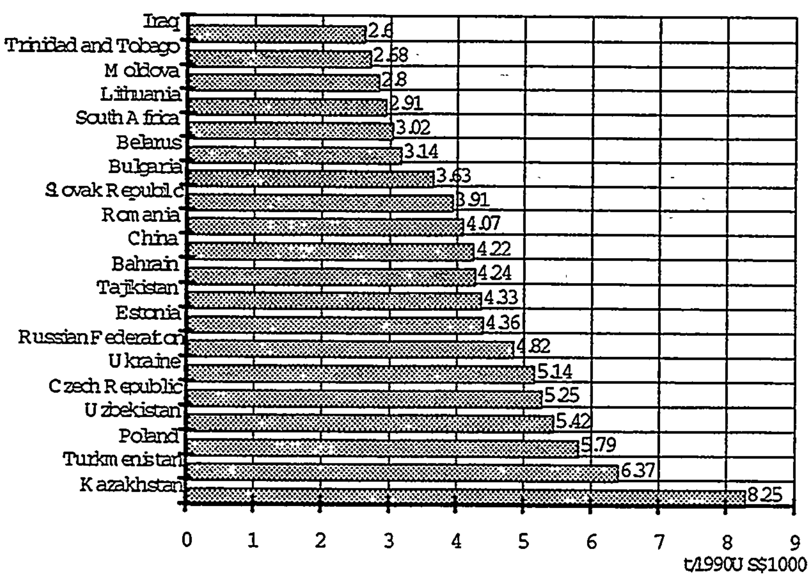
Source: IEA Statistic

Fig.5 World's largest emitters of energy-related CO_2 per capita (1993)



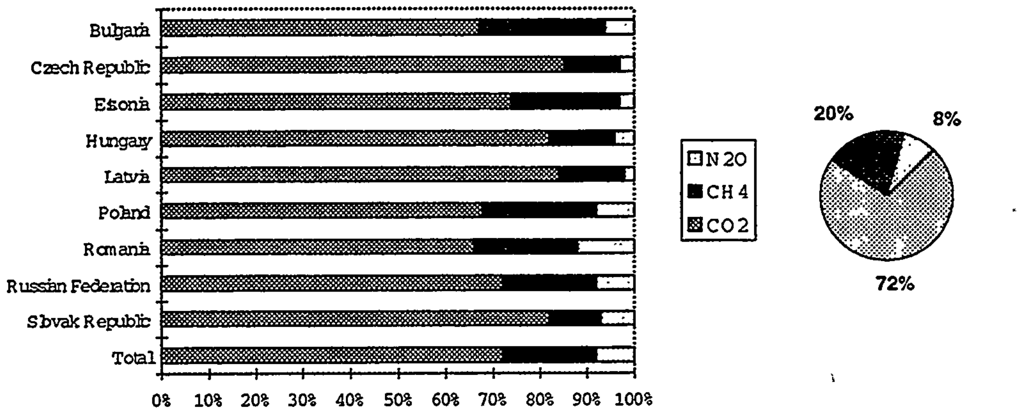
Source: IEA Statistic

Fig.6 World's largest emitters of energy related CO_2 per GDP (1993)



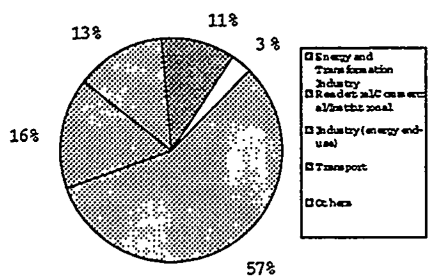
Source: IEA Statistic

Fig.7 Relative contribution of different GHG by EIT Parties



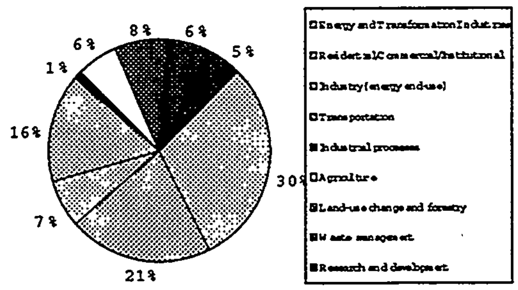
Source: National Communications and FCCC Data Base

Fig.8 Anthropogenic CO_2 emissions from fuel combustion by EIT Parties



Source: National Communications and FCCC Data Base

Fig.9 Sectoral distribution of mitigation measures by EIT Parties



Source: National Communications and FCCC Data Base

Energy Strategy and Mitigation Potential in Energy Sector of the Russian Federation

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ABSTRACT

This paper describes the mitigation potential in the Russian energy sector and presents CO_2 - emission scenarios. Based on the Russian energy strategy, energy conservation potential has been estimated and three groups of energy conservation measures have been pointed out. Taking into account the economic development scenarios and the scenarios of energy consumption and energy conservation, future CO_2 emission scenarios for 2000 and 2010 have been prepared. Some important characteristics of these scenarios have been presented and discussed.

For the period 2000-2010 annual growth rates for CO_2 emission in the Russian energy sector will not exceed 0.9-1.3 % , and emission levels in 2000 make up - 75-78 %, and in 2010 - 81-88 % of the 1990 level. For the probable scenario the CO_2 emission reducing will make up about 6% and 25% (for the optimistic scenario about 16% and 31%) of CO_2 emission for reference scenario in 2000 and 2010 respectively. Additional CO_2 emission reducing (3-5% of domestic CO_2 emission) will result from increasing share of natural gas consumption.

Introduction

The energy sector (or energy system) comprises two groups of branches of the national economy:

- energy supply branches (fuel-energy complex), including energy resources production and modification branches (gas industry, oil industry, coal industry, oil refinery, power and thermal power industry);
- energy consuming branches (transport, industry, municipal branches, agriculture, etc.)

The energy sector is the main source of greenhouse gas emission (up to 98% of CO_2, more than 50% of CH_4 and considerable amount of N_2O). This paper contains mitigation analysis only for CO_2, the main greenhouse gas in the energy sector.

1. Russian Energy Strategy

Many problems of CO_2 anthropogenic emission limiting are related to economic activities in the energy sphere. To provide solution of radical tasks of fuel-energy complex (FEC) a new energy policy is under development in the Russian Federation. In 1993-1994 principal clauses of the State Integrated fuel and Energy Program of the Russian Federation for the period under 2010 - "Energy Strategy of Russia" [1] were developed. The main clauses of the "Energy Strategy of Russia" were approved by the Russian Government on December, 7th, 1994. The principal goals of the Russian strategy in the energy sphere are as follows:

- determination of guidelines and establishment of conditions for a most effective use of energy resources and fuel-energy complex development;
- assignment of leading role to energy branch in layout productivity growth and improvement of life standards for the people;
- considerable reduction of the anthropogenic impacts on the natural environment.

During the transitory period, the Russian energy strategy gives the highest priority to the energy conservation and efficiency improvements of energy supply and energy use. As combined with specific elements of the structural, engineering, financial and legislative policies this approach will result in noticeable decrease in greenhouse gases emission. Therefore, the energy-efficiency programs offer a solution to both economic and climatic issues. Thus, energy efficiency is a key strategy for reducing CO_2-emissions [2, 6].

2. Options for improving energy efficiency and reducing CO_2 emission.

According to Energy Strategy, a wide range of options will be started in Russia in next years. They are aimed at restructuring energy system, raising energy efficiency and performing energy conservation. Mitigation analysis will permit to determine an additional criterion of assessing the Energy Strategy efficiency. It consists in decreasing a CO_2 specific emission in the energy sector estimated as a normalized value for the unit consumed energy.

Currently available mitigation options are associated with energy conservation and efficiency improvements of energy supply and energy use.

A large potential for cost-effective mitigation options exists in the following activities [3, 9] :

1.Energy conservation based on modern equipment and technologies of fuel use and management and engineering measures on energy resources conservation in two groups of branches:

- in obtaining and converting of energy resources (in FEC branches);
- in energy resources consumption (in industrial branches, transport, municipal branches, agriculture, etc.)

2. The optimisation of energy consumption patterns and switching to less carbon-intensive fuels:

- increased share of natural gas consumption;
- expansion of conventional (hydropower) and non-conventional (solar, wind, geothermal, biomass) renewable energy sources;
- more efficient conversion of fossil fuels.
- increased safety of nuclear power plants.

3. Institutional, legislative, economic, financial and other initiatives to support measures aimed at raising efficiency in the Energy Sector.

Specific methods have been used for assessment of Mitigation potential in Russian Energy sector [4, 5, 7, 8, 10].

3. Energy conservation potential and CO_2 emission reducing options.

Forecasting the future economic development and restructuring energy system in Russia has led to the formation of probable and optimistic scenarios for 2000 and 2010 (Table 1).

Table 1

Scenarios for economic development in Russia (percent, as related to 1990)

	1990	1995	2000		2010	
			optim	probab.	optim.	probab.
GNP,%	100	51*	63*	55*	112*	85*
Consumption fund,%	100	60	71	63	124	95

Source: Energy Strategy of Russia, Moscow, 1994, Materials of Institute of Energy Research, Moscow, 1996 and State Committee of Russian Federation for Statistics, Moscow,1995.
*) Understated.Official method of account of GNP has been changed already [13].

During the forecast period, energy consumption will depend on the duration of the economic crisis, the tempo of the economic development and the growth in the energy demand.

In Russia, decades of ineffective use of energy resources have created a huge unused potential of energy conservation (Table 2). Based on 1991 energy production and consumption this potential have been estimated at 450 million tce/year (the economically based portion of the potential) to 540 million tce/year (if one takes into account the possibility of the application in Russia of innovative technologies already available for implementation).

There is some reduction of potential at the present time because of intensive declaine of industry, construction sector and agriculture. When the economic will be restored this potential will increase because of equipment aging and energy consumption increasing. Therefore, in the following accounts, before estimated potential is used.

There are three groups of energy conservation measures: low cost, high cost and accompany [11].

The *low cost measures* represent more rational fuel and energy use; it's share in the total energy conservation potential is 20% . To the *high cost measures* may be related measures which require a high investment for realization and when the economy of energy resources is the main goal. It's share - 60%.Lastly, there are measures where the economy of energy resources is not the goal, but is the *accompany* factor of technical progress (for example, in the metallurgy industry - continuous steel casting).

Table 3 presents the estimates of energy conservation potential for these groups of measures for probable and enchanced investments into energy conservation. The estimates have been made assuming that fuel prices will achieve 60% of European average prices by 2000, and 85% by 2010.

Table 2.

Energy conservation potential (relative to 1991 energy production and consumption)

Industry	Direct-use fuel			Electricity, billion kWh	Heat, million GJ	Total, million tce
	Gas, bcm	Petroleum products, million t	Coal and coke, million tce			
Fuel and energy totals, incl.:	50-60	15-17	33-39	38-46	670-760	150-180
- crude production	8-10	1-1.5	-	3-4	10-15	10-15
- coal				8-10		3-4
- fuel and energy transmission	8-9	-	7-8	30-36	630-710	52-59
- heat and power	32-42	10-12	26-31	-	-	80-97
- petroleum refining	1-1.5	4.5-5	-	1-1.5	40	9-11
Municipal and residential sectors	10	0.6-0.8	21-23	65-70	500-600	75-83
Agriculture	1.4-1.5	14-15	1.5-1.7	8-10	15	27-29
Transport		29-34				42-50
Industry, incl.:	24-29	6-7	12-14	70-80	390-450	85-100
- metallurgy	12-15	2	10-11	20-24	20-25	34-39
- engineering	-(3-4)	0.5		55-60		15-16
- construction materials	10-11.5	1.7-2	2-2.5	-(8.5-10)	170-190	20-23
- chemicals and petrochemicals	5-6	-	-	4-5	50-60	9-10
- pulp & paper	0.3-0.7	1-2	-	-	150-170	8-10
Cross-sectoral measures	10-13	0.5		150-185	310-420	73-92
Total potential	**100-110**	**65-75**	**70-80**	**330-390**	**1880-2250**	**450-540**
Total 1991 consumption	**467**	**263**	**241**	**1056**	**-**	**1250**

The following conversion factors are used:
1.15 tce/1000 m3 gas
1.37 tce/ 1 t heavy oil
1 tce (tonne of coal equivalent)=0.7 toe= 29.31 GJ
41 kgce= 1 GJ heat
Source: Energy Strategy of Russia, Moscow, 1994

Table 3.

Energy Conservation Potential

and resulting CO_2 Emission reduction.

Parameter	2000		2010	
	Probable investment	Enhanced investment	Probable investment	Enhanced investment
Economy of energy resources, million tce/yr, due to measures:				
- low cost	50	90	90	100
- high cost	10	80	210	300
- accompany	-	5	20	70
- total	60	175	320	470
Reduction in CO_2 emissions:				
- million tonnes C/year	33	96	176	258
- as related to reference scenario of CO_2 emission, percent	6%	16%	25%	31%

Source: Materials of Institute of Energy Research, Moscow

Implementation of energy conservation options will result in CO_2 emission reduction, as summarized in Table 3. Reduction in CO_2 emmission is related to reference scenario of "frozen energy efficiency" [12].

4. Energy consumption scenarios to 2010.

The projections of primary energy resources consumption (the economic development, optimisation of energy consumption and the energy conservation options have been taken into account) are presented in Table 4.
Probable scenario of energy consumption is based on probable scenario for economic and energy sector development and probable investment into energy conservation. Optimistic scenario of energy consumption is based on optimistic scenario for economic and energy sector development and enhanced investment into energy conservation.

The rates of 2000-2010 energy intensity improvement for optimistic and probable scenarios are presented in Table 5.

Table 4

Scenarios of energy consumption and energy conservation potential

	Energy consumption		**Energy conservation potential**	
	Mtce/yr	as related to 1990, percent	Mtce/yr	as related to reference scenario of energy consumption, percent
1990	1257	100		
1995	962	76.5		
Optimistic scenario				
2000	1015	80.7	175	14.7
2010	1150	91.5	470	29
Probable scenario				
2000	970	77.2	60	5.8
2010	1060	84.3	320	23.2

Source: Materials of Institute of Energy Research, Moscow.

Table 5

Energy intensity improvement for optimistic and probable scenarios.

	2000-2010 growth rates (percent per year)	
	Optimistic scenario	Probable scenario
Economic development	5.75	4.35
Energy consumption	1.25	0.88
Energy intensity	- 4.5	- 3.5

Source: Materials of Institute of Energy Research, Moscow and Institute of Global Climate and Ecology, Moscow.

5. Switching to low carbon fossil fuels.

The Russian energy system has ample means switching to fuels with a lower carbon-to-hydrogen ratio, such as from coal (or oil) to natural gas.

CO_2 emissions from energy resources consumption are generally estimated as the product of the amount of resource consumed and the emissions coefficient:

$$c = k_1 \cdot e_1 + k_2 \cdot e_2 + k_3 \cdot e_3 = k_o \cdot E$$

where k_1, k_2, k_3 are emission coefficients for coal, oil and natural gas respectively, e_1, e_2, e_3, e_4 are amounts of consumed coal, oil, natural gas and renewable resources respectively, $E = e_1 + e_2 + e_3 + e_4$, $k_o = c/E$ is carbon intensity.

Switching from coal ($-\Delta e_1$) to natural gas (Δe_3) would reduce CO_2 emission by ΔC:

$$\Delta C = - k_1 \Delta e_1 + k_3 \Delta e_3$$

By letting $\Delta E_1 = \Delta e_3 = \Delta e$, we obtain:

$$-\Delta c/c = \{(k_1 - k_3)/k_o\} \cdot \Delta e/E$$

In general, switching from $(\text{resource})_i$ to $(\text{resource})_j$ would alter CO_2 emission by ΔC:

$$\Delta c/c = \{(-k_i + k_j)/k_o\} \cdot \Delta e/E$$

In both scenarios, probable and optimistic, share of natural gas consumption will increase by about 10% between 1990 and 2000-2010. This switching from coal (and oil) to natural gas in Russian energy system will reduce CO_2 emission by 3-5%.

Share of non-conventional renewable energy sources (solar, wind, geothermal and others) will increase and in 2010 will make up 1-2% of the energy consumption. This switching to renevable source will reduce CO_2 emmission by 1.2-2.5%.

6. CO_2 emission scenarios to 2010.

CO_2 emission scenarios in the energy sector (Table 6 and Figure 2) are based on the probable and optimistic scenarios of fossil fuel consumption (see Table 4).

Table 6

CO_2 Emission scenarios in the energy sector of the Russian Federation

	CO_2 emission		Reduction in CO2 emission due to energy conservation	
	MtC/yr	as related to 1990, percent	MtC/yr	as related to reference scenario of CO_2 emission, percent
1990	654	100%		
1995	483	73.9%		
Optimistic scenario				
2000	507	77.5%	96	15.8%
2010	575	87.9%	258	30.7%
Probable scenario				
2000	487	74.5%	33	6.3%
2010	531	81.2%	176	24.8%

Source: Materials of Institute of Global Climate and Ecōlogy, Moscow.

Table 7 outlines CO_2 emission levels, annual growth rates and carbon intensity for the period 2000-2010 in Russia considering CO_2 technogenic emissions in energy sector.

2000-2010 carbon intensity will make up 96% of the 1990 level. It will result from impact of fuel switching.

Table 7

2000-2010 annual growth rates and carbon intensity for CO_2 emission in the Russian energy sector

	As related to 1990, percent			2000-2010 annual growth rates (percent per year)	
	Energy Consumption	CO_2 emission	Carbon intensity	Energy Consumption	CO_2 emission
1990	100	100	100		
1995	76.5	74.3	~97		
Optimistic scenario					
2000	80.7	77.5	**~96**	**1.26**	**1.25**
2010	91.5	87.9			
Probable scenario					
2000	77.2	74.5	**~96**	**0.88**	**0.86**
2010	84.3	81.2			

Source: Materials of Institute of Energy Research, Moscow, and Institute of Global Climate and Ecology, Moscow.

For this period when the economic crisis has been overcome annual growth rates for CO_2 emission in the Russian energy sector will not exceed 0.9-1.3 % per year, and the emission level will make up:

2000 - 75-78% of 1990 level.
2010 - 81-88% of 1990 level.

The CO_2 emission scenarios presented above reflect possible development of Russian energy system. In this way the main uncertainties are related at the difficulties of carrying out of an efficient investment policy in energy sector and the uncertainties of subsequent development of nuclear power generation.

Conclusion.

In transition economy of Russia mitigation measures in energy sector are directly connected with general national energy strategy. Measures for energy sector modernization lead to saving of fossil fuel and related decrease in GHG emission. Mitigation options with the best parameters of economy, energy conservation and emission reduction efficiency will be included in the Action Plan. It is planned to undertake specific mitigation measures in the following directions:

1. Measures on energy conservation and transition to energy conservation technologies in fuel and energy production as well as in energy consumption branches (transport, industry, residential and commercial buildings, agriculture).
2. Structural and technological measures: a) increased share of natural gas consumption; b) expansion of conventional (hydropower) and non-conventional (solar, wind, geothermal, biomass) renewable energy resources; c)more efficient conversion of fossil fuels; d) reabilitation and upgrade of power plants by replacement with new economically and ecologically sound equipment ; and e) increase in safety of nuclear power plants.
3. Institutional, legislative, and other measures aimed to: a) formation of energy market (price and tax policy, refinement of legislation, and etc.); and b) support of measures listed above in points 1 and 2.

CO_2 mitigation will result from measures for energy supply and energy use. For the probable scenario the CO_2 emission reducing will make up about 6% and 25% of CO_2 emission for reference scenario in 2000 and 2010 respectively (for the optimistic scenario about 16% and 31%).

Additional CO_2 emission reducing (3-5% of domestic CO_2 emission) can result from increasing share of natural gas consumption (about 40% in 1990 to about 50% for the period 2000-2010) in the composition of consuming energy resources.

Acknowledgment

This work was carried out under the U.S. Country Studies Program, Cooperative Agreement DE-FCO2-93PO10118 with U.S. Dept. of Energy. The author would like to express their gratitude to John Millhone, Project Officer of the Program for support, great attention and valuable comments to work.

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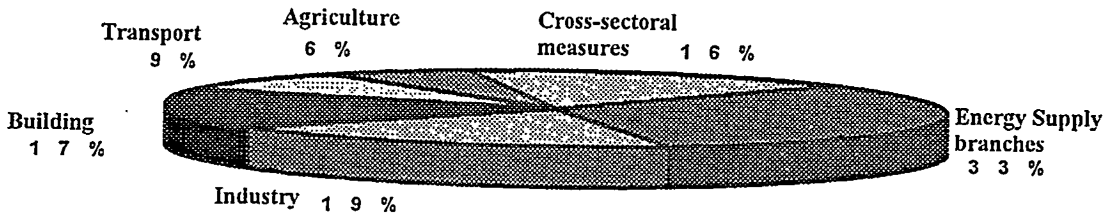
Share of braches in the Energy Conservation Potential

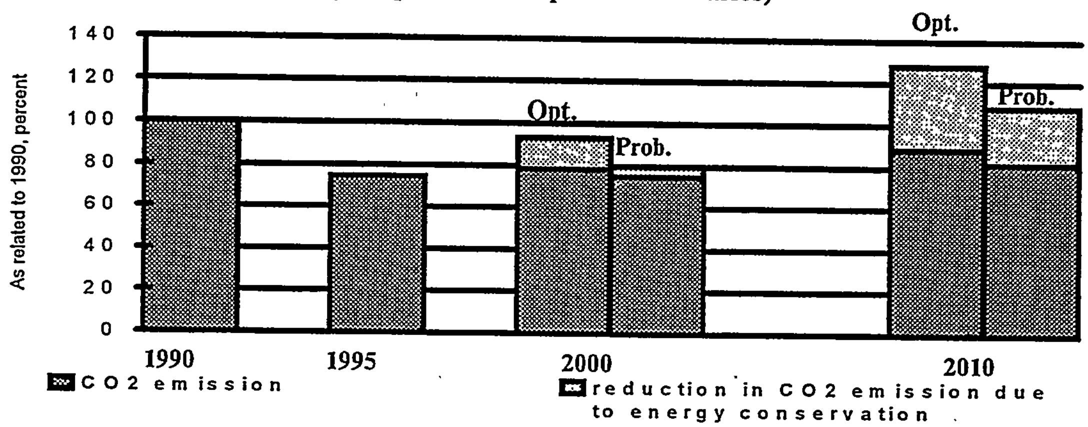
Figure 1



Sourse: "Energy Strategy of Russia" ,1994

Figure 2

CO_2 - Emission Scenarios in the Energy Sector and Reduction in CO_2 - Emission due to energy conservation (for optimistic and probable scenarios)



Sourse: Materials of Institute of Global Climate and Ecology, Moscow.

SCENARIOS OF ENERGY DEMAND AND EFFICIENCY POTENTIAL FOR BULGARIA

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The paper presents aggregated results on macroeconomic and final energy demand scenarios developed within the Bulgarian Country Study on Greenhouse Gas Emissions Mitigation, supported by US Country Studies Program. The studies in this area cover 5 main stages: (1) "Baseline" and "Energy Efficiency" socio-economic and energy policy philosophy; (2) Modeling of macroeconomic and sectoral development till 2020; (3) Expert assessments on the technological options for energy efficiency increase and GHG mitigation in the Production, Transport and Households and Services Sectors; (4) Bottom-up modeling of final energy demand; (5) Sectoral and overall energy efficiency potential and policy. Within the Bulgarian Country Study, the presented results have served as a basis for the final integration stage "Assessment of the Mitigation Policy and Measures in the Energy System of Bulgaria".

1. SCENARIOS FOR LONG-TERM ECONOMIC DEVELOPMENT OF BULGARIA

Two scenarios for economic development have been formulated within the study: the Basic Scenario and the Energy Efficiency Scenario.

The **Basic Scenario** assumes that the dominant features of economic players' behavior and the usual normal pace for adopting changes in their lifestyle and attitude towards economic and social environment will persist in time. This scenario is compatible with a development pursuing a gradual and smooth progress in the interest of production of material wealth and prevention of social cataclysms. It follows the route, already tread by other countries and use nearly obsolete, energy and material intensive technologies with a proven harmful effect on people and environment and might only turn to be efficient and progressive in a short-term run.

The most general characteristic features of anticipated medium-term development are modest but still relatively high Gross Domestic Product (GDP) growth rates (especially in the first half of the period), relative sustainability of the aggregated branch structure, acceptable level of accumulation. The average GDP growth of 4-5 % with unit elasticity of foreign trade looks quite feasible. Increased investment efficiency in the consumer sectors with shorter investment cycles may accelerate the growth rates by nearly 0.5 %.

The **Energy Efficiency Scenario** presumes a change in present inertial economic characteristics and consumer behavior. Development is aimed at maximizing the utilization of national resources by the means of economical and thrifty attitude to the elements of the national production potential (transformed on energy basis) and by taking into account the comparative economic advantages. The latter seems to be the crucial prerequisite for any rapid progress in the future. The scenario assumes more moderate short-term rates of economic growth. Over the first half of the forecast period economic growth will fall behind that of the Basic Scenario. The change in the behavioral patterns will come closer to a shock-like thrust, as far as changes in lifestyle are usually accepted reluctantly and painfully. To meet the scenario requirements means to actively resort to market mechanisms and levers in order to regulate economic processes and establish different institutional basis. Subsidizing energy prices as an instrument for meeting various notions for social leveling has been abandoned as a possible solution.

One of the main features of this scenario is the possible and probable turnaround in the long-term growth. The path of development with an emphasis on energy efficiency is an investment in the future. If processes are balanced and the proper economic behavior is established in the long-term perspective then the growth curve will change its trend. The Energy Efficiency Scenario, starting from low growth rates, described in the beginning as the "low" variant, will by the end of the period lead to an accelerated economic growth outstripping that of the Basic Scenario.

The main macroeconomic indices include the GDP, annual inflation, industrial production volume, unemployment, export, import and their balance, budget balance and total national debt. The rates of the economic growth for both scenarios are shown on Fig. 1.

The branch alternatives are analyzed for 38 economic branches over 5 indices (investments, production volume, import-export and manpower) and serve as basis for the scenarios of branch technological evolution and for the forecasting of final energy demand.

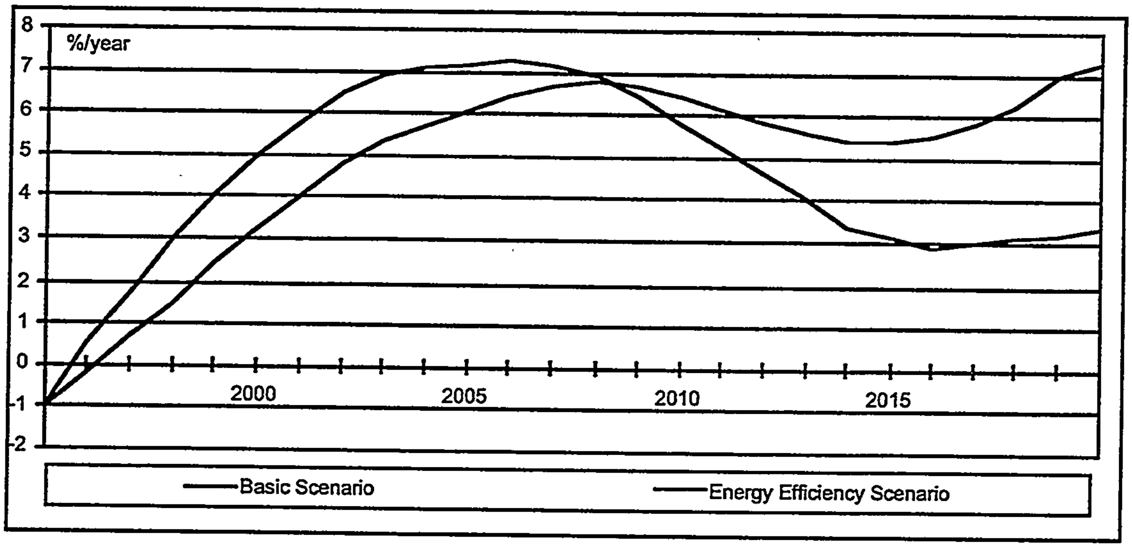

Fig. 1. Economic development forecast for Basic and Energy Efficiency Scenarios

2. ENERGY DEMAND SCENARIOS AND PROSPECTS

2.1. APPROACH TO SCENARIO FORMULATION

Several substantial factors have been determined influencing the energy demand: the economic growth characteristics, structural changes in the Gross Domestic Product, the structure of the fuel and energy resources, energy carriers policy, demographic development and the population lifestyle, characteristics of the housing stock, transport policy. The analysis and quantitative estimation of these factors are the base of the formulated two scenarios for technological and energy demand policies, corresponding to the scenarios for socio-economic development: "basic"- production, organization and technological evolution, characterized by limited introduction of perspective technologies according to the market conditions; and "energy efficiency" scenario, assuming more active technological and motivation policy (including improved institutional structure, prices and tariffs, standards, modern management systems, subsidies, preferential loans and other measures) with accent on energy efficiency and ecological priorities.

To formulate detailed scenarios for the extended "bottom-up" analysis, studies and expert assessments have been done in the following areas:

- technological evolution and alternatives of branches, sub-branches and main production activities;
- demographic development, human settlements prospects, the state and prospects of buildings and the prospects of the technological development for 5 processes: heating, hot water supply, food preparation, lighting and household appliances; substantial change in the Households and Services Sector is the introduction of a new energy carrier - the natural gas - which will cover 1.2 million people according to the Basic Scenario and 2 million people for the Energy Efficiency Scenario;
- the state and the alternatives of the Transport Sector covering passenger and freight transportation by railroad, water, air, automobile (public, corporate and private), urban electrical and pipeline transport types.

2.2. ENERGY DEMAND PROSPECTS

According to the macroeconomic and branch development alternatives and the two scenarios for technological evolution and energy conservation policy, the energy demand is simulated and projected by the MED model (a Bulgarian version of the EU MEDEE model) for all hierarchical levels of the energy consumption system:

- Production Sector includes the subsectors "Industry and Construction" and "Agriculture and Forestry"; the "Industry and Construction" subsector covers all industrial branches (ferrous and non-ferrous metallurgy, chemical industry, construction materials industry, machine building and metal works, electrical and electronics industry, wood and wood processing industry, glassware and chinaware industry, textile and confection industry, leather and footwear industry, poligraphy, food and beverages industry and other industrial branches) and construction (the most energy-intensive branches are analyzed by main production types); the subsector "Agriculture and Forestry" has been analyzed for the two constituting branches, and the Agriculture has been further subdivided by the two main sub-branches - plants and animal production, as well as by the main production types specific for the corresponding sub-branch.
- Transport sector have been analyzed by the type of transportation (passenger and freight), transport types (railroad, water, air, automobile, urban electrical transport and pipelines) and by energy carriers type - the automobile transport is further subdivided into public (passenger buses and cargo vehicles) and private (personal cars, taxi cabs and corporate cars); the water transport is subdivided into river and sea transport, and the air transport besides the passenger, includes also the medical and agricultural aviation; the pipelines includes the petroleum products lines and the natural gas pipeline system.
- The Households and Services Sector is analyzed by subsectors; households are analyzed according to demographic development, current housing patterns, household income and mean number of persons per household; analyses have been carried out for 5 processes: heating, hot water supply, food preparation, lighting and household appliances. For the heating process, the energy demand analysis for the households subsector is further subdivided depending on the share of houses with centralized heating and corresponding level of energy consumption comfort, the share of houses with "normal" or "improved" thermal insulation and the share of small and tall buildings. For the hot water supply process, the energy demand analysis is performed depending on the water heating technologies and the hot water use rate in the case of centralized heat supply. For the food preparation process in the households, the energy use rate per capita is similar for all settlement types for the given year. The electrical energy use characteristics for the lighting and appliances processes in the households subsector are determined by experts, accounting for the influence of the following factors: number, type and income of the household members; number and dimensions of the rooms in the house/apartment; geographic position of the building and the type of settlement.

The dynamics and the structure of the final energy demand in the energy consumption system are shown below by economic sectors and by fuel/energy types.

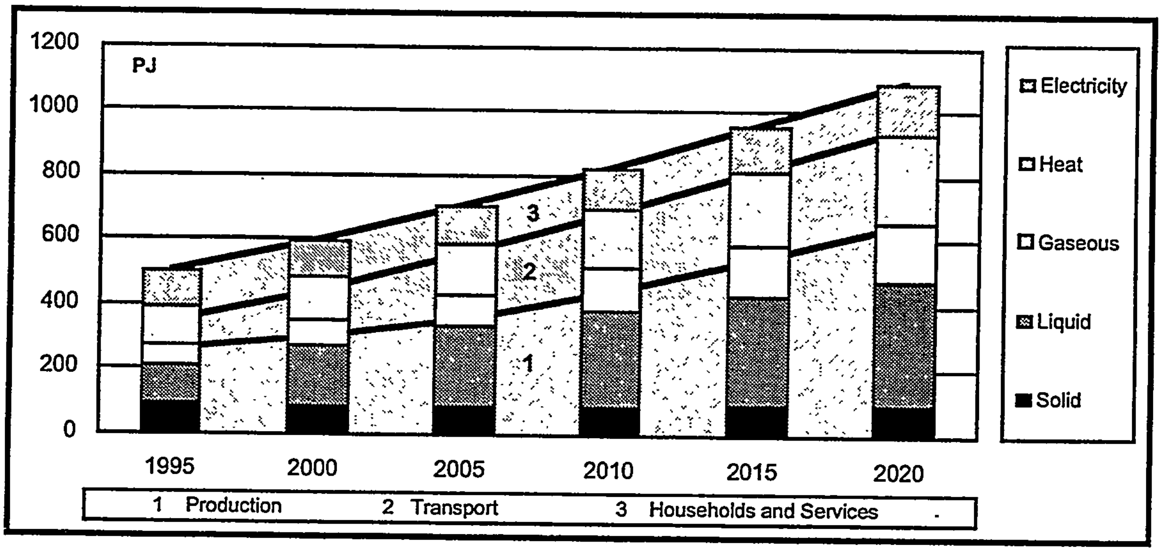

Fig. 2. Final energy demand for the Basic Scenario by fuel type and by economic sectors, PJ

Fig. 2 shows the final energy demand for the Basic Scenario by economic sectors. The final energy demand increases by a factor of 2.2, the share of production sector rises from 52.5% to 59%, the share of transport rises from 17.1% to 27.8%. The forecasted energy demand by fuel type is also shown on Fig. 2. The share of solid fuels decreases from 17.3% to 8.1%, the liquid fuels rise from 24.7% to 35.8%, the gaseous fuels rise from 13.8% to 16.6.%, the heat preserves its share (24.6% and 25.2%), the share of electricity decreases from 19.6% to 14.3%.

According to the Energy Efficiency Scenario (Fig. 3) the final energy demand rises by a factor of 1.8. The final energy demand in the energy consumption system according to the BS are greater than those according to EES by 61 PJ (10%) in 2000, by 132 PJ (16%) in 2005 and by 177 PJ (16.2%) in 2020. However, the relative share of the final electrical energy demand for EES is bigger throughout the period 2000-2020, mostly because of the restructuring of some energy-intensive industrial branches and the corresponding technological requirements; by the end of the period this share is 14.3% for BS and 16.4% for EES. The share of gaseous fuel demand is practically the same for both scenarios during the forecast period. The biggest share in gaseous fuels is attributed to natural gas (88% in 1995; 93% for BS and 95% for EES in 2020). The forecast assumes for both scenarios, that the natural gas, currently used only within the industrial sector, after 2000 will be introduced to households and services, rising by 2020 to 11 PJ for BS and to 18 PJ for EES.

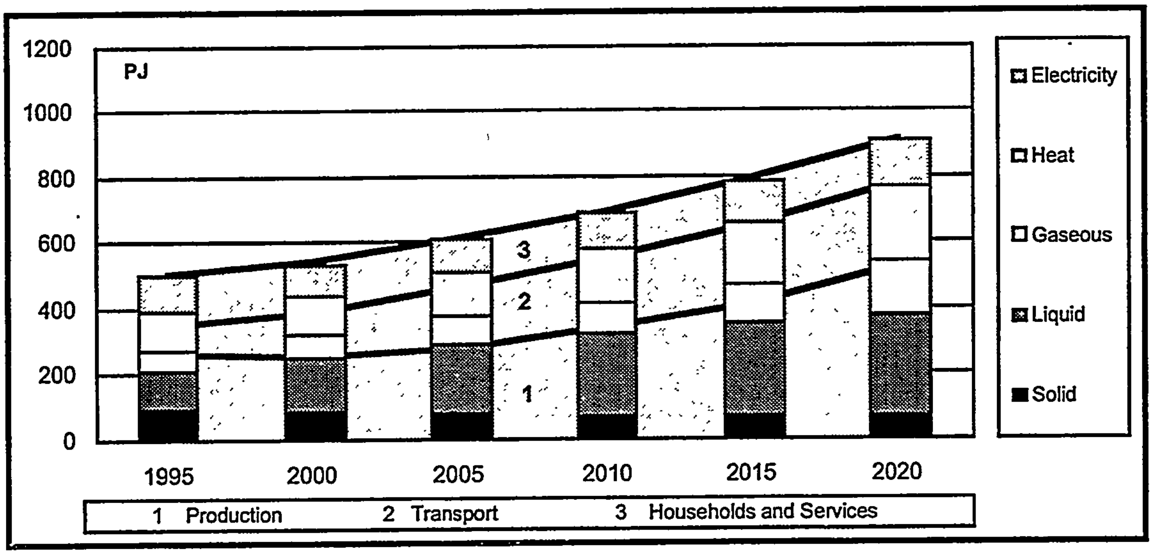

Fig. 2. Final energy demand for the Energy Efficiency Scenario by fuel type and by economic sectors, PJ

3. ENERGY EFFICIENCY POTENTIAL

3.1. METHODOLOGICAL APPROACH FOR ESTIMATION OF ENERGY EFFICIENCY POTENTIAL

The overall concept of energy efficiency increase covers the economic restructuring, energy efficiency of the final energy demand and of the energy supply. Our study was oriented to identification of the technically and economically viable potential for energy efficiency increase in the energy consumption system in reference to the historical trends (nearly frozen energy efficiency). Such approach was justified by the requirement that the national study had to serve as a base for the first national report within the obligations of Bulgaria as a member of UN GHG Convention. The analysis of energy efficiency potential was further subdividing it into (1) potential which can be implemented just by the influence of the normal market factors (market potential) and (2) potential depending on a purposeful policy (DSM potential). The identification of the possibilities for energy efficiency increase was divided into two categories: (1) conditions dominated by the energy cost (energy cost sensitive possibilities) and (2) actions dominated by more general criteria (possibilities not sensitive to energy cost).

For the assessment of energy efficiency potential in the production and transport sectors, one of the methods of the statistical structural analysis is used. The approach allows for separation of the different factors influencing the final energy demand and for determination of the perspective energy efficiency potential on the basis of energy demand development forecast. The information provided by branch expert assessments allows to divide this potential into (a) potential which depends on optimal load of production capacities, organizational measures, proper technological discipline, etc. (market potential), and (b) potential depending on purposeful efforts for energy conservation and requiring investments, energy price policy, energy legislation and standards, etc. (DSM potential).

The forecast and analysis of the energy conservation potential in the households and services sector is carried out for 5 main processes: heating, hot water, food preparation, lighting and electrical appliances. The possibilities (conditions) for energy efficiency increase in this sector, as a rule, are generic (i.e. they are subject of mass distribution) and sensitive to the energy cost, so their assessment can be performed using the relationship "energy savings - relative cost".

3.2. SECTORAL AND OVERALL ENERGY EFFICIENCY POTENTIAL OF BULGARIA

Production Sector. The data presented in Table 1 cover the sector as a whole, including the industry and its most energy-intensive branches, construction and agriculture and forestry. It illustrates the energy efficiency potential in this sector for the Energy Efficiency scenario (the DSM potential). The estimated potential for energy conservation in this sector in 1996-2000 amounts to 43.6 PJ/a and reaches 159.3 PJ/a in the last five-year period of the forecast.

Energy savings provided by energy efficiency increase only, is 15.7% of the total fuels and energy consumption at the beginning of the forecast period and reach 34.7% at the end. Additional savings are possible in case of positive structural changes in the sector. Their relative share in the total savings grow from 6% in 1996-2000 to appr. 15% in 2001-2005.

Generally, about 50% of the potential is provided by the full loading of the production capacities and implementation of low-cost energy efficiency measures. Their biggest share is in 2001-2005 (about 80%) and in 2011-2015 (over 71%). The rest is provided by additional investments and DSM measures.

Table 1. Average annual energy conservation potential in the production sector, PJ/a

Branches and influence type	1995 - 2000	2001- 2005	2006 - 2010	2011 - 2015	2016 - 2020
Energy efficiency influence, incl.	40.9	54.5	85.6	108.6	141.5
Industry, incl.	35.1	48.5	78.4	101.5	128.5
Ferrous metallurgy	0.3	15.9	13.1	14.2	15.1
Chemical industry	5.5	-	6.8	5. 4	4.2
Construction materials	4.5	3.6	4.8	6.5	8.6
Other industrial branches	24.8	29.0	53.7	75.4	100.6
Construction	2.4	1.7	2.4	2.9	4.0
Agriculture and forestry	3.4	4.3	4.8	4.2	9.0
Structure influence	2.7	9.8	8.8	15.8	17.8
Total	43.6	64.3	94.4	124.4	159.3
Total energy demand *	259.9	246.3	279.2	334.2	408.4

* Total energy demand in the production sector for the first year of the period according to the Energy Efficiency Scenario

Transport Sector. The analysis covers the influence of the volume of transportation, the structure by transport types and the energy consumption per unit of transportation activity on the dynamics of the final energy demand. The energy and economic characteristics of the sector are accounted for in the energy efficiency potential estimation and measures are proposed for energy efficiency increase. The expert assessments are based on the existing branch development programs and give approximate review of the investments needs for energy efficiency increase in this sector.

The analysis of the factors affecting the final energy demand in the freight transportation shows that the expected structure changes in the types of vehicles after the year 2000 will have a negative impact on energy efficiency during almost the whole period. The overall fuel and energy conservation potentials resulting from decrease in the energy intensity increases from 1.46 PJ/a for 1995-2000 to 4.74 PJ for 2016-2020. The larger portion of the energy savings is due to the automobile transport: 77 to 88 %. Next is the railroad transport whose share reaches 8-10 %. For the 5-year periods of the forecast the savings from energy conservation are 3.2 %, 6.7 %, 4.8 %, 2.2 % and 7.5 % of the final energy demand respectively.

The expected structural changes in the passenger transport (covering the public transport: railroad, automobile, water, air and urban electrical, and cars: personal, taxis and corporate) will have a negative impact on the energy efficiency of the final energy demand because of the expected growth of the share of more energy intensive types of transportation. However, the decline in the urban and car transport energy intensity not only compensates the energy intensity growth in the water transport but also provides overall fuel and energy saving. In relation to the final energy demand, this potential is 11.6 % for the period 1996-2000, 13.9 % for the period 2001-2005, 15.0 % for the period 2006-2010, 16.6 % for the period 2011-2015 and 18.1 % for the period 2016-2020.

The current state of the transport sector and the envisaged technological evolution show that the potential of organizational and other measures not requiring significant funds to achieve fuel conservation are big enough and will provide the greater part of the potential during the first 10 years of the study period. Its relative share in the energy conservation potential gradually decreases from 73.7 % in the period 1996-2000, to 55 % in the period 2001-2005 and later varies within 22.4 to 33 %. Larger potentials after 2005 are related to investments and replacement of transportation vehicles.

Households and Services Sector. Due to the strong interrelation of the energy carriers policy and final energy consumption technologies, the analysis of the energy efficiency increase potential is performed for two interrelated sub-systems: thermal processes (heating, hot water supply, food preparation), and non-thermal processes (lighting and electrical appliances).

The most substantial effect for the decrease of the energy consumption in thermal processes in the households and services sector during the next 25 years can be expected from the introduction of urban gasification. The analysis has been performed with the assumption, that by the year 2020 the number of population living in gasified buildings will be 1.2 mln. according to the BS and 2 mln. according to the EES, and covers questions such as gas-substituted electrical capacity, saved cost for solid and liquid fuels in the electricity generation system, additional cost of natural gas and gas pipelines system. The results of this analysis have been used to calculate the mean cost of saved electricity. Assuming the market electricity price in Bulgaria of 3.5 cents/kWh by the year 2000, the annual savings resulting from the household gasification for the BS are 28.1 million USD/a and for EES - 48 million USD/a.

The most substantial effect for the decrease of energy consumption of non-thermal processes during the next 25 years can be expected from lighting. The proposed Program "Lighting improvement in the households and services sector" includes:

- for the households subsector: replacement of 12.5 million incandescent lamps with compact fluorescent lamps (investments: 77.18 million USD; saved energy: 673 million kWh; cost of conserved energy: 1.89 cents/kWh; assuming price of 3.5 cents/kWh, the annual saving is 10.8 million USD).
- for the services subsector: replacement of the mercury lamps with sodium lamps (number of lamps: 250W - 100000, 150W - 360000, 70W - 340000, 50W - 100000; investments: 3.78 million USD; saved electric energy: 703.7 million kWh; CCE: 0.087 cents/kWh; assuming price of 3.5 cents/kWh, the annual saving is 24 million USD).

A summary of results of the studies performed for the economic sectors and the analysis of the influence of the structural factor and energy efficiency on the final energy and fuel demand in the production and services spheres shows:

- The structural changes on the macroeconomic level on the present stage of transition from centrally-planned towards market economy have positive influence on the change of the final energy demand up to the year 2005. After that, accounting for the production growth, this influence can be less effective - further restructuring can even lead to negative results.
- The biggest potential is in the production sector - its share varies from 81% to 87%. Next is the transport sector, whose share in the energy demand decrease potential decreases from 11% in the first decade to 8-9%. The share of services subsector is the smallest one: 6.7% before 2005 and between 3.8 and 4.8% after that. The overall energy savings potential due to energy intensity decrease (without the impact of structural changes) rises from ca. 12% of the total energy demand in the period 1996-2000 to 27.8% in 2006-2010 and to 43.1% in 2016-2020.
- The potential for reduction of final energy demand by sectors is presented in Fig. 4. The figure also shows a subdivision of this potential depending on the conditions for its implementation (low-cost organizational and behavioral measures or purposeful state investments policy for energy resource saving). It can be seen that the potential from organizational measures is quite substantial. Its share in the total potential is 41.7% in 1996-2000 and increases to 48.8% in the last years of the forecast period. The measures requiring additional investments and long-term development programs, legislative and institutional development, can lead to a decrease of the final energy demand from 28.9 PJ/a in 1996-2000 to 88.1 PJ in 2016-2020.

Integrated indicators of national energy development:

- The final energy demand per capita increases from 67.1 GJ in 1995 to 154 GJ (BS) or 128 GJ (EES) in 2020; the final electricity demand per capita increases from 3894 kWh in 1995 to 6562 kWh (BS) or 6208 kWh (EES) in 2020.
- The energy intensity of the final energy and electricity demand and primary energy resources per unit of GDP significantly decreases during the forecast period:
  - the energy intensity decreases for BS from 2750 kJ/BGL to 1750kJ/BGL (1.75 times) and for EES - to 1350 kJ/BGL (more than 2 times);
  - the electricity intensity per 1000 BGL decreases from 148kWh to 72kW (2 times) for the BS and to 65kWh (2.3 times) for the EES;
  - the energy intensity of the primary energy is decreases from 5000 kJ/BGL to 2550 kJ/BGL (almost 2 times) for the BS and to 2200 kJ/BGL (almost 2.3 times) for the EES.

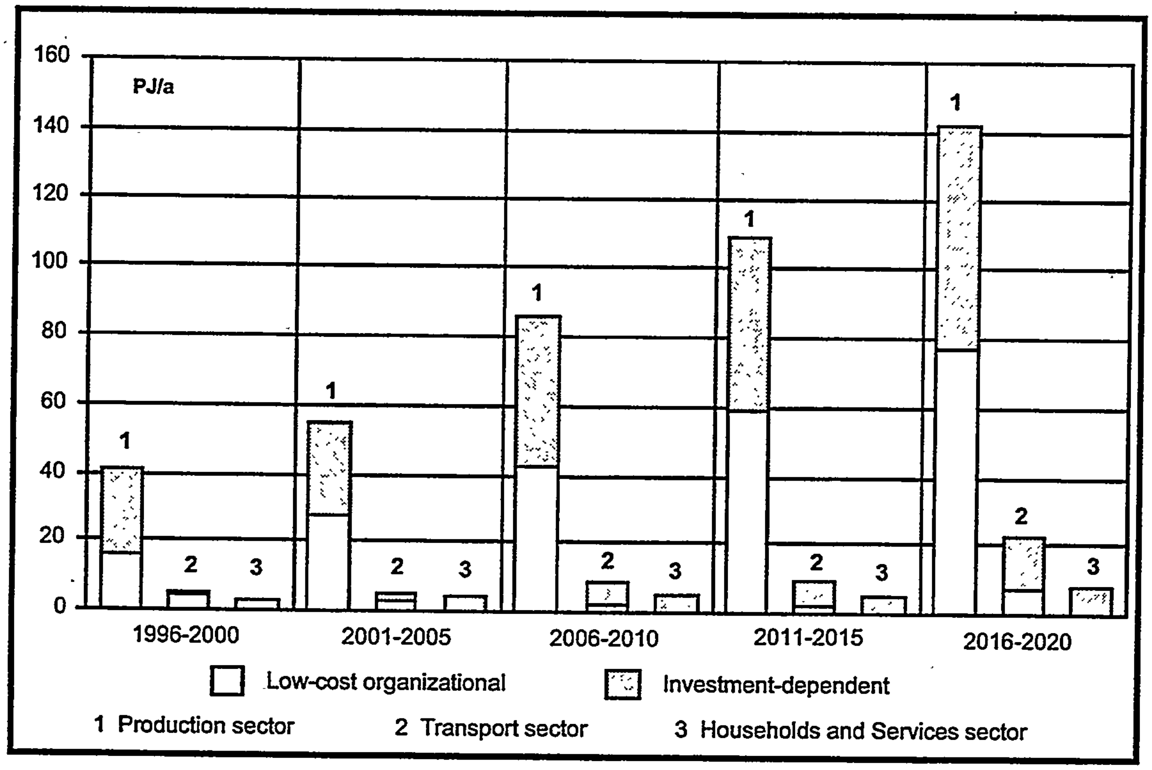

Fig. 4. Subdivision of the energy efficiency potential to "organizational" and "investment-dependent"

4. SOME REGULATORY ASPECTS OF ENERGY EFFICIENCY POLICY

The viability of the energy efficiency scenario, its energy demand prospects and energy efficiency potential depends on a number of regulatory aspects, three of which are considered to be especially important for Bulgaria:

- **Energy Efficiency Law** providing for establishment of conditions for unified energy efficiency policy in both energy production and consumption. The law, presented to the Parliament, covers: functions of the state energy authority; procedures for development of state standards; licensing of physical and legal persons for development of energy efficiency projects and energy consulting; requirements to, and procedure for energy efficiency review of new development projects and energy efficiency analysis of consumers with annual demand over certain level; creation and management of "Energy Efficiency Fund" for financial support of energy efficiency increase activities; administrative and legal procedures in case of non-conformation with legal requirements.

- **Integrated Resource Planning** (IRP) assuming coupled energy demand and supply analysis for energy service cost minimization. Our study analyses all stages for IRP implementation. A first priority task is inclusion of IRP into the general Energy Law currently being developed; the Law should require: the state energy authority and energy supply companies to hold the responsibility for IRP implementation in the field of energy development; a least-cost planning procedure, coupling the energy demand and energy supply alternatives for Bulgaria; an analysis of prices and tariffs according to long-term marginal cost provided by least-cost development plan; provisions for development of demonstration areas of DSM policy, DSM technologies and DSM investments; provisions for development of DSM programs based on successful DSM demonstration and consecutive analysis.
- **Motivation of energy supply companies** to increase energy efficiency. The National Electrical Company and district heating companies are novice in energy efficiency measures in both professional and managerial aspects. Moreover, such measures are in conflict with the current approach to economic indicators and procedures for prices and tariffs development. Motivation of the companies for DSM implementation in Bulgaria is a field which needs special investigations and regulation in the following directions: allow companies to reach profitability high enough (appr. 2.5 % higher than in conventional energy supply technologies) when investing into DSM measures (this approach is recommended mostly for investments in hardware projects); compensate the non-investment expenses for DSM measures (labor, materials, etc.) within the same year when they made such expenses by providing appropriate tariffs; transform the motivation of energy supply company employees from sales volumes to volumes of energy service and energy efficiency practice.

CONCLUSION

The study presents for the first time an integrated analysis of the long-term macroeconomic and sectoral alternatives, technological options for energy efficiency increase and GHG mitigation, final energy demand prospects and both market and DSM energy efficiency potential in Production, Transport and Households and Services sectors of Bulgaria.

Within the Bulgarian Country Study, the presented results have served as a basis for the final integration stage "Assessment of the Mitigation Policy and Measures in the Energy System of Bulgaria". The results have also been used for the formulation and implementation of the Bulgarian national policy for fulfillment of Bulgarian obligations as a member of UN Convention on the Climate Change. The study can also serve as landmark for elaboration of DSM programs and integrated resource planning of the national energy development.

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ASSESSMENT OF THE MITIGATION OPTIONS IN THE ENERGY SYSTEM IN BULGARIA [1]

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Bulgaria signed the Framework Convention on Climate Change at the UNCEP in Rio in June 1992. The parliament ratified the Convention in March 1995. In compliance with the commitments arising under the Convention, Bulgaria elaborates climate change polity. The underlying principles in this policy are Bulgaria to joint the international efforts towards solving climate change problems to the extent that is adequate to both the possibilities of national economy and the options to attract foreign investments. All policies and measures implemented should be as cost-effective as possible.

The Bulgarian GHG emission profile reveals the energy sector as the most significant emission source and also as an area where the great potential for GHG emissions reduction exists. This potential could be achieved in many cases by relatively low cost or even no-cost options. Mitigation analysis incorporates options in energy demand and energy supply within the period 1992-2020.

Methods

Mitigation options in energy supply were selected by using experts estimates of the potential of fossil fuel substitution and new energy technology implementation considering the existing structure of energy system and projects for mid-term and long term development. To project the electric system long-term development and to explore potential of different options in this system ELECTRIC module of ENPEP model was used (Simeonova, 1996). This is an optimisation program that allows to meet the electricity demand at minimum cost. Integration of mitigation options on energy demand and energy supply level and elaboration of different mitigation scenarios was accomplished by implementing ENPEP model. ENPEP uses non-linear equilibrium approach to determine the energy demand and supply balance considering at full scale the market processes. In the case of Bulgaria mitigation study at this stage ENPEP appears to be the most appropriate tool to simulate the performance of the entire energy system and to evaluate technical and economic effect of different mitigation options. Basically two modules of ENPEP were used - BALANCE - to calculate the energy flows and energy cost from primary fuel exploration and fuel import to the energy end-use, and IMPACT - to calculate GHG emissions.

The generic characteristic of base-line and mitigation scenarios in the energy supply could be summarised as follows:

- *Base-line* scenario - no major changes of existing fuel consumption pattern and moderate technology improvement is assumed.
- *Energy efficiency* scenario - significant change in the energy demand pattern is expected, including natural gas supply to the households and renewable energy driven not only by new technology development but also by active energy price

[1] The paper presents results from the Bulgaria Country Study to Address Climate Change (Christov, 1996) financed by the U.S. DOE, in the frame of U.S. Country Study Program, contract DE-FC02-93PO10099

policy. In the energy supply it is as... d drastic change of energy balance structure with increased shares of fuels with low-carbon and no-carbon content and accelerated penetration of new environmental friendly energy technologies.

Energy Demand Forecast

The dynamics of the final energy demand by sector, including production, transport and households and services, and by fuel and energy for both base-line and energy efficiency scenarios are presented in Tzvetanov (1996).

Energy Supply Alternatives

Energy supply was the key focus in mitigation analysis because it accounts for 59 % of the country's CO_2 emissions in 1990. Variety of GHG mitigation options in energy supply that are planned, implemented or under implementation now were studied.

Technology Upgrading in the Existing Thermal Power Plants (TPPs) and Options for New TPPs

The study of the technology upgrading of existing TPPs and choice of technology options for new TPP is the first priority in the GHG mitigation of energy supply, because the majority of the existing TPPs are almost at the end of their life-time. Now it is of great importance to take decisions about the energy sector short and mid-term development that will allow not only to meet the energy demand at minimum cost, but to minimise the impact to the environment, including reduction of GHG emissions.

Upgrading and Modernisation of Co-generation Plants and Switching from Thermal Plants to Co-generation Plants

Opportunities to upgrade and extend existing co-generation plants and heating plants with combined gas-turbine and steam-turbine modules are identified. This technology has some advantages already proven.

The study has proven the feasibility of construction of modern and efficient combined cycle co-generation modules with total capacity of 550-600 MW and total electricity output 3000-3500 million kWh over the next 10 years. In the energy supply this is the mitigation option with substantial potential that could be achieved in the very near term.

Nuclear Energy

Bulgaria has more than 20 years of experience in nuclear energy production in the nuclear power plant (NPP) „Kozloduy". Further nuclear energy development is related to the improvement of the nuclear safety of the future operation and the necessity, feasibility and expediency for the construction of new NPP „Belene" which construction was frozen some 6 years ago by Governmental decision. Technical and economic indices for a new NPP at the Belene plant site are analysed.

Hydro Energy

The feasibility studies indicate options for construction of 156 new HPPs with total capacity of 2800 MW, as well as about 800 micro-HPPs with an average capacity of less than 2000 kW each. This report explores four river valleys defined to have top priority in construction of HPPs with good technical and economic characteristics

Micro-HPPs in Bulgaria - potential and construction program

According to the proven technical potential data for 779 power plants are systematised, with capacity of 30-2000 kW each, total capacity of 237 MW and 921 million kWh electricity generation. This number includes 730 micro-HPPs to be constructed with total capacity of 210 MW and production of 795 million kWh electricity. The remaining plants are already existing.

Options to Reduce Transmission and Distribution Losses and Auxiliaries
Implementation of measures to reduce electricity losses and auxiliaries could result in electricity savings in compared to the base-line as follows:

- in year 2000 - by 1.0%;
- in year 2005 - by 2.5%;
- in year 2010 - by 4.5%;
- in year 2020 - by 6.0%.

The reported data for 1992 indicate total heat transmission losses of 15.5%, including 10.9% radiation losses, 4.1% leakage and 0.5% auxiliary losses. Recent studies have proven the annual heat transmission losses to be unduly high. Thus, their reduction should be priority in the rehabilitation addressing heat transmission networks. It is proposed the losses to be reduced to the level of 10-12%.

The most important parameter of above mentioned mitigation measures from investment view point are given in Table 1 (Christov, 1996).

Table 1. CO_2 reduction potential in the year of complete implementation of measures and investment cost per ton CO_2 emission reduction

Measure	Annual potential 10^6 t CO_2	Investment		Life cycle years
		Total 10^6\$US	\$US/t CO_2 per life cycle	
Reduction of electrical losses	3.2	91	1.9	15
Reduction of thermal losses	1.0	50	2.55	20
Upgrading of heat production plants	3.1	246	4.0	20
Micro-hydro potential	1.1	275	5.0	50
Hydro power projects	4.3	1 335	6.2	50
Belene NPP	9	1 300	8.5	30
TPP rehabilitation	1.3	585	28.0	15

Macroeconomic and Energy Scenarios to Mitigate GHG Emissions
The focus is on CO_2 reduction, although analysed options will reduce other energy related GHG emissions as well.

Two basic scenarios are elaborated for mitigation analysis - *baseline and mitigation* - that are consistent with corresponding scenarios of macroeconomy and energy demand. Scenarios incorporate different options to mitigate greenhouse gas emissions in energy demand and in energy supply, already discussed above. The baseline scenario and mitigation scenarios are constructed especially for this study in the way that allows to identify and compare potential effects of policies and measures with special attention to the energy efficiency issues and options to substitute fossil fuel-based energy by low-carbon or no-carbon energy. The baseline scenario is rather *likely-to-be* future scenario which means that it incorporates all policies and measures adopted before 1993. Comparison to the base-line scenario is important to identify what will be the future trends in energy demand and GHG emissions depending on the implementation of climate change policy in Bulgaria.

A set of other scenarios is also elaborated that serves to outline the potential and economic feasibility of different options for GHG mitigation. The combination of macro-economic development options with the energy demand and energy supply level and the brief description of scenarios is given below:

Base-line scenario includes base-line scenario for macro-economical development, base-line scenarios for technological evolution and energy demand as well as base-line scenario for energy supply. In the base-line scenario for energy supply it is assumed that the energy sector development will continue following existing pattern characterised by prevailing share of fossil fuels, moderate penetration of new energy technologies and increasing of efficiency.

Nuclear scenario is variation of the base-line scenario but with increased share of nuclear energy in energy supply.

Hydro energy scenario is also variation of the base-line scenario but the potential of increased share of hydro energy in energy supply.

Upgrading of co-generation plants and district heating boilers by natural gas combined cycle scenario is variation of the base line but it focuses on the potential of increased share of electricity and heat energy from natural gas combined cycle co-generation plants, which would increase the share of natural gas in the structure of primary energy carriers.

Natural gas combined cycle for electricity generation scenario represents variation of the base line scenario that explores the potential of new natural gas combined cycle power plants to be put in operation and thus to increase the share of natural gas in the primary energy demand.

Renewable energy scenario is variation of the base line scenario that deals with the potential to increase the share of renewable energy sources - solar, wind and biomass, for electricity and heat generation.

Losses reduction scenario is variation of the base line scenario that explores the options to reduce losses in the electricity and heat networks aiming to reduce the consumption of primary energy.

Aggregated mitigation scenario for energy supply. This scenario combines the base-line scenario of macro-economic development and base-line scenario of technological improvement and energy demand together with scenario for energy supply development which balances all mitigation measures in energy supply that are already analysed in the previous scenarios. This scenario aims to outline maximal mitigation potential that can be achieved if options in the energy supply only are implemented.

Energy efficiency scenario This scenario combines energy efficiency scenario for macro-economic development and energy demand with base-line scenario for energy supply. It aims to outline the maximal potential for GHG mitigation that can be achieved if only options at macroeconomy and energy demand level are implemented, while keeping the existing energy consumption pattern in the supply side.

Mitigation scenario This scenario combines energy efficiency scenario for macro-economic development and energy demand with aggregated scenario for energy supply characterised with minimum GHG emissions. This scenario explores the total potential for GHG mitigation that could be achieved if the problems of GHG mitigation, energy efficiency, economic restructuring and technology renovation will be given high priority at all levels of economy and society.

Base line scenario characteristics

Electricity and heat generation sector is based mainly on coal, nuclear and hydro. The main plants on indigenous and imported coal, as well as part of the nuclear units in Bulgaria have more than 20 years lifetime. Therefore, problems of the units rehabilitation and units decommissioning are considered together with the new units commitment in the mitigation analysis of energy sector. Rehabilitation of some of coal-fired and nuclear power plants is with no-doubt a mitigation measure. It is considered, however in each scenario starting with base-line scenario because in near-time horizon it allows to meet the electricity demand at lower cost compared to the new plants.

In mid and long-term horizon the heat and electricity demand is to be met by the new energy generating plants. New unit commitment schedule by type of fuel combustion technology, unit number and capacity is computed by ELECTRIC optimisation model of ENPEP package that allows to minimise the costs of electricity supply.

Projections of emissions of CO_2 and other GHG consist of two elements - projections of energy related emissions and projection on industrial process emissions. Only results for CO_2 emissions are discussed in this paper, because it is the most important GHG and also because the approaches to other energy related GHG are similar.

Scenarios for GHG Mitigation by Options in Energy Supply

The mitigation measures in energy supply are studied mainly in the field of electricity and heat generation systems, because other energy transformation industries either have a very limited impact on the energy balance and GHG emissions, or their development depends on structure of electricity and heat supply sectors.

Development of nuclear energy is one of the most efficient options for GHG mitigation. A modified plan of energy system is designed to assess the impact of its expanded development. This scenario results in CO_2 emissions in 2020 that are 11.8% less compared to the base-line scenario.

Accelerated development of hydro energy as far as the GHG emissions are considered can be evaluated as one of the most clean modes for electricity generation. In order to assess the CO_2 reduction potential of accelerated development of hydro energy in Bulgaria by 2020 the new unit commitment schedule is modified and hydro units of total capacity of 878 MW are added to the base-line scenario. This option of energy system development results in CO_2 emissions that are 2.75% less in the year 2020.

Upgrading of co-generation plants and district heating boilers Based on feasibility study for upgrading of 10 heating plants and co-generation plans by natural-gas combined cycle, this scenario envisages commitment or replacements of units with total capacity of 1180 MW. The electricity production in co-generation plants increases by 5.61 billion kWh together with the total increase of efficiency of electricity and heat production sector. This scenario for energy system development leads to reduction of CO_2 emissions by 3.15% in 2020.

Natural gas combined cycle for electricity generation scenario envisages natural gas combined cycle units with total capacity of 1800 MW and the unit capacity of 450 MW to be built in 2012-2019 period. The electricity to be produced on combined cycle units from imported natural gas is about 12 TWh annually. In this scenario the CO_2 emission in 2020 will drop by 4.9% compared to the base-line scenario due to the increased share of natural gas and higher efficiency of combined cycle gas technology.

Increase of renewable energy sources in the energy balance. A study on the potential of the renewable sources in Bulgaria has shown that theoretically they can meet the overall energy demand. Practically available potential, however, is considerably smaller. Taking into account the technical and economic characteristics of renewable technologies at different stages of commercialisation for 2000-2020 period, it was assumed that the renewable sources are able to provide up to 7% of the total energy demand by the year 2020. The electricity production from solar and wind energy and biomass has been studied under the assumption of installed capacity of 840 MW and 3200 million kWh annual production by 2020. The heat generation by solar energy and biomass of about 17444 TJ annually is also considered. The renewable energy scenario results in drop of CO_2 emission in 2020 by 7.7%.

Reduction of losses and auxiliaries. Using available studies and expert estimates a schedule has been designed for electricity losses and auxiliaries reduction by 6% for the period after 2000, and for heat losses reduction by 4%. In this scenario the CO_2 emissions in 2020 will decrease by 3.7%.

Aggregated mitigation scenario for energy supply is aimed to find the proper mix of the above options to ensure maximal CO_2 reduction that could be achieved by options in supply. Thus, the aggregated mitigation scenario compared to the base-line is characterised by addition of: 1000 MW NPP, 450 MW natural gas fired TPPs, 1180 MW co-generation plants, 840 MW capacity on renewable energy and 690 MW power losses reduction. These measures are replacing coal fired TPPs with total capacity of 4800 MW envisaged in the base-line scenario. In addition, the peak load in this scenario is by 900 MW less due to the extensive use of renewable resources and increased capacity with higher availability during the peak load of the power system. The implementation of these measures in the energy supply will reduce the emission level by 23.7 Tg, i.e. 20% compared to the base-line scenario in 2020.

The comparison to the emissions in 1988, which is the reference year for Bulgaria in implementation of FCCC, shows that in 2000 the CO_2 emissions will be 71% lower than in 1988, in 2013 they will reach the level of the emissions in the reference year and at the end of the period they will be 1.15 times higher. Therefore, any mitigation measures relying only on the reconstruction of the energy production could bring substantial reduction of the CO_2 emissions, but will be insufficient for a long term stabilisation of the emission level.

Energy supply cost in aggregated scenario indicates substantial reduction by about 5% compared to the base-line scenario. The total investments are by 20% less than those in the base-line scenario because of the low investments in upgrading of co-generation plants and low level of additional investment in NPP Belene (1000 MW unit) where construction works of about 1 billion $ US were already performed in the period 1986-1990 after which the construction was frozen.

Energy efficiency scenario is characterised by lower energy demand compared to the base-line while energy supply is analysed having the same assumptions about the structure as the base-line. Lower level of demand results in lower level of new capacities to be build by the end of the study period the mitigation potential if measures are implemented only in energy demand amounts to 68% of the mitigation potential if measures are implemented only in energy supply, that corresponds to 16168 Gg CO_2 saved in energy efficiency scenario against 23658 Gg CO_2 saved in aggregated supply scenario. Comparison with the CO_2 emissions in base-year indicate that only measures in energy demand or in energy supply do not guarantee long term stabilisation of the CO_2 emission level.

Energy supply costs in this scenario is lower by 19% compared to the base-line scenario mainly due to lower energy demand. Correspondingly, the overall investment for this scenario are by 5% less than those in the base-line scenario without the cost for energy efficiency improvement to be taken into account.

Scenario for GHG mitigation in energy demand and supply Mix of mitigation measures in the energy demand and supply is implemented in mitigation scenario that consists of the following basic elements:

- energy demand according to the energy efficiency case;
- schedule of old units and rehabilitation retirement as in the base-line scenario;

- the new unit commitment plan takes into account the following new units and measures not incorporated in the base-line scenario:
  - ◊ upgrading of existing heating and co-generation plants with natural gas combined cycle units;
  - ◊ natural gas combined cycle units in electricity generation plants;
  - ◊ micro-HPPs;
  - ◊ increased utilisation of renewable energy;
  - ◊ reduction of electricity and heat losses by 4% for 2001-2020 period.

Lower level of demand in this scenario compared to the base-line results in lower level of new capacities to be build by about 2370 MW that are mainly in coal fired-plants. This lead to a vivid tendency of diminished consumption of indigenous and imported coal by 34% and 21% respectively compared to the base-line scenario. The comparison with the base-line scenario indicates the decreasing tendency and by the end of period the primary energy demand is 20.5% less.

The CO_2 emissions from fossil fuels combustion by year for the various scenarios in comparison to the base-line scenario are shown on Figure 1. The implementation of CO_2 mitigation measures both in the energy demand and energy supply will reduce the emission level by 34.3 Tg, i.e. 29.1% compared to the base-line scenario in 2020.

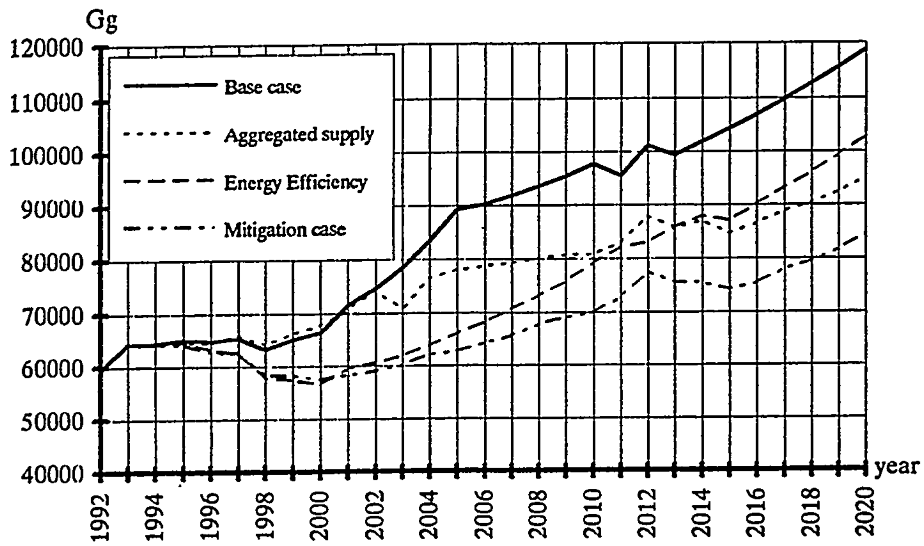

Figure 1. Projections of CO_2 emission from fossil fuel combustion

The entire energy system operation cost for each of the studied scenarios was calculated together with the CO_2 emissions year by year in order to perform thorough **financial assessment of mitigation scenarios in energy supply.** The following indicators are studied:

- average cost of 1 ton CO_2 emission reduction for the 2000-2020 period expressed in $US and calculated as ratio of total emission reduction for the period via the total change of production cost of energy supply due to the mitigation measures within the same time period;
- discounted (d=10%) at year 2000 costs of 1 ton CO_2 reduction for 2000-2020 period, calculated as ratio of total emission reduction for the period via the sum of discounted change of production cost of energy supply due to the mitigation measures within the same time period.

These results are given in Table 2. The measures are ranked by the discounted cost of emission reduction, is of significant importance, especially when comparing mitigation measures with different life cycle.

Table 2. Assessment of mitigation measures compared to the base scenario

Scenario	Reduction potential in 2020		Cost of emission reduction	
	Tg	%	Average $US/t CO_2	Discounted $US/t CO_2
Losses reduction	4.4	3.7	-38.2	-11.59
Upgrading	3.7	3.1	-15.41	-5.76
Hydro	3.2	2.7	-39.78	-5.58
Renewable energy	9.1	7.7	3.2	1.56
Nuclear	13.9	11.8	4.72	2.25
Combined cycle	5.8	4.9	11.36	2.58
Aggregated supply	23.7	20.0	-19.83	-4.91

Remark: The negative value indicates that the measure is cost efficient compared to the base line even without valuing CO_2 emissions reduction.

The aggregated supply scenario turns to be more efficient than the base scenario, but its implementation is hindered by financial and political obstacles.

Conclusions:

1. In reducing GHG emissions the mitigation measures in energy demand are more effective in near and mid-term horizon because of the national economy transition from energy intensive to energy efficiency pattern. In long-term horizon, the potential for structural changes and energy efficiency improvements is exhausted and the mitigation measures in energy supply turn to be more effective due to the optimised structure of energy supply and shift to low-carbon or no-carbon fuels.
2. The mitigation measures addressing just one of the sectors, i.e. either energy supply, or energy demand, are not sufficient the emission stabilisation to be achieved. A proper mix of measures in both sectors are needed to gain significant emission reduction.
3. GHG emissions mitigation measures requires substantial investments which are not available in Bulgaria. Therefore, only an intensive international co-operation could help to implement envisaged mitigation measures at full scale and will make the reported mitigation results really achievable.

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GHG Emission Mitigation Measures and Technologies in the Czech Republic

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Abstract

The paper presents a short overview of main results in two fields: projection of GHG emission from energy sector in the Czech Republic and assessment of technologies and options for GHG mitigation. The last part presents an overview of measures that were prepared for potential inclusion to the Czech Climate Change Action Plan.

1. Introduction

The US Country Studies Program provided an exceptional opportunity to assess future possible development in regard to GHG emission mitigation and measures to reverse its steady increase. Czech Country Study to Address Climate Change concentrated on projections till 2010 and initial assessment of mitigation technologies and measures [1]. It is being followed by project of preparation of Climate Change Action Plan under US Program "Support for National Action Plan" (SNAP) [2]. The presented contribution is a short overview of main results of both project in two fields:

- projection of GHG emission from energy sector
- assessment of technologies and options for GHG mitigation.

The last part of the paper presents an overview of measures that were prepared for potential inclusion to the Czech Climate Change Action Plan.

2. Projections of GHG emission from energy production and use

In the framework of the Country Study, we chose to use technologically-oriented models and established the following approach of CHG emission projections[1]:

- projections of macroeconomic development
- projections of energy demands
- modeling the coverage of the given demand and calculation of greenhouse gas emissions using technologically oriented models.

2. 1. Methods and input data

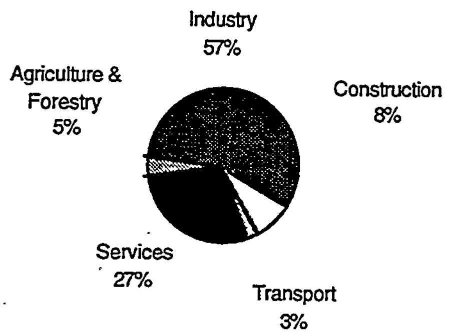
The periond 1990- 2010 was selected for study; the starting point coincide with reference year for FCCC and year 2010 it the farest point where any projection of a transitional economy may have some validity.

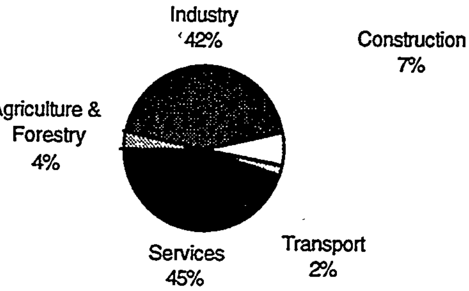
GDP growth: Dramatic changes in the economy over the past four years ruled out the use of standard macroeconomic models, which are usually based on time series and their smoothness. Therefore, macroeconomic projection was produced by means of a simple spreadsheet tool which helps experts to express their views on future development and ensures the internal consistency of the projection. According to [3], the projections of macroeconomic development carried out by several organizations vary in their growth rates from zero to seven percent, which means that there is a wide range of future possibilities. The basic parameter of the scenarios - **GDP growth - can thus be established *a priori* (by expert opinion) within a certain range.** The predicted changes in GDP structure are based on the assumption that by the year 2005, the GDP structure of the Czech Republic (CR) will be similar to that of western

[1] It is necessary to keep in mind the advantages and limitations of the chosen approach: the "one-way" approach of inferring from the total GDP assures the internal consistency of the results, but the absence of feedback - that is, the reaction of the national economy to energy prices that are too high (or too low) - may lead to unrealistic results.

countries [4] (see Fig.1). Two macroeconomic **scenarios**[2] were developed: **high (4.7%) and medium (3.2%) annual growth.** The higher rate was found more appropriate later (ex post confirmation in 1996) and also for simplicity only results concerning this development will be presented.

Fig.1: Structure of GDP in 1990 and assumed structure in 2010





Energy Sector Modeling: We have chosen to process the energy sector data using three independent models in parallel: LEAP, EFOM+MAED, and Markal. Since the **Markal model best fulfilled the demands**[3] that the study made on technology-oriented models, only results of this model are presented here.

We have performed a base-line scenario and several scenarios concerned on specific mitigation technologies. The following assumptions of the base-line scenario, were done:

- The base-line scenario includes **emissions mitigation measures** of regional pollutants (SO_2, NO_x, CO, fly-ash) currently in use and coming to full power within the Czech energy sector. These norms require the treatment of exhaust gases, changes in fuel, and the reconstruction, and in some cases closing, of most main electric power plants, boiler plants, and district heating plants[4].
- The removal of energy price subsidies was also included in the base-line scenario. Subsidies for heat as well as cross-subsidies for electricity and gas will be gradually eliminated [2].
- A constant level of **energy intensity** in all categories of heat consumption except for consumption in new buildings is assumed[5]

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[2] Scenarios were developed as the unofficial opinion of experts from the Economic Institute of the Czech National Bank [4].

[3] Models EFOM and Markal were found almost equal in performance of optimization, but the later offers much better user interface for preparation of data and interpretation of results.

[4] In the case of the major producer (77%) of electricity, ÈEZ (the Czech Power Utility), the situation is fairly predictable; a schedule has been published for plant closings totaling about 2200 MW_{el} of installed capacity [5]. This capacity will be replaced by the Temelín nuclear power plant. This measure represents an yearly CO_2 emissions decrease estimated to about 15 Mt in 1999 (about 10% of emissions in 1990). Estimating the impact of the new laws on boiler plants and heating plants is more problematic, because the method of treatment of the individual sources depends primarily on large number of the plant owners. The estimate according to [1] - 13.3 Mt of CO_2 per year - partially takes into account the drop in demand, which stems mainly from decreased production in industry.

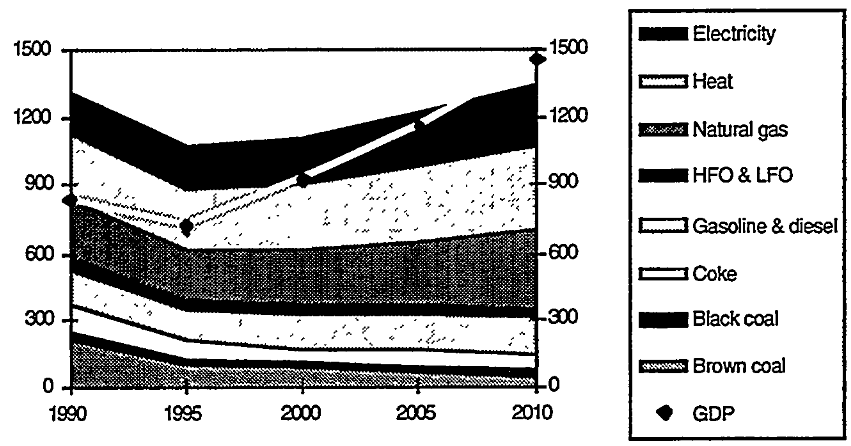
[5] An almost imperceptible increase (0.05%) is predicted in new residential buildings, as a result of the increased size of apartments (that is, energy intensity per m^2 remains constant). In the service industry, we expect a decrease due to improved insulation and higher energy prices than for households. The specific consumption of non-substitutable electricity - electricity for lighting and air-conditioning (in offices) - will grow as the number of electric demand devices in offices increases. The exception is lighting in households, where an increase in amenities is not expected, and current prices do not motivate energy conservation. Natural savings (i.e., those which are realized through the implementation of new technology designed for a purpose other than energy efficiency) in industry act to counter the increase in amenities, and the result is a more or less constant energy intensity for non-substitutable electricity.

- Other input factors in end-use consumption are the **efficiencies of demand devices**. We predict a constant level of efficiency among current demand devices as a conservative estimate. The efficiency of all new demand devices in both existing and new buildings can be expected to rise.

Modeling work on the MARKAL model for the Czech Republic started in 1994, when 1990 was set as the reference year and a test period composed of five time intervals each five years long, that is, the second period of the model, is 1995. Because energy sector in the CR undergone very significant changes during the years 1991-5, we revised (under framework of SNAP) [6] the database of the model in both the source section and the end-use section (demand for energy) on the basis of all available data. For 1995 we prepared a preliminary energy balance. Therefore, the changes primarily concern 1995, in which were included actual data, or results from the preliminary energy balance. Additional corrections were also made for the following period. These mainly concerned trends of intensity and control variables on the demand side of energy sector (for details see [2]).

2. 2. Results

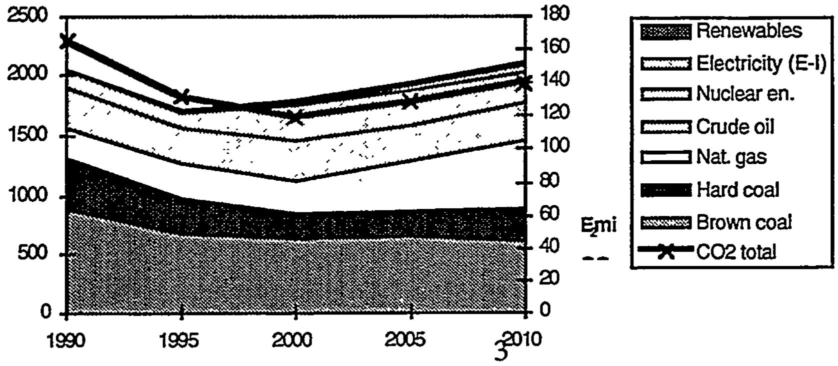
Fig. 2: GDP and energy end-use consumption according to Markal model, base-line scenario



The result of the optimization of fuel use (primarily for the production of heat) is their end-use consumption. In the Fig 2 the end-use consumption is shown together with corresponding GDP growth. The end-use consumption is expected to grow at an average rate of 1,5% per year since 1995. The graph shows also that as long as the economy develops according to the stated premises, end-use consumption grows 2-3% slower than the rate of GDP growth. In 2010 end-use consumption will reach 6% higher level then in 1990.

The development of primary energy sources (PES) consumption is similar to that of end-use consumption (see Fig.3): after a decrease in the years 1990-95, there is an expected **increase 1.7%/year** which is almost the same increase as we see in end--use consumption. The major change in the fuel structure (roughly the same for both scenarios) is the **replacement of coal with gas and nuclear energy**. The share of coal, which was 64% in 1990, drops to 58% in 1995 and to 41% by 2010. It is predicted that by the year 2010, gas will be the second-largest energy source (27%), even though its average price is expected to be 160 CZK/GJ (for households). In the same figure we can see „delayed increase" of CO_2 emissions caused mainly by improvements in energy sources (as a consequence of Clean Air Act).

Fig. 3: Primary energy consumed and total CO_2 emissions, base-line scenario Markal model, base-line scenario.



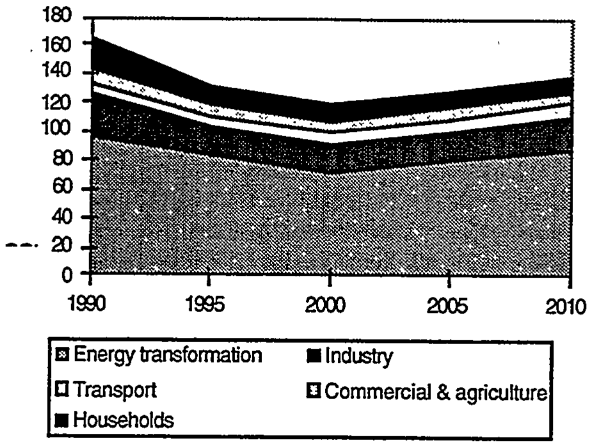


Fig. 4: Sources (by sector) of CO_2 emissions according to Markal model, base-line scenario.

The distribution[6] of CO_2 sources is gradually changing. (see Fig.4) The decrease and subsequent increase in emissions from transformation, as well as the changes in the household, service, and agricultural sectors, reflect the growing share of gas and the increasing consumption of electricity and centralized heat in end-use energy consumption.

The following conclusion were done on base of the presented results:

- The development of CO_2 emissions indicates a relatively **positive state of affairs**: as long as the economy develops according to the stated premises, **the Czech Republic will have no difficulty in fulfilling the FCCC obligation not to exceed 1990 emissions levels in the year 2000.**
- The decrease in emissions in 1990-2010 is a result of the drop in GDP during the years 1990-95, and of new laws regarding regional air pollution, and not of any specific policy on climate change.
- **CO_2 emissions may increase much more sharply** if the mentioned assumptions are not fulfilled. The main factors which could lead to the non-fulfillment of these assumptions are the following:
    - Pressure to ease the limits set on emissions of regional pollutants.
    - The enormous growth in electricity consumption, especially due to the effect of mass use of electricity for heating.
    - Resignation on energy price liberalization, which means the elimination of direct subsidies to district heating systems and of cross-subsidies for electricity and gas.
- Under the above-mentioned predictions, the difference in **the rate of GDP growth and of end-use consumption differs by 2-3%.** The growth in primary energy consumption is basically the same as that of end-use consumption. CO_2 emissions shows "a delayed growth" [7]and it cannot be assumed as a linear function of end-use or PES consumption.

3. Assessment of technologies and options for GHG mitigation

In the following paragraphs we would like to present two case studies:

- technologies for mitigation as technological solution mainly from energy conservation field and
- mitigation options as government policies or programs to reach lower CO_2 emissions.

3. 1. Assessment of technologies for GHG mitigation

The first assessment of economic potential of energy savings in all sectors using Markal model showed the amount of saved energy increasing with time. In 2010, a total of 7-8% of end-use consumption is saved in comparison to the base-line scenario. It is equivalent to mitigation potential about 9 Mt_{CO2}/year of technologies having cost of saved energy below the cost of

[6] The distribution in Fig. 4-11 does not correspond exactly to the distribution according to the IPCC - categories 1A1-6.

[7] A remarkable thing on Fig. 3 is that CO2 emission growth is „delayed" comparing to other quantities like GDP or final energy consumption.

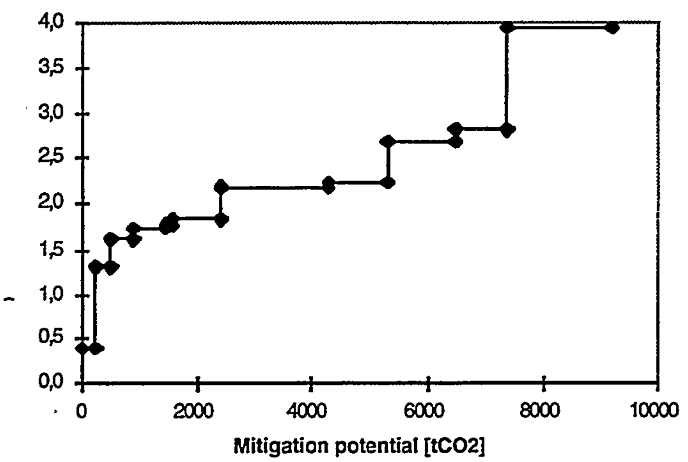
energy produced. The largest savings in the absolute scale were in the area of technological heat in industry (almost one third of the total savings). The relatively largest portion (relative to end-use consumption in the given category) of energy was saved in household lighting (47%) and hot water preparation (24%), and a smaller proportion of the savings came from the service sector. The levelized **cost per non-emitted ton of CO_2**, fluctuates within the range of one order of magnitude- from 15 to 150 USD/t_{CO2} [8]- but for **most of the technologies, it fluctuates between 40 and 55 USD/t_{CO2}**. It must be noted that the achieved potential is highly subjective because it depends on the "production" limit[9] of the technology, which is difficult to establish. These limits (as mitigation potential) and corresponding costs of saved energy is in Fig.5 (for more detailed description of technologies see [1].

In the framework of SNAP program two "conservation" problems were studied:

- continuation in subsidizing electricity in households
- energy conservation in heating of residential buildings.

3. 1. 1. Continuation in subsidizing electricity in households

Fig. 5: Saving potentials and costs of saved energy



One of the big dangers for a favorable development of CO_2 emission levels, is the significant increase in electricity consumption for heat and preparation of hot water for households. In order to estimate the consequences of this development we created two extreme scenarios, results of which are given in Fig.6. The base-line scenario includes the plan to eliminate cross subsidies for household electricity prices; an average annual growth of 8.3%[10] is expected during the period 1995-2010. A substantial increase will appear during the first five-year period. Up to the year 2000, it is expected that prices will reach the level of production costs for electricity; and in the year 2005, prices including expenses and profits of distribution and production companies.

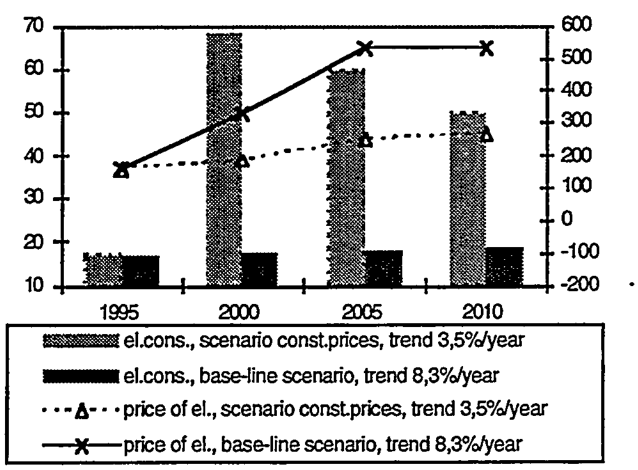


Fig. 6: Increase in demand for electricity for heating households corresponding to an average annual price increase of only about 3.5% ; the basic scenario projects an increase of over 8%.

The second extreme scenario is an average annual increase of 3.5% in real electricity prices for heating in households. From Fig.6 it is clear that if the price of electricity for heating rises in households up to the year 2000 only to 186 CZK/GJ (0.67 CZK/kWh) instead of the base/line projected level of 332 CZK/GJ (1.20 CZK/kWh), there could be an increase in

[8] Currency rate 27 CZK/USD is used in the study.

[9] This limit which is called rather production than penetration express realistic assessment of their deployment taking into account more technical than economic limits.

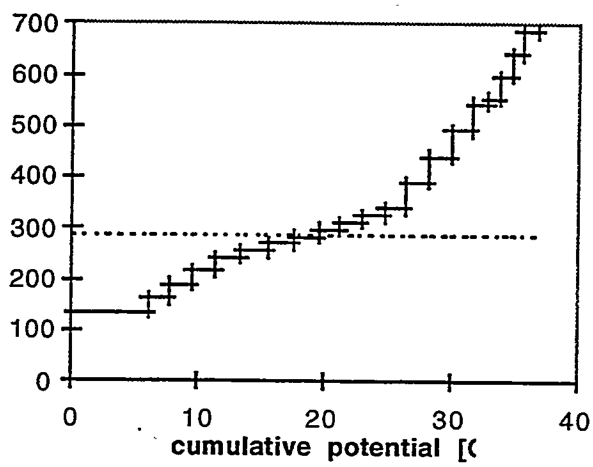
[10] The increase "above" the inflation.

demand in this category of more than four times[11] in comparison to 1995 levels (from 17 PJ to 68 PJ). On a country-wide level, this means an **increase of almost 30% in total electricity consumption** assuming that consumption in other categories will stay on the same level as that of 1995. This obviously has consequences for CO_2 emissions: electricity is the most carbon/intensive means of heating.

3. 1. 2. Energy conservation for heating residential buildings

The goal was to ascertain changes in energy consumption for the residential sector in implementing a group of technologies. A set of twenty technically similar groups concerning energy consumption in buildings differing in costs and potential[12] were included into Markal model.

Fig. 7: Potential and costs of groups of energy efficiency technologies for residential buildings

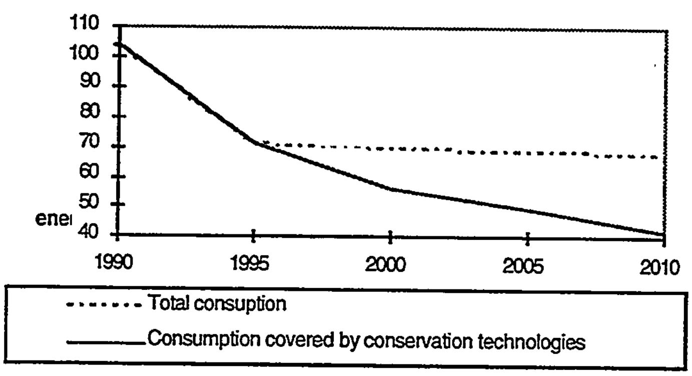


Each group (package) of technologies is corresponds to a group of residential buildings and contains the following technologies:

- comprehensive weatherization, including roofs, walls, windows, doors, and sealing;
- insulation of heat pipes;
- central regulation, and metering and regulation of the heating system; and
- energy management (monitoring and rationalizing consumption).

This group is characterized by total investment costs per saved unit of heat[13] and potential savings per year (see Fig.7). The total technical potential is 37 PJ/year, which is about 50% of the energy consumed in the subsector in question.

Fig. 8: Proportion of savings to cover demand for heat usable for residential buildings



"Offered" energy efficiency technologies replace actual heat sources in the model when their costs are lower than the price of the most expensive heat carrier used. The model accepted the first eight groups with costs less about 280 CZK/GJ (dashed line in Fig.8). Fig.8 shows clearly the **capacity of energy efficiency technologies** to cover demand for usable heat for the residential sector (the area between the full and dashed lines). Their amount

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[11] This increase is of course "a modeling effect" because a real maximum increase which could appear (counting number of households where such change is expectable in 5 year period) is approximately two times.

[12] Residential buildings were categorized according to insulation properties and the levels of possible savings into 20 separate groups, and to each of these was included a group of energy efficiency technologies with investment costs and corresponding energy savings.

[13] The basic figure on the investment demands of a group of technologies is the total investment costs (paid out over the lifetime of the project) resulting in saving 1 GJ/year [CZK/GJ/year]. These values for various energy efficiency technologies, also entered into the model as investment costs, cannot be compared, because the lifetime of the technologies is different. Investment costs [CZK/GJ] derived from multiplying by the annualizing coefficient (see Chapter 1) can also be compared with fuel prices. They are given in the Fig. The annualizing coefficient used assumes a lifetime of 25 years and a discount (interest) rate of 10%. In view of the fact that the model assumes economy without inflation and discount rate represents only capital price 10% is a relatively high rate. The table of investment costs is given in].

ranges between 11 and 20 PJ, or **17-30% in the medium-growth scenario**; and between 13 and 26 PJ, that is **20 - 40% in the high-growth scenario**. This share is thus the "economic potential" of given groups of technologies.

Changes in consumption are also interesting from the perspective of a change in the composition of energy carriers used. In comparison to the base-line scenario, the consumption of brown and black coal[14] stays effectively the same. Energy efficiency technologies replaces the most expensive end-use fuels like coke, electricity, gas, and district heating at rate starting from a level few percent to 20%[15]. The biggest changes are those with the last carrier (see the Fig. 9). Here, the model diverges (to a certain extent) from the reality that could be expected: modernization of the apartment stock is often linked with a conversion from heating with solid fuels to heating with gas.

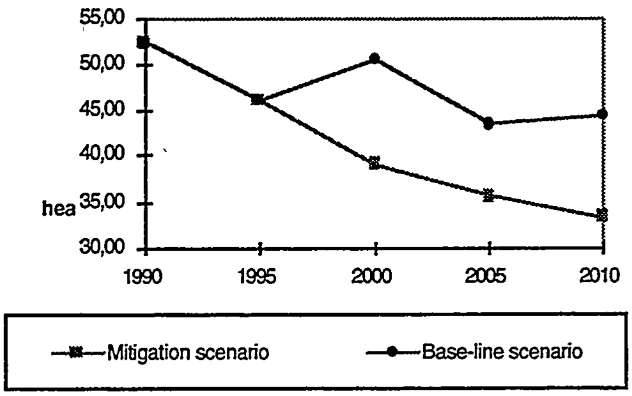

Fig. 9: Changes in the consumption of central heating in energy efficiency scenarios.

The **potential to mitigate emissions** corresponds to the energy-saving potential. This is significant in the first period (1995-2000), where it is possible to save about **1.3 Mt_{CO2}(/year), which represents about 0,7% of countrywide CO_2 emissions** during this period. The energy-saving technologies work further and in other period will bring additional (more expensive) savings, but to a lesser extent (2005: 0.6 Mt_{CO2} and 2010: 0.12 Mt_{CO2}).

However, **average investment costs** to reduce emissions are high **(1400-2300 CZK/t_{CO2})** and will rise over time, treir **incremental costs are negative**, that is, during the lifetime of the project there will be earnings from reduced fuel costs.

3. 2. Mitigation Options (measures) prepared for Climate Change Action Plan

This chapter contains a list of specific government policies proposed by SEVEn to interministerial committee for preparation 2nd National Communication to FCCC and for Climate Change Action Plan.

Methodologically they based on "Technology Assessment Report"**Error! Unknown switch argument.**] prepared in the framework of SNAP. In several cases, presented polices might apparently be contradictory but they represent a various response of the same problem. For example, heat subsidies could be eliminated or converted to subsidies for energy savings or energy tax burden can be enlarged by increase of VAT or introduction of carbon/energy tax.

Legislative and standardizing policies

Introducing a standard method for energy audits in buildings

Create a basic method for carrying out energy audits of residential buildings. The audit will evaluate the current state of the building, determine the annual energy consumption under normal operating conditions, and, on the basis of the audit, recommend appropriate energy-saving measures. In essence, it would be a kind of "building energy label," that will be used in the framework of additional measures if appropriate.

Mandatory energy audits for applicants for support for energy efficiency projects

The state can introduce mandatory energy audits for applicants for support for energy efficiency projects in order to obtain better information for a efficient allocation of state support. Such a measure would be a necessary condition for receiving state support. Decisions on support could

[14] After 1995, the consumption of liquid fuels is practically zero.

[15] Depending on fuel and period (2000-2010). This behavior is logical from economical point of view but it is unlikely in a real world. It is another "model effect".

thus be better qualified and at the same time increase knowledge and thereby the possibilities to make use of audits between potential implementers of energy efficiency measures.

Introducing energy labels

In accordance with a directive by the European Union, introduce labels with data on annual energy consumption (and, where appropriate, on energy payments) of selected widely used energy appliances, such as refrigerators, freezers, water heaters, etc. Make it possible for customers to select appliances that need less energy, and gradually improve the selection of available appliances in regard to lower consumption.

Introducing energy standards for appliances

Together with energy labels, the states of the EU are preparing to introduce energy standards. As a rule, these standards are formulated according to energy efficiency minimums that the product in the given category must attain. In the event that the standard is not met, the product could be subject to a fine or be barred from the market. There is a proposal for a similar measure to protect the Czech market from outdated energy appliances with a disproportionately high consumption of energy.

<u>Tax policies</u>

Reducing the tax on profits from municipal bonds used to reduce CO_2 emissions

Make profits from municipal bonds exempt from income tax. In some countries, this policy is common for all forms of municipal bonds. In the Czech Republic, at least municipal bonds that finance measures that reduce emissions could be exempted. The envisaged use of financing will be given in the prospectus of the bond issuer. For this purpose, the prospectus will be supplemented by data according to which a tax exemption will be granted and according to which adherence to the investment plan will be verified.

Bonds are an appropriate source of financing for wide-ranging investments in reconstructing heating systems as well as in new, energy-efficient technologies. Municipal bonds are a relatively expensive source of financing. To make the net income from bonds attractive to investors, the issuer must set relatively high interest rates since the interest on bonds is at the present time subject to a 25% tax..

Reducing the write-off period for energy-saving equipment

The current tax laws consider several applications of energy and energy-saving technologies to the investments in construction with a write-off period of 45 years, which is far longer than the lifetime of most of these technologies. It is also too long in comparison to the payback period required by most investors. This time-span should be reduced, at least for investments that concern environmental protection, such as energy-saving technology.

Introducing a tax on hydrocarbon fuels and a tax on energy consumption

Introduce a tax on hydrocarbon fuels and a tax on energy consumption calibrated to EU levels. The tax on hydrocarbon fuels and energy could become part an entirely new economic trend in which the consumption of fossil fuels would be taxed instead of labor.

This concerns wide-ranging systemic changes throughout the entire economy that could not be carried out without prior in-depth analyses of how the economy would change. At the same time, it would be necessary to carefully assess how the envisaged motivational character of this tax would actually appear and, if necessary, to adjust the amount of the tax to the necessary level. Calculations of the future situation made beforehand on energy and econometric models are indispensable.

It would be necessary to gradually harmonize this tax with those of EU countries. The CR should test this possibility and get ready to carry it out in advance, especially if the proposed work gives evidence of additional benefits stemming from this change.

In regard to its effect on energy efficiency levels, this policy would be a very powerful tool. While analyses from several West European countries support the view that it would be possible to expect a strong effect on consumption after imposing a tax of $10/barrel on crude oil, this effect would come into play sooner under conditions in the CR because of a lower price level.

Adjustment of value added tax for energy sources

All energy sources should be subject to full value added tax (17%). Contemporary rate, 5% should only be allowed for energy from renewable sources meeting all environmental protection requirements. Increasing the VAT is a necessary condition for initiating full competition between energy-saving technologies and the supply of various forms of energy, especially in residential buildings.

The low tax rate originated because of a theory, that survives today, that the easy access to cheap raw materials and energy is a necessary condition for the successful development of a modern society. This concept has already been discredited. Over the long term, low end-use energy prices could cause significant damage to the environment, which future generations would have to bear. At the present time, the proposed change is primarily being hampered by social policy.

Subsidization policies

Complete elimination of energy-price subsidies

After changes in energy-price tariffs at the beginning of the 90s, the price structure stabilized in a situation where households have highly subsidized energy prices. Energy-price subsidies for the households are provided without regard to the income bracket of recipients. The source of subsidies for heating apartments is the state budget; other subsidies are essentially emergency subsidies within specific sectors. Over the next several years, it will become impossible to support households with emergency subsidies because of rises in gas prices and the cost of electricity production. The state budget is increasingly burdened with heat subsidies. Nevertheless, energy subsidies for households have become a political issue, since households with a lower per capita income would only be able to pay full energy prices with difficulty.

Energy subsidies could be eliminated altogether and support targeted on low-income groups could be introduced. This support could be gradually reduced in conjunction with rises in average wages in the Czech economy. In addition to the fact that part of the resources devoted to subsidies would be saved, this measure would also have a significant effect on the introduction of energy-saving technologies. Energy savings would bring more rapid payback on investments, since they would be computed according to actual prices. The current, deformed energy prices (reduced by subsidies) make energy efficiency projects less economically attractive.

Converting heat subsidies to energy-saving subsidies

Energy intensity could be reduced by systematically introducing energy-saving technologies. Existing heat-price subsidies act against the rational use of heat. It would be far more effective to use at least part of these resources to reduce the consumption of subsidized energy and thereby also indirectly the amount of subsidies from the state budget.

At the present time, the difference between the maximum price of heat from central heating (6.7 USD/GJ) and expenses that the producer can demonstrate are compensated by a subsidy amounting to 185 - 260 USD million from the state budget annually. On the average, this means 2.6-3.7 USD/GJ (1.525 million households, each with a total consumption of 65.6 PJ/year), or 170 USD/apartment. There is a potential for less expensive savings in apartments in concrete prefabricated residential buildings amounting about USD 740 per apartment i.e. total expenses of CZK 1.15 million. That correspond to savings of 22 million GJ. Heat subsidies used for partial financing of these investments would decrease payback period to 4-6 years, which is a shorter period than the lifetime of usable energy-saving technologies.

Tax breaks, or subsidies, for investments in renewable sources of energy

The spread of renewable sources of energy is not proceeding because of, among other reasons, conventional sources of energy, whose prices are distorted by various indirect - and in some cases even direct - subsidies. Compensating this market imbalance should be done by the state through appropriate supporting measures. Tax policy is one of the fields where there could be a partial rectification, for example, through income tax credits or depreciation rate reductions.

Supporting mortgages on energy-efficient buildings

Constructions meeting previously set criteria should be eligible for more state support for mortgage credit, or in the case of constructing a new apartment building it should be possible to have a higher level of state support for mortgage credit. Constructions should meet previously determined technical criteria whose fulfillment should be verified by an energy audit that would necessarily accompany the issuance of the construction permit.

In the event of the purchase of an unfinished or already-built apartment building, there should be state support for mortgage credit. The energy audit would be a necessary document accompanying the purchase contract. In the event that the previously determined technical criteria are met, the buyer should have the right to receive a certain level of state support.

State support for preparing energy efficiency projects financed with commercial sources

Overcoming barriers to financing energy efficiency projects with commercial sources by giving assistance in the preparation of feasibility studies and guarantees on the quality of preparation of the groundwork necessary for banks or private investors to make a decision.

This measure is linked to the "Revolving Fund" project. Experience gained, for example, by the Czech Energy Agency in evaluating projects for the fund could also be used later in helping to secure sources of financing. A common problem is the fact that, from the bank's perspective, the amount of investments is relatively small in comparison to the atypical construction of the project (the production of energy savings). A financial analysis of the project endorsed by a respected state institution would increase the credibility of the project in the eyes of financial institutions.

Negotiations with producers and buyers

Voluntary agreements between manufacturing groups

Voluntary agreements with producers as a step accompanying the goals proclaimed by the state represents a new, continuously developing form of cooperation. In the Czech Republic it is possible to gradually adopt these experiences and initiate similar activities. The proposal is oriented towards institutional support and concrete possibilities to stimulate these voluntary agreements focused on increasing energy efficiency.

Voluntary agreements between state organs and associations of manufacturers have developed in several industrially developed countries, especially in the field of environmental conservation. They express a willingness on behalf of manufacturing groups to cooperate in energy-saving programs and programs to mitigate the negative effects on the environment, thereby rendering restrictive measures by state organs unnecessary.

Technology procurement

Technology procurement for energy-efficient technologies is a special kind of tender organized either to develop new or to spread existing modern technology emphasizing energy efficiency. In this way it is possible to achieve the rapid incorporation of technologies meeting qualitative and financial demands of users, including energy-saving measures. It generally concerns a large-scale order or an application that can be repeated many times. There is a proposal to implement this progressive method in the Czech Republic (for example, through the Czech Energy Agency).

An organization concerned with carrying out the "technology procurement" process will meet with producers and consumers (distributors or consumer organizations) to discuss the technical specifications and prices of high-efficiency products that the producers are capable of either manufacturing or developing. The result should be an agreement between the producer and consumer on the purchase of a certain quality of products at a previously set price, assuming that the producer succeeds in meeting the agreed-upon parameters.

Organizing competitions between manufacturers

Competitions between manufacturers for the best technological parameters or parameters meeting certain fixed requirements is a practice followed in many industrially developed countries. This method of increasing the efficiency of electric appliances could precede that application of standards (it would ensure that the producers would be prepared to meet standards) or to develop appliances with efficiency higher than standards. "Golden-carrot" competition was carried out in the USA, and because of its positive benefits in increasing the efficiency level of refrigerators it became a known standard around the world. The winner of the competition gets a certain bonus, thereby effectively reducing product development costs.

It is also possible to consider linking competition between producers to the introduction of labels. Voluntary standards, such as, for example, "environmental product" or "Czech made" should meet the following conditions:

- The producer pays for testing the efficiency of the product and, where appropriate, the development of the testing method, but should not pay for using the rating label (and especially not for production surcharges).

- The criteria for giving assessments (meeting standards) should be known beforehand, and assessments should only be made on the basis of whether the conditions are met. (Linking assessments to the decision of a bureau or a government official is not appropriate for such a competition. It gives unnecessary incentive for corruption.)

Facilitating the leasing of energy efficiency technologies

Support the creation of new leasing products, such as, for example, operating leasing. Stimulate the development of leasing in this field.

An example of these products can be the utilization of non-traditional financing with variable repayment based on obtained energy savings, which would help optimize the cash flow of the leaseholder. Another possibility is expanding the operating lease of high-efficiency motors in a wide capacity range, which would make it possible for leaseholders to react flexibly to changes in the extent of business activity.

An operating lease makes it possible to exchange leased equipment in the framework of a single contract. It is very advantageous for leasing high-efficiency motors. With the expectation of future expansion, excessively large electric motors are often purchased; and they therefore operate outside of the optimal routine. If the operator has the possibility to exchange the electric motor at any time, the operating lease contributes to energy efficiency and thus to the optimal distribution of financing.

4. Conclusions

Under framework of Country Studies Program a set of three technological models were prepared and tested for GHG emission projection. Projections of energy demand and related emissions for period 1990-2010 were calculated using the best suited model Markal. This model was calibrated to data of 1995 year in the framework of SNAP Program.

The projections shown a relatively positive state of affairs, that the Czech Republic will comply with FCCC requirement on stabilization of GHG emissions. The main drivers included in the base-line scenario which ensures the above goal are: decrease of overall production, increase of nuclear energy use and Clear Air Act coming into full force in 1999.

On the other side, several dangers to the presented development were accessed. Enormous increase of use of electricity for household heating was of special interest. Using the Markal model a possible increase of electricity consumption of tens of percent was demonstrated if the trend of favorable household tariffs will continue.

The second case study has shown economic potential of 17 to 40% of energy use in households. This correspond to 0.7% of the national GHG emissions inventory.

A set of government policies and measures was developed for preparation of the Climate Change Action Plan and the 2nd National Communication. These options will be considered by interministerial committee to develop consensus.

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Energy-Saving Options for the Mitigation of Greenhouse Gas Emissions from the Mongolian Energy Sector

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ABSTRACT

The Energy sector is the largest contributor to GHG emission in Mongolia. The Energy sector emits 54 percent of CO2 and 4 percent of methane. All emissions of other greenhouse gases are accounted from energy related activities. The activities in this sector include coal production , fuel combustion, and biomass combustion at the thermal power stations and in private houses (stoves) for heating purposes.
This paper presents some important Demand-side options considered for mitigation of CO2 emissions from energy sector such as Energy Conservation in Industrial Sector and in Buildings.
Changes in energy policies and programmes in the Mongolian situation that promote more efficient and sustainable practices are presented in the paper. These energy saving measures will not only help reduce greenhouse gas emissions, but will also promote economic development and alleviate other environmental problems.

Energy Saving Options for Mitigation of Greenhouse Gas Emissions from Mongolian Energy Sector

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Introduction

The energy sector of Mongolia is the largest contributor of Greenhouse Gas emissions. The cold continental climate (average winter temperature is 25 degree C below zero) and the reliance on the low energy content of Mongolian coal contribute to a high rate of carbon dioxide CO_2) release when measured on per-capita bases. Estimated national CO_2 emission for 1990 was 26 million tons or roughly 10,4 tons per-capita. This estimate is greater than per-capita rates for developing countries and exceeds the world average. Earlier studies (1,2) examined the Base Case and Mitigation Scenarios and a range of mitigation options were considered for the Energy sector on the mitigation scenario (2).

This paper presents Demand-side options considered for mitigation of CO2 emissions from energy sector such as Energy Conservation in Industrial Sector and in Buildings.
Changes in energy policies and programmes in the Mongolian situation that promote more efficient and sustainable practices are also presented in the paper. These energy saving measures will not only help reduce greenhouse gas emissions, but will also promote economic development and alleviate other environmental problems.

Energy consumption

A brief review of the the energy consumption in Mongolia is given below in order to find priorities and criteria to be applied in selection of Demand-side options for mitigation of Greenhouse Gas Emissions from Mongolian energy sector.

A major part of the primary fuel consumption (75%) is used for generation of electricity and heat in the power plants in Mongolia (Table 1) (3). The present consumption of primary fuels in Mongolia is illustrated in Figure 1.

Table 1. Conversion of fuels in Mongolia in 1993

Energy conservation	Coal (Mtoe)	Electricity (Mtoe)	Heat (Mtoe)	Diesel oil (Mtoe)	Fuel oil (Mtoe)	Others (Mtoe)	Total (Mtoe)
Primary Energy available	1,778.8	15.4		165.2	69.0	188.1	2,216.4
Thermal power Conversion losses	-1,312.8	721.3 -469.9	696.8 -112.2	-53.0	-52.3		0 -582.1
Station use Transmission losses		-71.0 -24.9	-169.1				-71 -194
Final consumption (by consumers)	465.9	170.9	415.5	112.2	16.7	188.1	1,369.3

The total final energy consumption in Mongolia (1993) is 1,370 Mtoe (1 Mtoe equals 41.86 TJ). Primary fuels amount to 2,216 Mtoe, and the total of coals and fuels consumed directly by end-users is 798 Mtoe. The thermal power sector consumes 1,418 Mtoe, and with total losses being 847 Mtoe, the electricity and heat consumed by end-users is 571 Mtoe. Approximately 160 Mtoe is electricity and 410 Mtoe is steam and district heating.

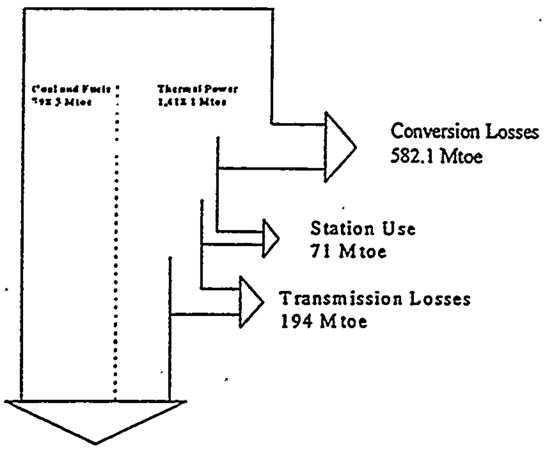

Figure 1 Energy conversion and final consumption in Mongolia. (1993).

The total end-use energy consumption is 1,369.3 Mtoe, distributed on fuels/energy forms as shown in figure 2 below .

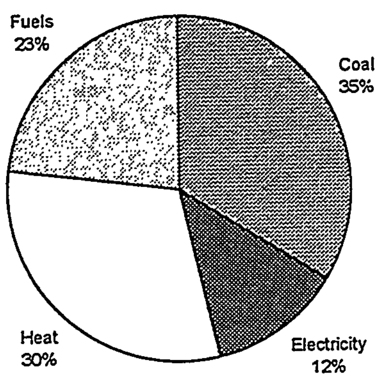

Figure 2 End-use energy consumption by fuels (1,369.3 Mtoe in 1993).

Approximately 50% of the consumption of "fuels" is gasoline products for transportation (cars, busses etc.). The majority of the 35% coal indicated as end-use consumption is consumed by industries. Figure 3 shows the end-use energy consumption distributed on consumer sectors .

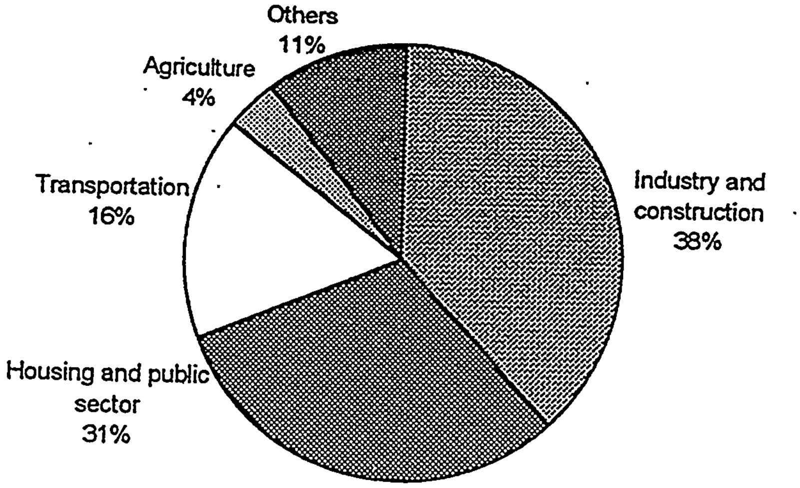

Figure 3 Energy consumption by sectors in Mongolia (1993).

Industry and construction are the most energy intensive sector with a consumption of 38% (approx. 520 Mtoe) of the total. Next to this sector is the housing and public buildings sector, representing a consumption of 31% (approx. 425 Mtoe) of the total energy consumption in Mongolia.

Energy saving options in industry and public buildings

Energy saving potential

During the last 2 years detailed energy audits were carried out in the several industries and public buildings. Energy audits in the Brewery and Textile mill in Ulaanbaatar carried out by the Swedish company AF-Energykonsult. These two surveys suggested possible energy savings of about 20% in the brewery and 10 15% in the textile mill based on housekeeping and low cost measures (5). AF-ENERGYKONSULT of Sweden also examined building standards and conducted energy audits of modern dwellings in Ulaanbaatar. Compared to buildings in Sweden, energy intensities for domestic heat and hot water were found to be very high. The study estimates that heat demand in existing buildings could be reduced by up to 60% using such measures as installation of thermostatic valves, and balancing, installation of weather strips in windows and doors, improved attic insulation, facade renewal, conversion of heating from one-pipe to two-pipe systems. In 1996 detailed energy audits were carried out in two food factories, one tannery and in a kindergarten and a hotel in Darkhan city by the Danish COWI company together with Mongolian ENERGY CONSERVATION company. In addition four short audits were conducted , one in the food industry, and three dealt with building and construction materials. Comparison of the specific energy consumption with figures for similar European industries shows up to 3-4 times higher consumption in Darkhan, indicating a large potential for savings (4).

The energy saving potential in industries can be divided into "easy" (no- and low-cost) savings, medium-cost savings and long-term possibilities.

The total saving potential in industries is in the range of no less than 50-60% of the present consumption, comprising:

1. a 15-25% saving potential by "easy" savings with a payback-period of less than 1 year.
2. a 15-25% saving potential by medium-cost actions with a payback-period of less than 3 years.
3. a 20-30% saving potential by long-term possibilities with a payback-period of 5-10 years.

Energy saving measures in industry

Important technical areas for energy saving measures relevant for most industries Mongolia include the following:

- *Rehabilitation of Steam Systems:* Many steam systems are badly operated and maintained. The losses in the steam sub-stations and piping systems audited are estimated to be as high as 20% of the heat consumption (or even more) due to steam traps out of operation, lack of insulation of piping and valves, leakages in valves and fittings, loss of condensate Rehabilitation of the steam systems inside the industries, e.g. return of condensate, insulation, repair of steam traps, installation of meters etc. should be carried out and combined with installation of new industrial boilers where relevant.

- *Industrial Boilers:* Most industries in main cities are supplied with steam from the power plants. A few industries have own coal-fired boilers or are supplied with steam from other factories nearby. For coal-fired boilers the energy audits have shown efficiencies as low as 40%, and major problems with maintenance of the boilers occur due to the low quality of coal (resulting in low availability of the boilers and hereby severe problems for the production). Installation of oil-fired steam boilers in industries could solve many of these problems and give significant fuel savings. The actual price of oil compared to the price of steam from the power plants is, however, an obstacle to such solutions. But this may change with introduction of new more cost-based tariffs. Based on experience of developed countries, implementation of such industrial boiler-installations should be initiated, if economic possibilities can be developed.

- *Plate Heat Exchangers (condensate cooling):* Only few heat exchangers for waste heat recovery are today used in industry, and all of them are based on older types (drum heat exchangers), which are inefficient (mixed flow heat exchangers) and difficult to maintain. There is a large saving potential by waste heat recovery in the major sectors of food industry, tanneries and textile companies, for example by utilization of condensate cooling, recovery of heat from cleaning or process water etc., or for process heating, production of cleaning water, building heating etc. For such installations, modern type plate heat exchangers are very well suited, providing simple installations, high efficiency with equipment that is easy to maintain and repair. These heat exchangers can further be used for heating of technical water by district heating, a solution that is highly recommended as an alternative to the present use of steam for low-temperature heating purposes.

- *Motors and Drives:* Electric motors and drives are generally oversized and badly maintained with a significant decrease of the efficiency for these installations. Especially in milling factories and tanneries/textile factories, a very high number of electric motors are installed. The load of such machinery has in the audits been measured to be as low as 20-30%, typically resulting in efficiencies in the range of 50-60%. This should be compared to an efficiency of more than 80% for properly designed and maintained motor-installations.

- *Process Technology:* Most process technology in the Mongolian industry is of Russian or Eastern European origin, having a low efficiency in terms of energy usage and capacity (product-rate related to size and cost of equipment) compared to Western European technology. An example of such process technology is the drying process in tanneries (and in textile companies), where skins (clothing etc) are dried in cabins with very limited control of the air flows, a complete lack of heat recovery, and long drying time due to inadequate fresh air intake. Modern type drying cabins of Italian or German fabricate are completely different designed, which means: a 40-50 % energy saving, improved products, increased capacity.

Energy saving measures in public buildings

The electricity consumption has in recent years been reduced, as many technical installations have been shut down in order to reduce energy costs. Furthermore, the general level of "energy service" is low compared to Western European standard. However, electricity savings are still possible in some areas such as kitchen equipment where large potential savings are apparent, both with respect to how the equipment is operated and with respect to the efficiency (capacity and flexibility of operation versus energy consumption).

As regards heating systems in the public sector, the buildings in Darkhan have a relatively low room temperature with only limited possibilities for saving energy. But the refurbishment programme developed in the District Heating component of the present TACIS (6) project involves renewal of building installations so as to adjust room temperatures in accordance with the need for heating, which in principle will provide the possibility for energy savings. However, after implementation increased heating comfort will most likely mean higher energy consumption.

Possible energy savings by increasing building insulation would be relatively expensive to implement, and the payback-period would be very high. Therefore, it will in the short term not be profitable to initiate insulation projects in existing buildings but rather focus on standards for new buildings.

The saving potential by such "easy" savings similar to the industries should be in the magnitude of 20% of the present consumption, while medium-cost and long-term actions will have a lower saving potential than found possible in the industry.

Barriers to energy efficiency
For implementation energy saving options must be determine most important barriers to energy efficiency. A number of barriers to energy efficiency have been identified, such as:

- Lack of general *awareness of energy efficiency*
- Lack of awareness of profit optimisation
- The general industrial crisis
- Lack of institutions and strategies for energy efficiency
- Lack of energy consultants and energy audit know-how
- Lack of suppliers and manufacturers of equipment
- Lack of targetted information material
- Lack of capital for energy saving investments
- Lack of metering of consumption.

Organization national activity for Energy Efficiency

The national activities are important for nation wide information and promotion activities and for the regulative, economic and informative means (Figure 4). These activities will be necessary to initiate on the medium and long term for implementing the full saving potential, both regarding no and low cost measures and investment projects. Especially the regulative and economic means will provide a substantially strengthening of the regional, more soft, informative means.

Elements of Energy Saving Activities

Regulative	Economic	Informative
• Compulsory energy audits schemes • Building standards for new constructions • Standards for energy efficient equipment • Obligation to use specific types of energy e.g. district heating or natural gas • Obligations for energy utilities	• Energy and environmental taxes • Tariff structure reflecting the real costs of production, transmission and distribution of energy • Economic investment subsidy • Attractive loan with low interest rate • Economic operational subsidy for energy producing plants such as cogeneration supplying electricity to the grid	• Campaigns • Demonstration and pilot projects • Technical brochures and books • Personal visits at the major consumers • Telephone counselling • Informative meetings • Seminars • Courses

Figure 4. Elements of Energy Saving Activities

The regulative and economic means will, however, require more analyses of the specific design and consequences and a political debite before they will be implemented. These main groups are:

- *Increasing the use of energy audit and energy management through a scheme*: Execution of energy audits and establishment of energy management routines at the energy consumers are important actions for reducing the energy consumption. By the audits, the consumers will have a detailed knowledge on the energy consumption and the saving possibilities and by the energy management the consumers will have a continuous control of the energy consumption.
- *Achieving cost based energy prices through energy tariffs and taxes scheme:* The energy prices for the consumers are still not reflecting neither the world market prices nor the actual production costs. The energy prices over a period of years will be cost real i.e. reflecting the costs of production and delivery for each consumer group. The next step is to include in prices or through an energy tax a price element reflecting the social costs of the energy production and consumption, especially concerning the environmental impact. The energy tax revenue can be used partly or fully for energy efficiency subsidies, as presented in next section.
- *Promoting energy efficiency projects through economic subsidies*: A grant subsidy scheme for promoting energy efficiency measures necessary implement during a period of years. The scheme could subsidise either through investment support or loans with reduced interest rate: execution of energy audits; clearly defined energy efficiency standard measures and more comprehensive energy efficiency projcts. The funds for the subsidies could origin from the energy tax scheme. In this way, neither the government budgets nor the consumers as a whole will be influenced economically. Only consumers which are not implementing energy efficiency measures will pay to consumers carrying out measures.
- *Reduce the energy consumption for new equipment and buildings through standards for energy efficiency*: In the longer term, energy efficiency standards will be implemented which mainly will apply for standard components as electric motors, compressors, blowers etc. or buildings as a whole. The standards will only regard new constructions or new spare parts.

Conclusion

Estimated national CO_2 is greater than per-capita rates for developing countries. A range of mitigation of Greenhouse Gas emissions shows that demand-side options are most important for reduction of energy consumption which means reduced coal consumption at the energy producing coal fired plants. Energy saving potential in Mongolian industries estimated no less than 40-60 % of the present consumption comprising a 15-25 % saving potential by easy savings, a 15-25 % saving potential by medium-cost actions and a 20-30 % saving potential by long tern possibilities. Main technical areas for energy savings in industries are rehabilitation of steam systems; installation of oil-fired industrial boilers, provided economic feasible tariff conditions and fuel prices; installation of plate heat exchangers for condensate cooling; improved motors and drives and improved process technology. Heat demand in existing buildings could be reduced by up to 60% using such measures as installation of thermostatic valves, and balancing, installation of weather strips in windows and doors, improved attic insulation, facade renewal, conversion of heating from one pipe to two-pipe systems.

A realisation of the complete energy saving potential in the long term require national means and incentives. For these national activities following main groups have been considered as important to assess in more details: Increasing the use of energy audit and energy management through a scheme; Achieving cost based energy prices through energy tariffs and taxes scheme; Promoting energy efficiency projects through economic subsidies; Reduce the energy consumption for new equipment and buildings through standards for energy efficiency; Increasing the promotion and information on energy efficiency through establishment of an Energy Information Centre.

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Mitigation Technologies and Measures in Energy Sector of Kazakstan

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ABSTRACT/ An important commitment in the UN Framework Convention on Climate Change is to conduct mitigation analysis and to communicate climate change measures and polices. In major part reducing CO_2 as well as the other greenhouse gas emissions in Kazakstan, can be a side - product of measures addressed to increasing energy efficiency. Since such measures are very important for the national economy, mitigation strategies in the energy sector of Kazakstan are directly connected with the general national strategy of the energy sector development. This paper outlines the main measures and technologies in energy sector of Kazakstan which can lead to GHG emissions reduction and presents the results of current mitigation assessment.

The mitigation analysis is addressed to energy production sector. A baseline and six mitigation scenarios were developed to evaluate the most attractive mitigation options, focusing on specific technologies which have been already included in sustainable energy programs. According to the baseline projection, Kazakstan's CO_2 emissions will not exceed their 1990 level until 2005. The potential for CO_2 emission reduction is estimated to be about 11 % of the base line emission level by the end of considered period (in 2020). The main mitigation options in the energy production sector in terms of mitigation potential and technical and economical feasibility include rehabilitation of thermal power plants aimed to increasing efficiency, use of nuclear energy and further expansion in the use of hydro energy based on small hydroelectric power plants.

INTRODUCTION

Kazakstan has used the opportunity to participate in the US Country Studies Program in order to enhance its ability to address climate change issues. Fulfilling its commitments on US Framework Convention on Climate Change, Kazakstan has developed its National Greenhouse Gases (GHG) Inventory for 1990 and has been conducting vulnerability and adaptation assessment as well as an assessment of the priority mitigation options for the period through the year 2020, and has started activity on developing National Climate Change Action Plan.

The Government of Kazakstan has expressed its concern about climate change, but its current policies will continue to focus primarily on solving the severe economic problems. At the same time there are a number of programs on energy, agricultural and environmental policy, forestry, which include measures that have GHG mitigation effect.

Kazakstan is the largest emitter of GHG in Central Asia. An inventory of Kazakstan GHG emissions and sinks indicated that the country emitted the equivalent of about 65 Million Metric Tones of Carbon Equivalent (MMTCE) during 1990 (*Monocrovich et. al.*, 1996). Of this amount, the energy sector contributed about 58 MMTCE, or almost 90 percent of the total. Thus, a main effort to reduce future emissions of GHGs from Kazakstan will have to focus on reductions from the energy sector. In major part reducing GHG emissions in Kazakstan, as in the most developing and transition countries, can be a side-product of measures addressed to increasing energy efficiency. Since such measures are very important for the national economy, mitigation strategies in the energy sector of Kazakstan are directly connected with the general national strategy of the energy sector development.

This paper is to outline the main measures and technologies in energy sector of Kazakstan which can lead to GHG emissions reduction and included in energy development programs, as well as to present some possible GHG abatement scenarios evaluating several mitigation options in energy production which has been already included in sustainable energy programs.

BACKGROUND

Kazakstan, like all the other Republics of the former Soviet Union, has been undergoing a drastic reorganization of its economy. The gross domestic product of the country declined by almost 60 percent between 1990 and 1994. During the same period, energy use declined by only about 15 percent resulting in a doubling of the energy intensity (*Bazarbaev*, 1996). This intensity is 2-4 times more than that of the advanced industrial countries.

The energy sector in Kazakstan is characterized by the number of fundamental problems including low energy prices, weak institutional structure and legislative framework, inefficient practices and old equipment. Energy savings program, which would address to those problems, is long over due. It is also very important for the national economy because it can generate many benefits, including energy and capital saving, improved environmental conditions, increased technology transfers, greater foreign exchange earnings or savings, lower production costs and higher profits for large energy consuming enterprises, enhanced capability for enterprises to withstand future energy cost increases, etc. Recognizing this, the Government of Kazakstan has prepared a comprehensive National Program for Energy Saving developed a list of priority measures of implementation. It is generally known that measures to reduce GHG emissions from the energy sector can be grouped as follows:

- Improving the efficiency of energy use, so that the same output can be achieved while using less energy; and
- Fuel switching to energy sources with low carbon or not carbon content, such as water, wind, solar and nuclear energy.

Components from both of these groups are included in the main energy programs, reflecting priorities and strategies in energy development adopted by the Government of Kazakstan as follows:

1. National Program on Energy Saving in Republic of Kazakstan (1995)
2. On Measures Regarding Implementation of Energy Saving (1996).
3. Program on Urgent Measures on Energy Development (1996).
4. Program on Involving Renewable Sources of Energy in Energy Saving in Republic of Kazakstan until 2020 (1995).

ENERGY SAVING MEASURES

The potential for energy savings is very high in Kazakstan. Based on research (*Schipper L., S. Meyers* 1992; *Bazarbaev*,1996); and on the assumption that the energy systems in Kazakstan can be characterized as similar to the energy systems of the former USSR, manufacturing fuel intensity can be reduced by 25 percent and manufacturing electricity intensity by 10 percent over the short to medium term and 40 percent and 20 percent, respectively, over the longer term. Based on the energy audits obtained on selected industrial plants in Kazakstan the short- to medium term measures can result in energy savings between 15 to 25 percent of the energy consumed in Kazakstan in 1994.

In developing its National Program for Energy Savings, the Government of Kazakstan initially placed a high priority on the recommendations listed below.

1. Increase end-user energy prices (according to principles, listed further below);
2. Focus initially on energy savings in the industrial sector, and those energy savings investments whose costs are recoverable in less than one year once the investments are operational.
3. Installing of equipment that measures energy consumption,
4. Establish the Energy Conservation Department within the Ministry of Economy as the coordinator of the Government's energy savings policies and establish an independent energy Conservation Agency to implement the programs associated with these policies;
5. Assess various financing options, focusing in the short term on demonstration zones, energy savings fund, and multilateral bank funded projects.
6. Focus initially on policies and programs achievable in a timely and effective manner during the next three years as the country progresses to a market-based economy, and then consider policies and programs that will yield energy savings in the longer term.

Energy Pricing Principles

In Kazakstan energy prices used to be low and subsidized, that caused weak energy conservation "ethic," due to low prices and historical perception of energy as a free good. Evidence in the OECD countries suggest that rising real energy prices generally result in energy savings: Between 1992 and 1994, many of Kazakstan's nominal energy prices increased by a factor of ten or more. Despite these substantial energy price increases, many domestic energy prices remain at only a fraction of world equivalent levels and severe sectoral disproportion continue to exist.

The Government of Kazakhstan places a high priority on the adoption of the following energy pricing principles:

- Price levels must be set "X percent" higher than cost; with "X" representing the necessary return on investment needed to meet projected demands. Retail price levels also must be set "X percent" higher than costs and set to achieve government/society's goals, including contributing needed to finance energy-sector related goals and stimulating conservation measures.

- Energy prices should be set according to the marginal cost principles.
- When traded in world markets, energy prices should reflect full border equivalent prices available in export markets, fully accounting for transportation costs and quality differentials, appropriately measures.
- Regional energy prices should reflect different transportation costs and regional supply-demand pressures within Kazakhstan. Proper weight should be given to energy policy objectives when considering tax policies.

As a general rule, energy prices should be increased to reflect real economic costs of supply, or when traded in world markets, the export value. With sustained increased to world equivalent levels, most energy price subsidies will be eliminated resulting in energy savings.

Energy Saving in Industrial Sector

Industry is the largest energy consuming sector, accounting for 45 percent and 38 percent of end-use consumption in 1990 and 1994, respectively *(Energy Saving Program,* 1996). Evidence in the OECD countries suggests that the largest and quickest reduction in energy intensity can be achieved in the industrial sector. The electric power, district heating, nonferrous metals are the largest energy consumers, have viable future and important to the term economic development of Kazakhstan, and have potential for exports and the energy saving program focuses initially on these sectors. According to information and data compiled by the Ministry of Economy, Ministry of Energy and Coal, Ministry of Industry and Trade the potential for energy savings in these industries over the longer term is immense. Approximately 30-40 percent of the total electric energy could be saved if a comprehensive energy savings program in energy production and consumption is implemented. Several main tasks for each industry are presented in the Energy Saving Program. These recommendations were categorized in terms of short, medium, and long term energy savings measures.

Short-Term Measures include no-cost or low-cost improvement in plant operation with minimum equipment modifications. It is expected that most of these measures will take a maximum of 2.5 years to complete the project preparation will have an average of about 0.5 years.

Medium-Term Measures will require investments up to several million dollars for equipment or plant modifications and probably the use of outside engineering/contractor services. It is expected that most of these measures will take a maximum of 5 years to complete project preparation and have an average payout of about 3 years.

Long-Term Measures include major investments in new or revamped facilities to improve and increase the plant utilization. These type of investments would require justification based on significant potential for sale increases through market analysis and a comprehensive economic analysis for each measure suggested for implementation. It is expected that most of these measures will take a maximum of 9 years to complete project preparation and procurement and have an average payout of about 6 years.

RENEWABLE ENERGY

Considerable renewable energy resources exist in Kazakstan, particularly in the southern part of the country. Excellent, but not fully utilized hydro resources and considerable potential wind resources exist. There are a number of sites that are considered as prime locations for the development of renewable energy projects, especially for wind and small hydro (for example, the Dzhungar Pass, near the border with China, where an excellent wind corridor exists).

Hydro power resources are of great importance. Hydro potential of rivers is roughly estimated to be 30 bill. kilowatt hours of electricity per year, of which at present a little more than 20 % is used. During past years several ecological disasters have created an interest in renewable energy sources (RES), such as wind power turbines, photovoltaic power plants and geothermal sources, into the energy balance is the pressing problem. Nowadays, the fraction of RES in the overall electric power output is 0.3 %, of which 80 % is provided by small hydro power plants, and the fraction of solar, wind and thermal water power amounts to less than 0.06 %. According to our previous mitigation option screening analysis (*Monocrovich, et.al.*,1996) developing renewable energy has a sufficient mitigation potential in Kazakstan. A Word Bank Mission (*Word Bank*, 1996) identified wind power and small hydro as amongst the promising sources of renewable energy for the country.

MITIGATION ANALYSIS

As mentioned, electric and heat sectors are among the most important sectors from the point of view of energy consumption. The current Kazakstan electric power deficit is estimated to about 15%. As Kazakstan economy evolves based on market principles, the energy demand will grow faster and lack of available energy will possibly become a limiting factor in the economic development of the country. In addition, as the Inventory of GHG emissions indicated energy production sector contributed about amount to 25.5 MMTCE or more than 40% of the total . Energy production is the largest source of CO_2 emissions, which contribute more than 50% of total CO_2 emissions. Taking this into account, our current mitigation analysis initially was to analyze technologies that give low CO_2 emissions in energy production sector.

Most power and thermal plants in Kazakstan are over 20 years old and are operating with obsolete equipment or with components requiring considerable renovation. Increasing the efficiency of existing plants, extending their life and implementing Demand Side Management programs are the most cost-effective approaches for improving the power industry situation. Estimates indicates that approximately energy saving potential in energy production amounts to about 20% of total electric energy. Additionally, a significant potential exists for the introduction of renewable energy technologies, small hydro plants, wind power systems, solar electric sites and developing nuclear energy use.

In the mitigation analysis some energy-generating technologies were evaluated using the ENPEP model (*Hamilton* et. al., 1994) with regard to their possible contribution to the reduction of CO_2 emissions and costs of emission abatement. Among these options are extended and rehabilitation of use of cogeneration with conventional technologies and with fuel cells, fuel switch from coal to natural gas and nuclear energy, the number of renewable options, such as wind energy, solar (photovoltaic) energy and extended use of hydro-energy, based on small hydro plants. Almost all of considered technologies (except nuclear energy) have been included either in the Energy Saving Program mentioned above or in Programs on urgent energy development measures and involving renewable sources. These programs have been proposed by Kazakstan's power agencies, including Ministry of Energy and Coal, for planned addition and retirement of electric capacity to the Kazakstan power industry.

All technologies were evaluated against the baseline scenario. The final energy demand projection as component of baseline scenario, which directly defines GHG emissions projection, was projected based on GDP growth rate, import-export balance and population growths until the year 2020. The macroeconomic and sociodemographic scenarios were based on methodology designed at the Kazak Institute of Market Relations. For baseline scenario we used one of the most "optimistic" scenarios of economy development to estimate "the worst" case of CO_2 emissions development.

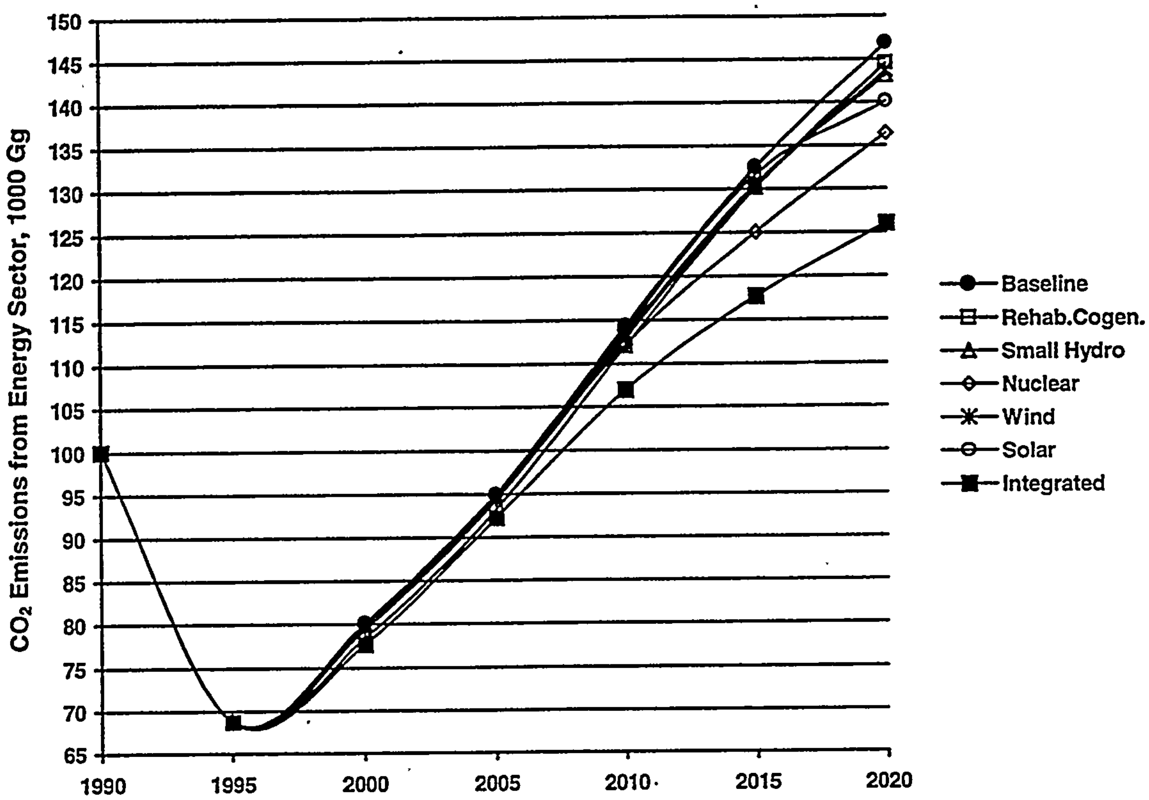
To develop mitigation scenarios, at first all possible GHG mitigation options in the energy production sector in 1996-2020 were considered. Based on screening mitigation options by the number of major criteria, only five of them have been chosen for further analysis. They are: the rehabilitation of cogeneration and thermal power plants (TPP) aimed to increasing efficiency; further expansion in the use of hydro power energy and the use of wind, solar and nuclear energy. Table 1 presents the estimated additional electricity generation by new, more efficient TPPs and possible produced electricity at the expense of installation of renewable and nuclear power plants according to the data of the Ministry of Energy and Coal Industry of Kazakstan (*Program for Urgent Measures on Energy Development,* 1996) .

Table 1. Electricity Generation for Different Mitigation Options, (TWh)

Mitigation option	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020
Modernization of TPPs:					
Cogeneration cycle	3.10	7.70	10.20	14.70	18.20
Combined-cycle	8.56	14.03	15.47	16.01	16.01
Hydro Power Plants	0.680	1.7	2.9	4.1	6.5
Solar Power Plants	0.125	0.250	0.250	0.500	0.500
Wind Power Plants	0.914	0.675	0.750	0.900	1.050
Nuclear Power Plant	-	-	-	2.00	5.00

As the result, in addition to the baseline scenario we developed the following six alternative scenarios: (1) **Rehabilitation of cogeneration** scenario, which includes the options on modernization of cogeneration and thermal power plants; (2) **Small Hydro** scenario, which includes hydroelectric power plants installation; (3) **Wind** scenario, which includes wind power plants installation; (4) **Nuclear** scenario, that include installation of a nuclear power plant; (5) **Solar** scenario, which includes installation of photovoltaic power plants and (6) **Integrated** scenario which includes all mentioned mitigation options. The projections of CO_2 emission according to the baseline and the mitigation scenarios are presented in Figure 1.

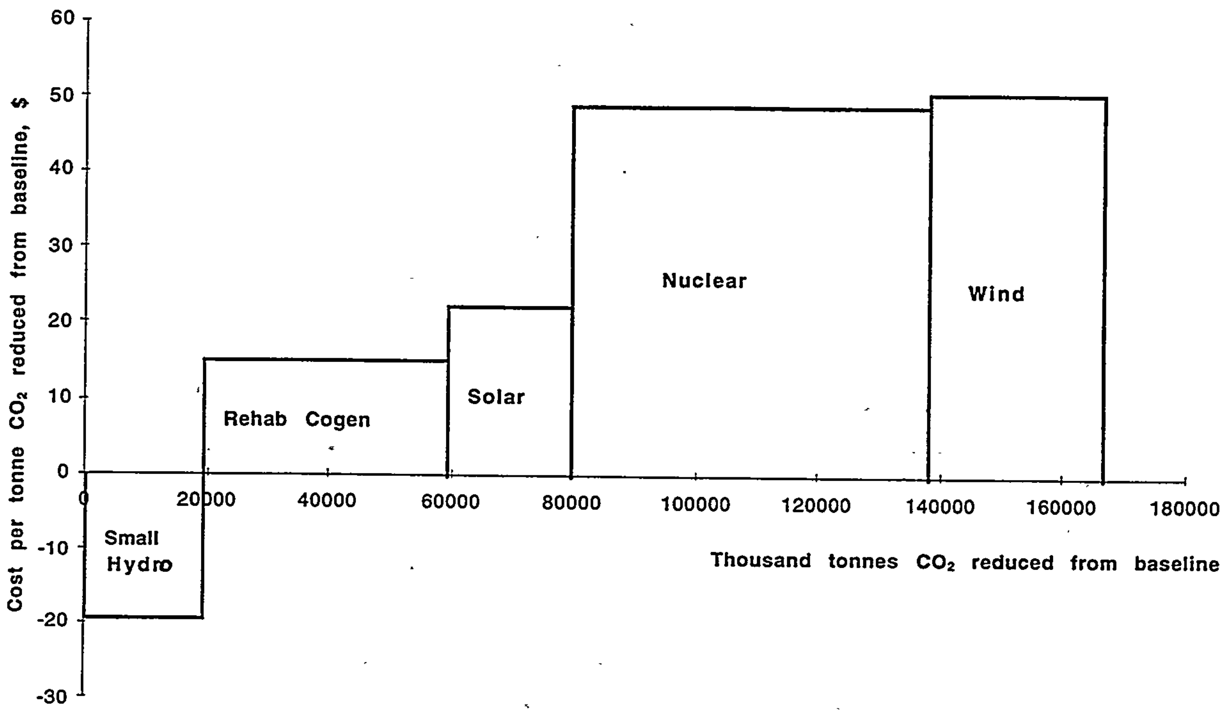
Figure 1. CO_2 Emissions for the Baseline and Mitigation Scenarios, 1000 Gg



As it can be seen from Figure 1, even in "the worst" case baseline CO_2 emissions will exceed the 1990 level after 2005, and Kazakstan will have no difficulties to meet its commitments of the UN FCCC. The total maximum potential for CO_2 emission reduction due to implementation of new technologies, renewable energy sources is about 21 % of the base year 1990 emission level by 2020. Potential of annual reduction in CO_2 emissions ranged from 3 % in 2000 to 11 % in 2020. Implementation of these measures would result in reduction of coal and oil utilization as well as reduction of import of electricity.

The costs of emission abatement for each mitigation scenario was based on discrete step CO_2 - reduction cost curve (see Figure 2).

Figure 2. CO_2 - Reduction Cost Curve



The blocks of such curves correspond to individual mitigation scenarioes with the widths representing the potential GHG reduction and the heights representing the cost per unit of GHG reduction. In current analysis we considered average costs which reflect the difference in total energy system costs, expressed in sum of difference of producer energy prices under mitigation and baseline scenario when a specific mitigation scenario is compared to baseline, divided by the difference in emissions between the two scenarioes. The cost curve in Figure 2 was developed for all considered time period and presents cumulative reduction over the time horizon studied.

In Table 2 the description of all considered mitigation options with respect to the cost of CO_2 emissions abatement and the other main criteria is presented. As one can see, the introduction of small hydro power plants is the most profitable option. It is the only option that leads to reducing the cost of electricity and therefore saves funds. Rehabilitation of power plants is one of the most cost effective measures. Nuclear energy development is the most expensive one, but it has high GHG emissions mitigation potential.

Cost analysis showed, that reducing 1 % of CO_2 emissions "costs" about half of percent of increasing price of electricity for Rehabilitation scenario, this value for Nuclear and Wind scenarioes amounted to about 2 %; for Solar scenarioes it is about 1.5 %.

Table 2. Summary of Mitigation Options

Criteria	Nuclear	Rehab. Cogen.	Wind	Small Hydro	Solar	Integrated
GHG reduction CO_2 (1000 tonnes): • Cumulative over the period • Annual average • Methane (net annual average change, tonnes)	58,288 10.40 104	40,083 2.33 20	28,622 3.14 31	19,421 3.74 37	18,022 6.74 52	157,851 20.82 206
Cost of emission abatement, $/tonne	49.05	15.26	50.33	-19.96	22.35	31.21
Reduced import (average annual value, USD)	Uncertain	Uncertain	64,606	68,793	24,088	145,522
National environmental impacts (net annual reduction, tonnes): • Sulfur oxides • Particulates	745 863	148 112	224 256	265 297	375 106	1466 1619
Potential impacts implementation policies	Low	High	Medium	High	Low	-
Sustainability of option	Medium	High	Medium	High	Low	-
Consistency with national development goals	High	High	Medium	High	Medium	-
Uncertainty of data : • Technology performance and costs • Costs of implementation programs	 Low Low	 Low Low	 High High	 Low Low	 High High	 - -

Taking into account the mitigation analysis as well as priority set in the energy development plans, we can identify the following priority of considered mitigation options:

1. Rehabilitation of cogeneration, which includes the options on modernization of Thermal Power Plants;
2. Small hydroelectric power plants installation;
3. Building a nuclear power plant;
4. Wind power plants installation;
5. Use of a solar energy.

As mentioned, the mitigation analysis was focused only on heat and electricity production sector. Energy end-use technologies were not considered. In addition, it should be noted, that the cost analysis has mostly qualitative nature because of high level of aggregation and high level of uncertainties of cost data. We do not present here the total impacts of foreign exchange, however it is obviously that implementation of considered mitigation measures in a transition country like Kazakstan would require foreign investments.

CONCLUSIONS

Mitigation strategy in the energy sector of Kazakstan is directly related to the national strategy of the energy sector development.

The most important policy measure include increasing energy prices. Within the industrial sector the energy development programs focuses on energy savings in electric power, district heating, nonferrous metals - specifically copper, and fertilizers. Approximately 30-40 percent of the total electric energy could be saved if a comprehensive energy savings program is implemented.

A significant potential for renewable energy has been proven, including small hydro plants, wind power systems, solar electric sites and cogeneration, as well as the potential for energy efficiency measures in the industrial, commercial, institutional and residential sectors.

The results of the Kazakstan mitigation assessment in energy sector include evaluation the most attractive mitigation options, focusing on specific technologies in energy production, which is the main source of GHG emissions in Kazakstan. GHG emissions will not exceed the 1990 level until 2005, and Kazakstan will have no difficulties in fulfilling the commitments of the UN FCCC.

The main mitigation options in the energy production sector in term of criteria of mitigation potential and feasibility, are as follows: rehabilitation of thermal power plants aimed to increasing efficiency; use of nuclear energy; further expansion in the use of hydro power energy on the basis of small hydro power plants introduction; use of wind and solar energy. All these measures have been included in sustainable national plans for energy development.

Preparation of implementation strategies is the most difficult problem in implementation of such programs, because of a lot of barriers. The most important of them are lack of funds, absence of proper control system, weak institutional structure and legislative framework. The energy development and energy saving programs focus initially on policies and programs achievable in a timely and effective manner during the next three years as the country progresses to a market-based economy, and then consider them in middle and long terms.

Next step on developing further mitigation analysis is in-depth evaluating all relevant energy saving measures and technologies, which have been included in the energy saving and the other energy development programs, from the point of view of their mitigation potential and cost effectiveness to include them into the National Action Plan.

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ESTIMATING ENERGY INTENSITY AND CO_2 EMISSION REDUCTION[¶] POTENTIALS IN THE MANUFACTURING SECTORS IN THAILAND

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ABSTRACT

The final energy consumption in Thailand increased at about ten percent annually within the last 10 years. To slow the energy demand growth rate while maintaining the country economic advance and environmental sustainability, the Energy Conservation Promotion Act (ECPA) was adopted in 1992. With this Act, a comprehensive Energy Conservation Program (ENCON) was initiated. ENCON commits the government to promoting energy conservation, to developing appropriate regulations, and to providing financial and organizational resources for program implementation. Due to this existing ENCON program, a great benefit is expected not only to reducing energy consumption, but also to decreasing GHGs emissions substantially.

This study is a part of the ENCON research program which was supported by the German Federal Government under the program called "Prompt-Start Measures to Implement the U.N. Framework Convention on Climate Change (FCCC). The basic activities carried out during the project included (1) An assessment of Thailand's total and specific energy consumption in the industrial sectors and commercial buildings; (2) Idenfification of existing and candidate technologies for GHG emission reduction and energy efficiency improvements in specific factories and commercial buildings; (3) Identification of individual factories and commercial buildings as candidates for detailed further study. Although the energy assessment had been carried out for the commercial buildings also, this paper will cover only the work on the manufacturing sector.

On the basis of these steps, 14 factories were visited by the project team and preliminary energy audits were performed. As a result, concrete measures and investments were proposed and classified into two groups according to their economic characteristics. Those investments with a payback time of less than four years were considered together in a Moderate scenario, and those with longer payback times in an Intensive scenario. The Moderate scenario results in energy input reductions of approximately 7 percent in the cases studied. CO_2 emissions are reduced by approximately the same fraction. The Intensive scenario identified an additional potential for energy savings of 3 percent and additional CO_2 reductions of 5 percent.

¶ Paper Presented at the International Workshop on Greenhouse Gas Mitigation Technologies and Measures, Beijing International Convention Center, Beijing, The People's Republic of China, Nov. 12-15, 1996.

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INTRODUCTION

The final energy consumption in Thailand increased at about ten percent annually within the last 10 years. To slow the energy demand growth rate while maintaining the country economic advance and environmental sustainability, the Thai government has passed the Energy Conservation Promotion Act (ECPA) in 1992. With this Act, a comprehensive Energy Conservation Program (ENCON) was initiated which aims to promoting energy conservation, to developing appropriate regulations, and to providing financial and organizational resources for program implementation to support the ECPA bill. The budget for the activities of the ENCON Fund (ECF) during the coming five years is approximately 20.4 billion Bahts. The Department of Energy Development and Promotion (DEDP) is responsible for the Compulsary Program of the ECF, which means that it organizes the support of energy conservation in Designated Facilities. These activities represent 70 percent of the five-year budget of more than DM 13.6 billion Bahts.

Due to the existing ENCON program, a great benefit is expected not only to reducing energy consumption, but also to decreasing GHGs emissions substantially. This ENCON program can be integrated into the country no regret policy to reduce the emissions of GHGs. Of 43.8 Mtoe, the final energy consumed in 1994, [1] approximately 13.9 Mtoe (31.0%) and 11.6 Mtoe (25.9%) went to the manufacturing sector and the commercial/Residential sector, respectively. It can be seen that the industrial and commercial/residential end users represent more than 50% of the country's final energy consumption. It thus shows high energy saving potentials in these two sectors. Implementation of the ENCON program, however, requires assessment of energy and technological application for different kind of manufacturing processes.

This study is a part of ENCON research program, which was supported by the German Federal Government under the program called "Prompt-Start Measures to Implement the U.N. Framework convention on Climate Change (FCCC)[2]. The work carried out by a joint study team between the DECON (Germany) and King's Mongkut Institute of Technology Thonburi (Thailand).

The project is focussing on selected manufacturing sectors for energy assessment, economical analysis, and quantified reduction of CO_2. The study included

1. Assessment of Thailand's total and specific energy consumptions in the manufacturing sectors;
2. On the basis of exiting auditing reports, candidate factories were chosen to represent in-field assessment of energy consumption;
3. Identification of existing and candidate technologies for GHG emission reduction and energy efficiency improvements in the factories belong to the target sectors;
4. Estimation of the total GHG reduction potential based on the results achieved for individual cases.

The results are discussed in the following sections.

Assessment of Thailand's Final Energy Consumption

This section presents an overview of the final energy consumption in Thailand's Manufacturing sector. To compile this summary was the first task of the identification of energy intensive industrial establishments. This overview leads the way to the formulation of concrete energy saving opportuniities and permits a first rough estimate of the enrgy saving potential in this sector. It also guided the analysis of existing reports of energy audits which were studies to identify concrete factories for which energy saving potentials were estimated.

Total energy consumption in Manufacturing Sector

Table 1 shows the total consumption in 1992 of the final energy forms solid, liquid, gases, electricity, and biomass for each Manufacturing subsector. The *Food and Beverage* sector consumed the highest quantity of energy with a total value of 159,700 TJ. *Non-Metallic products and Chemicals and Chemical Products* ranked second and third with total consumptions of 117,000 and 39,900 TJ, respectively. Looking at energy costs, we find that the *Non-Metallic Products* sector's spending on energy is at the highest (9.1 billion bahts) whereas energy costs in the *Food and Beverages* sector is lower, ie., 8.4 billion Bahts. This is the result of different patterns of energy use in these two sectors. The lower energy costs in the food sector is due to its higher use of the lower-cost biomass.

Energy Intensity (per Value-Added) of Manufacturing Sector

To compare energy consumption figures of different manufacturing processes, the energy consumption value is normalized in unit of MJ per Baht of value added. The values of energy intensity, (MJ/Baht) for the Manufacturing subsectors are shown in Table 2. *Non-Metallic Products, Basic Metal* and *Food* industries are the branches with the highest energy intensity.

The energy intensity for the Thai manufacturing compared with the USA[3] is shown in Table 3. the differences in energy intensity varied from some negative value up to 81%.

Comparison between Thai Manufacturing energy intensities with those observed in the US shows that the Thai Manufacturing sector seems rather inefficient in comparison, but there are two points that must be considered before drawing such a conclusion. One is the difference in structure between the Manufacturing sectors in the two countries. these differences can influence the calculation into either direction, and taking the result in which total intensities were used, they just might cancel out. The second factor, differences in price levels, introduces a systematic bias, however. This is a general problem in most international comparsions of energy intensity which therefore nowadays often include the concept of Purchasing Power Parity (PPP). Applying this concept to energy intensities, means calculating correction factors that reflect the difference between market exchange rates of currencies and the estimated ratio of purchasing power, usually relative to the US. dollar. For the Thai Baht, a recent estimate (UNDP, 1993) of the PPP with respect to the US dollar suggests a correction

Table 1: Ranking of Final Energy consumption by Manufacturing Sub-sector, 1992.

Sub-sector	Solid (TJ)	Liquid (TJ)	Gaseous (TJ)	Eelctricity (TJ)	Biomass (TJ)	Total Energy (TJ)	Energy Cost (10^6 Baht)
Food & Beverages	4,478	21,882	422	14,532	118,452	159,766	8,416
Non-Metallic Products	49,045	42,117	11,828	8,195	5,956	117,141	9,137
Chemical & chemical Products	5,660	10,012	6,379	12,377	5,534	39,962	5,360
Textile	1,732	21,291	-	16,517	-	39,540	6,878
Basic Metal Industries	5,369	10,392	-	5,787	-	21,548	2,859
Pulp and Paper	6,041	5,661	-	3,506	-	15,208	1,764
Fabricated Metal products	-	2,492	-	8,449	-	10,941	2,662
Wood & Wood Products		2,239	-	1,521	591	4,351	685
Other Manufacturing Industry	42	-	-	2,577	-	2,619	739

Source: Thailand Energy Situation 1992, DEDP (1993).

Energy Cost: Coal = 0.0337 B/MJ; Fuel Oil = 0.0983 B/MJ, Natural Gas = 0.0568 B/MJ; Electricity = 1.03 B/kwh (assume no demand charge);Biomass: Wood = 0.05 B/MJ, Rice Husk = 0.01 B/MJ, Bagasse = 0.01 B/MJ.

Conversion Factors:

Coal 6.37 MJ/kg; Fuel Oil 39,77 MJ/L; Diesel 36.42 MJ/L; LPG 26.62 MJ/L, Natural Gas 1.02 MJ/scf; Fuel wood 15.99 MJ/kg, Charcoal 28.88 MJ/kg, Paddy husk 14.40 MJ/kg; Bagasse 7.53 MJ/kg; Saw dust 10.88 MJ/kg. Source: Thailand Energy Situation 1992, DEDP (1993).

Table 2: Manufacturing Energy Intensity of the Thai Industry.

Sub-sector	Eenrgy Consumption[1/] (1992) (mil. MJ)	Value Added[2/] (1992) (mil.Baht)	Energy Intensity (MJ/Baht of Value Added)
Food & beverages .	159,766	140,614	1.14
Textile	39,540	208,712	0.19
Wood & Wood Products	4,351	28,297	0.15
Pulp, Paper, & Printing	15,207	17,878	0.85
Chemical & Chemical Products	39,962	83,984	0.48
Non-Metallic products	117,141	45,013	2.60
Basic Metal Industries	21,548	11,511	1.87
Fabricated Metal Products	10,941	191,031	0.06
Other Manufacturing	2,619	66,409	0.04

1/ Thailand Energy Situation 1992, Department of Energy Development and Promotion (1993).
2/ Custom Department, Ministry of Finance (1993).

Table 3: Comparison of Thai energy Intenisities with U.S. Values.

Sub-Sector	Gross Intensity (MJ/Baht)		Differences
	Thai	USA[1/]	(%)
Non-Metallic Products	2.60	1.29	50
Chemical and Products	2.18	0.89	59
Basic Metal Industry	1.87	2.13	-12
Paper and Paper Product	1.54	1.85	-17
Food and Beverages	1.40	0.17	81
Wood and Wood Product	1.07	0.77	28
Fabricated Metal Product	0.53	0.17	68
Textile	0.41	0.45	-9

1/Manufacturing Consumption of Energy 1991, DOE/EIA-0512(91), 1994.

factor of 2.81. this means that using this factor for correcting the exchange rate would reduce Thai energy intensities by 76 percent! Of course, the PPP concept describes an average correction factor for the general purchasing power, but the size of this factor makes the biggest part of the difference between Thai and US. intensity figures go away. No precise quantitative conclusion can be drawn from this calculation. However, this gives a valuable guideline for assessing the validity of international estimates of saving potentials for Thailand.

Specific Energy Consumption (per Ton of Product) in Manufacturing Sector

Another index of specific energy consumption is the amount of energy consumed per unit of physical output (MJ/tonne of proeduct). However, this index is meaningful only for a comparison between two industries of the same kind. This is due to the nature of the manufacturing processes which are quite varied in their production outputs. This section reports the average value of the specific energy consumption for different industrial branches. The data source for this analysis were energy assessments of approximately 740 factories that were compiled in the last 5 years by the DEDP. This study thus made use of the already existing auditing data to determine the value of the specific energy consumption of the Thai industry. Table 4 shows that the *Textile* industry has the highest energy intensity per weight of production output. (11.68 GJ/tonne), followed closely by the *Basic Metal* industries (10.97 GJ/tonne). the third ranking *is Non-Metallic Product* subsector which consumed about 6.37 GJ per tonne of production output. Other industries having the values around 3 GJ/tone are *Pulp and Paper*, *food*, and *Chemical Products.* The specific energy consumption in the *Fabricated Metal*, *Rubber and Plastic*, *Wood Products*, and *Electrical Machinery* sectors are within a range of 1-1.5 GJ/tonne.

Table4: Specific Energy Consumption of the Audited Manufacturing Enterprises.

Sub-Sector	No. of Assessed Factories	Specific Energy Consumption (GJ/Tonne)
Textile	18	11.68
Basic Metal	10	10.97
Non-Metallic products	38	6.37
Pulp and paper	5	3.69
Food	195	3.57
ChemicalProducts	12	3.05
Fabricated Metal	7	1.48
Rubber and Plastic	32	1.19
Wood Products	11	1.15
Electric Machinery	4	1.09
Beverage	8	0.88
Petroleum and Products	1	0.11
Wearing Apparel	5	0.08
Furniture and Fixture	2	0.03

Based on the results obtained from the energy intensity per value added and per unit of product output, 14 factories were identified for further energy assessment. these selected factories will represent the energy saving potential using two scenarios to determine their least cost reduction of energy consumption and CO_2 reduction. The list below shows the number of factories visited by our study team.

Sector	*No. of Factory assessment*	*Sector*	*No. of Factory assessment*
Food	3	Wood Products	1
Fabricated Metal	3	Basic Metal	2
Chemical	3	Textile	1
Non-Metallic	1	Total	14

Energy Audits in Factories

The 14 factories described above were visited by the study team, who performed a preliminary assessment to determine potentials of energy saving from these representative factories. For each of the factories visited, the following was assessed.

- The annual quantity and costs of energy consumed. The consumption of both purchased forms of energy and derived forms of energy was estimated and valued. The energy inputs must be disaggregated by the main energy processes of the plant.
- An identification of energy waste and inefficiencies of energy use.
- Gaps in the metering and reporting of energy consumption.
- Assessment of priority areas for further investigation in order to find the most promising areas of energy efficiency improvements.

As a result, several kinds of measures- such as energy management measures and equipment replacements- were proposed. All of these aim at decreasing the energy intensity and CO_2 emissions of energy consuming processes analyzed. Of the proposed equipment replacements, 10 specific technologies were subsequently analyzed in more detail, assessing their economic parameters using spreadsheet technique. All measures together were classified according to three criteria: time frame, profitability, and type of process.

The time frame criterion was used to define (1) immediate measures that all belong into the group of energy management; (2) medium-term measures are those requiring minor equipment changes, e.g., the replacement of incandescent by compact fluorescent light bulbs; and (3) long-term strategic measures such as the combined production of heat and power.

The profitability criterion was used to divide all measures into those that pay back in less than four years and those that have longer pay back times. The first group was used to define the *Moderate* and the other one to define *Intensive* scenario. The profitability criterion is the most volatile of the three because it depends on uncertain parameters. To handle this aspect in an appropriate way, 10 technologies were analyzed in more detail, i.e., using a spreadsheet that calculates several indicators of the attractiveness of investment projects. These include levelized costs of the output of a technology, the present value of the investment, the internal rate of return, and the payback period. To permit the evaluation of the cost of replacement, the spreadsheet can calculate total replacement costs which take account of the residual value of equipment that is to be replaced. All parameters that define the economics of energy-consuming production equipment are placed in one area of the spreadsheet so that new information can be readily evaluated, and the consequences of using alternative values of uncertain parameters can be seen immediately.

Result of the Proposed Investments

Energy, CO_2, and cost savings in the two scenarios can be calculated by comparing the new numbers with the actual situation in 1994. For each of the two reduction scenarios, the *Moderate Energy Conservation Policy* and the *Intensive Energy Conservation Policy*, we present final energy consumption, energy costs, and CO_2 emissions in Table 5 through 7.

The comparsion of the two reduction scenarios with the situation in 1994 shows that in the *Moderate* scenario, 1994's energy consumption is reduced by 6.6 percent.

(See Table 5). The *Intensive* scenario yields a further reduciton by approximately 3 percentage points.

Table 5: Final Energy Consumption in 1994 and Two Scenarios.

Factory	Total TJ	Total TJ	Percent Saved	Total TJ	Percent Saved
	1994	Moderate		Intensive	
1	294	290	1.4	287	2.4
2	74	73	0.1	99	0
3	227	226	0.3	210	7.2
4	13	12	0.6	12	4.7
5	69	60	13.1	63	8.1
6	638	609	4.5	565	11.5
7	63	62	2.3	59	6.7
8	58	58	0.4	55	5.5
9	268	94	64.8	82	69.3
10	102	102	0.0	102	0.0
11	320	320	0.0	307	3.9
12	835	835	0.0	831	0.5
13	337	337	0.0	309	8.3
14	49	49	2.7	46	6.6
Total	3,345	3,125	6.6	3,026	9.5

The most significant reductions of energy consumption are realized for Factory 5 and Factory 9. In Factory 5, the savings come predominantly from replacing one boiler and from improved maintenance of the thermal system in the *Moderate* case. In the *Intensive* case, CHP (combined production of heat and electricity) technology is proposed in addition. This is the reason why Factory 5's final energy consumption seems to be higher in the *Intensive* case. For a realistic comparison, however, it must be taken into account that an extra 5.7 Gwh of electricity is generated. In the Thai situation in which the Electricity Generating Authority (EGAT) encourages delivery by private enterprises into the public net grid, this surplus electricity can be sold to EGAT. In Factory 9, 65 percent of final energy consumption is saved due to the proposed replacement of an old boiler.

Table 6: Final Energy Costs in 1994 and Two Scenarios.

Factory	Total million Baht	Total million Baht	Percent Saved	Total million Baht	Percent Saved
	1994	Moderate		Intensive	
1	39	38	1.3	37	4.5
2	35	35	0.0	47	0
3	73	73	0.1	66	9.8
4	3	3	0.3	3	8.4
5	13	12	6.7	6	52.7
6	224	211	5.4	187	16.5
7	12	12	2.7	11	13.2
8	27	27	0.2	25	5.2
9	6	6	1.0	5	12.2
10	120	120	0.0	120	0.0
11	65	65	0.0	59	8.9
12	872	872	0.0	870	0.2
13	175	175	0.0	164	6.5
14	9	9	2.5	8	12.2
Total	1,672	1,658	0.9	1,608	3.8

In the *Moderate* scenario, in which only cost-free measures and investments with a payback time of less than 4 years are included, energy cost savings dominate the overall savings. The biggest savings of annual energy costs are found for Factories 5 and 6. In both cases, boilers which are already 20 years old were proposed to be replaced with new ones. Both companies are expected to save in excess of 5 percent of their 1994 energy costs in the *Moderate* scenario. (See Table 6). Total annual cost savings in this scenario (i.e., for all factories together) are approximately 10 percent.

CO_2 emissions are reduced by 7.2 and 12.6 percent respectively in the two reduction scenarios. (See Table 7). As a consequence of the substantial reduction of final energy consumption, the biggest savings are due to replacing the boiler in Factory 6. The other big savers are Factory 5 (10 and 31.7 percent) and Factory 6 (5.1 and 14.4 percent).

Table 7: CO_2 Emissions and Reduction in Three Scenarios.

Factory	Total Tonne CO_2	Total Tonne CO_2	Percent Saved	Total Tonne CO_2	Percent Saved
	1994	Moderate		Intensive	
1	26,256	25,897	1.4	25,361	3.4
2	13,221	13,217	0.0	18,025	0
3	33,489	33,429	0.2	30,504	8.0
4	1,465	1,458	0.4	1,362	7.0
5	7,137	6,422	10.0	4,874	31.7
6	89,177	84,662	5.1	76,303	14.4
7	6,869	6,698	2.5	6,176	10.1
8	6,753	6,722	0.5	6,173	8.6
9	31,806	11,738	63.1	10,266	67.7
10	2,191	2,191	0.0	2,191	0.0
11	35,884	35,884	0.0	3,526	6.6
12	52,902	52,902	0.0	52,132	1.5
13	52,103	52,103	0.0	47,096	9.6
14	5,189	5,057	2.5	4,705	9.3
Total	364,441	338,380	7.2	318,695	12.6

CONCLUSIONS

The propose of this project was to identify and assess investments in energy efficiency improvement and carbon dioxide emission reduction in Thailand. The study focussed on concrete measures for individual energy consumers in the manufacturing sector.

The main result of this study is the quantification of two energy intensity and CO_2 emission reduction scenarios. The *Moderate* scenario comprises those measures that have a payback time of less than four years. The *Intensive* reduction scenario includes all measures that have longer payback periods but which are still cost-effective (i.e. the internal rate of return is greater than 9%). An important conclusion is that significantly higher energy savings can be achieved when loger payback periods are accepted (See Table 6). However, factory reluctance to invest in projects with payback periods longer than four years is a major draw back. Reducing this reluctance could be one of the most important strategic goals of the support granted by the ENCON Fund.

The small size of the present project allowed only for the selection of a sample for the investigation that is small relative to the overall energy consumption by the *Manufacturng* sector. The resutls can therefore not readily be generalized for the entire sector, but they give an informative baseline for further study.

A rough approximation of the total savings potential in Thailand's Manufacturing sector is obtained by assuming that the saving potentials identified here are representative for the entire sector. If they are, then we have identified CO_2 emissions savings of approximately 7 percent for measures with payback of 4 years or less, and 12% for measures with payback over 4 years.

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Mitigation Options For The Industrial Sector In Egypt

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Abstract

Though its contribution to the global Greenhouse gases emission is relatively small, Egypt has signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC) and has been playing an active role in the international efforts to deal with such environmental challenge. Energy efficiency has been one of the main strategies that Egypt has adopted to improve environmental quality and enhance economic competitiveness.
This paper highlights three initiatives currently underway to improve energy efficiency of the Egyptian industry. The first is a project that has been recently completed by OECP to assess potential GHG mitigation options available in Egypt's oil refineries. The second initiative is an assessment of GHG mitigation potential in the Small and Medium size Enterprises (SME) in the Mediterranean city of Alexandria. The third one focuses on identifying demand side management options in some industrial electricity consumers in the same city.

1- Introduction.

Energy is a vital tool for economic development in developed and developing nations. However, energy production and consumption have been known to emit to the atmosphere gases whose atmospheric physiochemical reactions have impacts on the earth's climate system. This has led to enhancement of the natural greenhouse effect. Greenhouse gases (GHG) include carbon dioxide(CO_2), methane(CH_4), nitrous oxide (N_2O) and some other ozone precursors such as carbon monoxide (CO), Oxides of Nitrogen (NO_X) , and Non Methane Volatile Organic Compounds (NMVOC). Fossil fuel combustion has been the major source of the global GHG emissions. In Egypt nearly 92 % of the country's energy demand are met by oil and natural gas. Policies and measures that can reduce greenhouse gas emissions from energy use include energy efficiency, fuel switching to less carbon fuels, and increased use of less energy intensive materials. Energy efficiency is one of the most viable options for GHG emissions reductions in industrial sectors. Improving energy efficiency has become a highly indispensable tool to achieve a set of objectives, it can enhance economic efficiency through optimal allocation of economic resources, conserve depletable energy resources, reduce cost of production, improve competitiveness of industrial enterprises in international markets, and mitigate the adverse environmental impacts. Although Egypt is a country that is not a particularly significant contributor to the global Greenhouse Gases emissions, its energy policies for many years have been developed and adopted to achieve a number of objectives. This includes enhancement of natural gas utilization, energy conservation and more efficient energy use, energy prices reform, and promotion of renewable energy utilization.

This paper highlights three initiatives currently underway to improve energy efficiency of the Egyptian industry. The first is a project that has been recently completed by OECP to assess potential GHG mitigation options in Egypt's oil refineries. The second initiative is an assessment of GHG mitigation potential in the Small and Medium size Enterprises (SME) in the Mediterranean city of Alexandria. The third one focuses on identifying demand side management options in some industrial electricity consumers in the same city.

2. Demographic And Economic Situation Of Egypt.

The Arab Republic of Egypt has an area of about one million square kilometers with a total population of about 60 million inhabitants (end of 1994/95). The inhabited area along the River Nile, at the Delta and along the Northern Coast represents about 5% of the country total area giving an average population density of more than one thousand persons per square kilometer. The Gross Domestic Product (GDP) of Egypt in 1994/95 was about 146.1 billion Egyptian Pounds (LE) at 1991/92 price levels. The industrial sector represents about 17% of total GDP, oil and gas accounts for nearly 10 %, agriculture represents about 16.5% [1].

3. Energy Situation In Egypt.

Egypt's main energy resources are oil, natural gas, coal and hydropower. In addition, there are good potentials for renewable energy resources. Oil and gas are the main sources of energy which accounts for nearly 92 % of the total commercial energy demand, while hydropower nearly represents the remaining 8 %. The current level of oil reserves is 3.3 billion barrels, most of which are located in the Gulf of Suez. The present annual production of oil is nearly 44 million tons Mt (about 870 thousand barrels per day), of which about 18.5 Mt are consumed domestically. The second major energy source is natural gas with a current reserve level of about 22 trillion cubic feet. Most of the gas resources are located in the North Coast, Nile Delta and Western Desert. Hydropower is the third major energy resource in Egypt. Nearly 90% of the Nile's hydropower potential has already been exploited to generate about 11 TWH of electricity annually. In addition, Egypt has a limited coal reserve estimated at about 27 Mt. The only commercial mining is now being developed in "Maghara", Sinai to produce about 600 thousands tones per year. About 1.3 million tones of coal are being imported now as feedstock for the steel industry. Egypt also has a potential of non commercial or renewable energy resources. This include solar and wind energy resources in addition to biomass such as agriculture wastes and dung which are being used in rural areas to meet some energy demand. It is estimated that about 3 million tones of oil equivalent (TOE) of biomass energy is consumed annually.

Per/capita primary energy consumption is nearly 0.54 TOE, which is generally higher than the average of most developing countries. According to 1994/95 figures, the total energy consumption in Egypt was about 31.6 million tones of oil equivalent (MTOE) of which oil represents about 58%, gas about 34 % and hydropower about 8 %. The electricity sector has been characterized by heavy reliance on petroleum products and natural gas due to limited hydropower resources. Thermal power generation using petroleum products and natural gas represents nearly 80% of the total electricity generation, while the rest is met by hydropower. In addition to power generation, energy is consumed in four major end use sectors; industry, transport, residential and commercial, and agriculture. Fig. (1) presents the energy consumption by sectors in 1994/95.

4. GHG Emissions From the Energy Sector

Table (1) shows the GHG emissions for All-Energy sectors in 1990/91 estimated using the latest IPCC guidelines [2]. Total CO_2 emissions are estimated at about 81.6 Mt. As a major contributor to CO_2 emissions from fossil fuel burning, the industrial sector accounts for nearly 21 % of the total. Oil refining accounts to 2% of the same total [3]

5. Efficiency and Mitigation Measures for Industry.

Energy efficiency is the most widely recognized option for GHG mitigation analysis. Based on experience of the last two decades, there are many technologies and practices that could enhance industrial energy efficiency. These measures could be either "low cost" or "capital" measures. Minor operational changes, such as housekeeping and good maintenance practices, are typically the cheapest, easiest to implement, and least risky, but usually yield the smallest energy and cost savings. Process equipment changes and energy conservation add-on technologies typically involve large investments, but yield higher energy and cost savings.

a. Measures For Existing Processes

A brief overview of some examples of energy efficiency measures that can reduce GHG emissions in existing facilities are presented below:

- Housekeeping, equipment maintenance, and energy accounting;

Good housekeeping measures would include activities such as monitoring of energy consumption, turning off equipment when not in use, installing and using energy monitoring equipment, wrapping tanks and pipes with insulation, repairing leaks of process streams, and regular maintenance routines.

- Flare gas recovery including recovery of hydrocarbon vapor flows by improving system technology.
- Stack gases heat recovery.
- Hot water and Condensate recovery.
- Energy management systems which can be used to systematically turn off or turn down different process equipment and lights.

- Motor drive system improvements which include use of high-efficiency motors, improved motor rewinding, power conditioning, drive control (especially with adjustable-speed drives), and use of more efficient associated equipment (pumps, fans, compressors, etc.)
- Improved steam production and management which include use of economizers and other heat recovery systems, insulation of steam distribution systems, and use of more efficient boilers.
- Industrial co-generation which allows the substitution of waste heat from electricity generation for steam that would otherwise be raised in a boiler burning fuel. Co-generation is an important option for industries with large process heat requirements as oil refining.
- Heat recovery systems which may involve transferring heat from high-temperature waste heat sources to more useful media such as steam or raising the temperature of. other low-temperature streams.

b. Measures For New Equipment (Technologies)

Adoption of more energy-efficient new equipment is an option for devices widely used across industries such as using CO boilers, using more efficient process heaters, pumps, fans, compressors, and boilers. It is an especially important option in countries where industry is growing rapidly and the manufacturing equipment are outdated.

c. Fuel Switching To Less Carbon Fuels

Opportunities for switching to lower-carbon fuels vary among countries depending on the available resources. Some of the most viable options in mitigation analysis are switching to natural gas or renewable energy sources (e.g. wood from managed plantations for boilers or solar thermal energy for low-temperature process heat demands). In the case of Egypt, with the current reserve levels and annual production of 520 billion cu.ft (1994/95), it is planned that natural gas would play an important role in the country's fuel mix. A gas substitution policy has been adopted and implemented to promote the use of natural gas in electricity generation, industrial, residential and commercial utilization.

6. Energy Efficiency Program In The Egyptian Refineries

Egypt owns 8 refineries with a total refining installed capacity of about 29 Mt per annum. The domestic production of petroleum products in 1994/95 is nearly 26.8 Mt of which fuel oil accounts for nearly 47%. This secures self sufficiency of most of the petroleum products, and the surplus is exported. Total exports of petroleum products is about 8.9 Mt, however, Egypt has to import nearly 0.2 Mt of some products especially diesel fuels to meet some domestic needs.
Based on an agreement between five petroleum refineries, owned by the Egyptian General Petroleum Corporation (EGPC), and the Organization for Energy Conservation and Planning (OECP), a two-phase project aimed at providing technical

assistance to the petroleum refineries to improve their energy efficiency has been completed. The main objectives of the project were:

1- To analyze energy consumption patterns in these refineries.
2- To evaluate the performance of the energy consuming equipment.
3- To recommend feasible energy conservation measures.
4- To reduce GHG emission through energy efficiency, and
5- To monitor the implementation of the energy efficiency measures.

During the first phase of the project, a program of comprehensive energy audits was undertaken to assess how energy is being used in the participating refineries, identify energy efficiency improvement opportunities, develop cost-effective energy saving measures and, more importantly, institutionalize the energy efficiency concepts at different levels within the plants' system of management. As a result, appropriate recommendations to improve the efficiency of energy utilization were developed. The audit program showed that the most common potential sources for improving energy efficiency in the Egyptian refineries could be achieved through one or more of the following measures:

- Improving steam traps performance.
- Efficient insulation of steam distribution system.
- Proper management for repairing air, steam, and water leaks.
- Improving boilers efficiency.
- Improving furnaces efficiency.
- Improving cooling system efficiency.
- Condensate recovery.
- Using high efficient lighting systems, and
- Improving electric power factor.

Total petroleum energy consumption in the audited refineries in 1994/95 was found to total nearly 675 thousands T.O.E [4]. Out of this consumption, fuel oil was found to be the major source of energy that contributes about 59 % (Fig. 2). The difference between the total output products and the input refined crude accounts for the fuel used for refining requirements and the losses in Egypt's petroleum refineries. About 65% of that difference is the fuel used for refining requirements and the balance represents the energy losses. Fuel used or lost in refining operations estimated to be about 5% of the total crude refined in Egypt. Taking into account the comparatively mild climate, possibly lower products quality specifications, and lack of environmental regulations, the Egyptian refineries have had a lower specific energy consumption similar to refineries in North America. Specific energy consumption (S.E.C) in Egyptian refineries were found to range between 0.02 and 0.08 T.O.E / tonnes crude depending on the complexity of each refinery [5]. In comparison the US refining industry, the energy consumed in refining a barrel of crude oil is on average about 7% of the energy contained in the barrel. Some refineries that produce lube oils and petrochemicals consume much more, up to about 14%. Some simple refineries that sell process residual oil consume lower, as low as 4.5% [6].

According to the results of the audit program, it was concluded that some measures will have the highest return on investment as well as the highest potential for reducing GHG emissions. This. includes low-to-medium-cost improvements of energy efficiency of the existing capital stock, use of more energy-efficient equipment such as CO boilers, condensing economizer, low excess air burners, high efficient motors, high efficient lighting systems, in addition to fuel switching to less carbon fuels. Table 2 shows the results of cost-benefit analyses undertaken to some identified mitigation options in one of the Egyptian refineries [7]. It is noticable that all of the identified options, which have high potential of replicability within the Egyptian oil refineries, do have negative costs for Carbon dioxide reductions that put them under the "No-regret" category. It is worth mentioning that Egypt promotes such policies and measures with double dividends,i.e., environmental and economic benefits. Among the listed options, improving combustion efficiency of boilers is the most cost-effective one based on cost benefit analysis and potentials to reduce GHG's (see table 2).
The second phase of this program started immediately after completion of the audit program. It aimed at monitoring the implementation of the energy conservation projects developed in the audit phase. Periodic on-site visits to each of the participating refineries were undertaken by a team of specialists to measure actual energy-related process parameters. These field measurements were used to analyze plant's energy efficiency, and the impacts of implementation of energy efficiency recommendations on the overall refinery's specific energy consumption and GHG emissions. Due to the cost effectiveness of the recommended measures, and the volume of capital needed, the refineries' management have decided to invest in their implementations. Refineries' own financial resources have been successfully used to gain energy savings with payback periods in the order of one to two years, in addition to reducing air pollutants.

7. GHG Mitigation Projects in Alexandria

Alexandria is an important business and commercial center and home to about 5 million people. It is both Egypt's and Africa's largest port and second largest city and is also an important "cross roads" between Africa, the middle East and the Mediterranean countries. As it is expected to grow and develop quickly within the next few years, Alexandria has been the focus of many energy efficiency initiatives during the last few years. The following sections briefly summarize two of the ongoing efforts currently undertaken by OECP and some other institutions in Alexandria to promote energy efficiency and environmental quality.

7.1 GHG Mitigation Potentials In Small & Medium Enterprises (SMEs).

This project is partly financed by the OECP of Egypt, ENEA of Italy and the SYNERGY programme of the Commission of the European Communities (CEC). One of its main objectives is to analyze the energy-environmental status in small and medium enterprises (SME) in Alexandria by conducting selective energy and environmental auditing in the main industrial activities such as food, textiles, wood, metallurgical, chemical and others. The project outcomes, to be completed by the end of 1996, will include the identification of the energy efficiency opportunities together with their GHG mitigation options. The technical and economic feasibility of such options will be assessed to determine their potential of large scale replicability in the SME in Alexandria and nationwide. These outcomes will also serve as a valuable input to the current efforts aimed at developing national action plan to deal with climate change in Egypt.

7.2 Demand Side Management (DSM) Pilot Program

The Alexandria Electricity Distribution Company (AEDC), the Egyptian Electricity Authority (EEA), the Organization for Energy Conservation & Planning (OECP) and the Energy Conservation and Environment Project (ECEP) are teaming together for the implementation of the Alexandria's DSM pilot project. The pioneering effort is supported by USAID to apply DSM technologies in a limited number of industrial plants to assess their effects and to gain experience toward the future development of full-scale or national DSM programs. The new program will investigate explicitly the potential for beneficial impacts of DSM on electricity supply companies.

The main objectives of the DSM pilot program include the following :

1- Train and establish within the Alexandria Electricity Distribution Company an operating unit that can independently plan and conduct DSM activities after the pilot program is completed.

2- Evaluate the potential benefits of industrial DSM for the Egyptian Electricity Authority.

3- Promote the results of the DSM pilot program among other Electricity Distribution Companies.

4- Evaluate the effects of DSM on GHG emissions to support Egypt's climate change action plan.

5- Dissemination of information related to DSM activities to promote large-scale DSM programs in Egypt.

Conclusions

Energy efficiency is a viable means to improve competitiveness and enhance environmental quality in the industrial sector, it increases plant productivity and improve products quality. As one of the large energy consuming sectors in Egypt, the industrial sector has been the focus of many energy efficiency improvement initiatives for the past two decades. The policies of the energy sector has been developed to adopt energy efficiency as one of the strategies to enhance economic efficiency of the Egyptian economy and save the environment. There are a number of energy efficiency activities that have been undertaken by OECP in collaboration with some other institutions. These activities have clarified the potential of energy saving that can be achieved through investing in energy efficiency. An energy efficiency programme in the Egyptian oil refineries concluded that nearly 5 % of the crude oil refined in those refineries is being burnt and lost during the refining processes. This makes oil refineries a major source of GHG emissions. Improving the energy efficiency of these processes would lead to enhance both environmental quality and economic competitiveness. There are many options that are economically viable to improve energy efficiency and reduce GHG emissions from burning fossil fuels in refinery processes. Cost benefit analyses prove that these options have negative costs which means that while reducing GHG emissions, their adoption would not incur any extra cost to the economy.

OECP's experience indicates that the major energy wastage in the existing Egyptian industrial facilities and oil refineries could be reduced by implementation of some low - to - medium cost improvements to the energy efficiency of existing capital stock, use of more energy-efficient equipment, and fuel switching to less carbon fuels.

Acronyms :

OECP	Organization for Energy Conservation and Planning
EEAA	Egyptian Environmental Affairs Authority.
AEDC	Alexandria Electric Distribution Company.
CEC	Commission of European Communities
ENEA	Ente Per Le Nuove Tecnologie, L'Energia El'Ambiente
IPCC	Intergovernomental Panel on Climate Change.
SME	Small and Medium Enterprise.
TOE	Tonns of Oil Equivalent.

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Figure 1. Energy Consumption Profile By Sectors in (1994/1995)

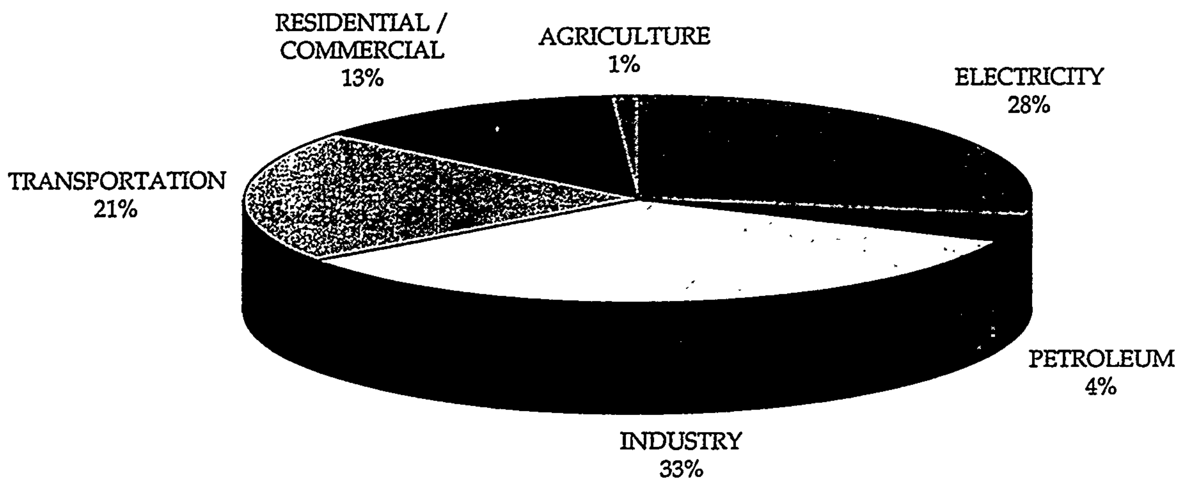

Figure 2. Petroleum Energy Consumption Pattern in Audited Refineries (1994/1995)

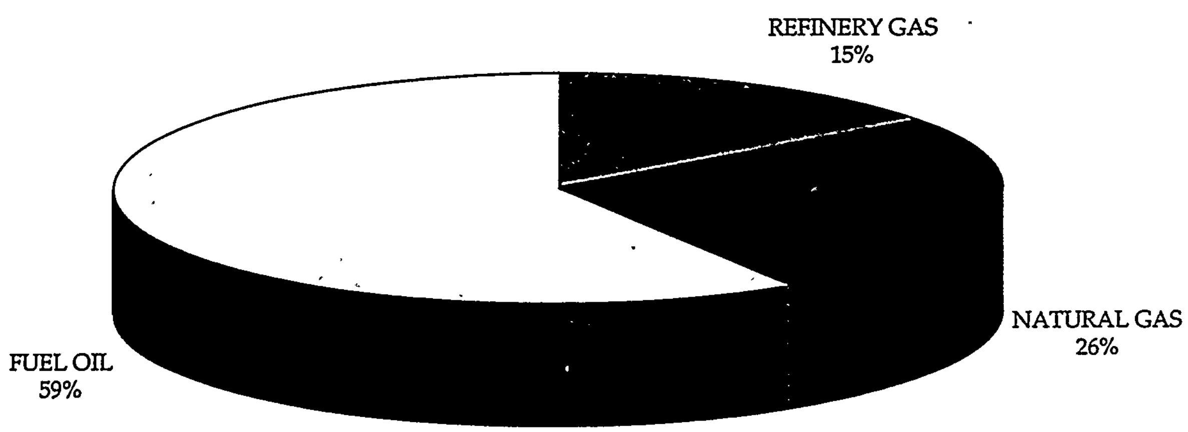

Table (1)
GHG Emissions From The Energy Sector
(1990/1991)

Sectors	CO2 Gg	CH4 Gg	N2O Gg
Energy & Transportation	25520	0.08	0.97
Industry	17300	0.09	1.87
Transport	17650	10.83	7.04
Small Combustion	21100	0.68	1.32
Total	81570	11.68	11.2

Source:
Support for National Action Plan, SNAP, Egypt's GHG's Inventory, Energy Sector, Aug., 1996

Table (2)
CO2 Reduction & Cost of Saved Carbon in
An Egyptian Oil Refinery

Project Title	Annual Energy Savings*		Annual Cost Savings ***	Investments	Payback Period	CO2 **	Cost of Saved CO2
	F.O # 6 (Tonne)	Total (TOE)	1000 $	1000 $	(Years)	Reduction (Tonne)	$/ton CO2 World Price
Improving combustion efficiency of the process heaters	3539	3442	252.47	75.3	0.30	123024	-7.90
Improving combustion efficiency of the boilers	7995	7775	570.36	120.48	0.21	277894	-8.31
Recovery of the condensate for desalters	2085	2028	148.74	45.18	0.30	72485	-6.57
Reparing faulty steam traps	784	762	55.93	13.55	0.24	27235	-2.76
Total	14403	13999.716	1027.5	254.51	0.25	500638	

* Annual Energy, Cost Saving and Capital Investment are based on the energy audit, OECP, 1993.
* * CO2 Cumulative Reduction is calculated over the life time of the projects (10 Years).
*** Local Energy prices in Egypt are Subsidized, Accordingly, the cost savings are based on economic prices.

STATUS OF NATIONAL CO_2-MITIGATION PROJECTS AND INITIATIVES IN THE PHILIPPINE ENERGY SECTOR

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1.0 INTRODUCTION

The Philippines has a huge energy requirement for the next 30 years in order to achieve its economic growth target. Based on an expected annual GDP growth rate of 6.9 percent, the Philippines' total energy requirement is estimated to increase at an average of 6.6 percent annually from 1996 to 2025. Gross energy demand shall increase from 219.0 million barrels of fuel oil equivalent (MMBFOE) in 1996 to 552.4 MMBFOE in 2010 and 1,392.6 MMBFOE by 2025. These energy demand levels shall be driven primarily by the substantial increase in fuel requirements for power generation whose share of total energy requirement is 28.3 percent in 1996, 48.0 percent in 2010 and 55.0 percent in 2025.

With the expected increase in energy demand, there will necessarily be adverse impacts on the environment. Energy projects and their supporting systems - from fuel extraction and storage to distribution - can and will be major contributors not only to local but also to regional and global environmental pollution and degradation. International experiences and trends in greenhouse gas (GHG) emissions inventory have shown that the energy sector has always been the dominant source of carbon dioxide (CO_2) - the principal contributor to global climate change. The energy sector's CO_2 emissions come primarily from fossil fuels combustion. Since energy use is the dominant source of CO_2 emissions, efforts should therefore be concentrated on designing a mitigation strategy in this sector.

2.0 CARBON DIOXIDE (CO_2) EMISSIONS

2.1 Baseline Scenario: National Emissions Inventory (1990)

Initial results of the national GHG emissions inventory conducted by the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) using 1990 as base year showed that the total CO_2 emissions from energy amounts to about 38,272 Gigagrams (Gg) (see Annex, Table A.1). Emissions in the energy sector are mainly associated with fossil fuels combustion with the energy and transformation and the transportation subsectors being the major contributors of CO_2 at 32% and 28%, respectively. The energy conversion sector, in particular electricity generation, emits the largest amount of CO_2 from fossil fuel combustion.

2.2 CO_2 Emissions Outlook

Based on the 1996-2025 energy mix forecast, total CO_2 emissions from energy sources are projected to increase by 482,700 Gg from 84,590 Gg in 1996 to 557,290 Gg by 2025 (see Annex, Table A.3). The major sources of CO_2 emissions are oil, coal and woodwastes which shall collectively account for 92.1 percent of the total CO_2 emissions for 1996, contributing 54.5 percent, 14.5 percent and 23.1 percent, respectively.

The expected construction of large coal-fired power plants shall put coal as the primary CO_2 emission source contributing 40.0 percent of the total CO_2 emissions by 2025. On the other hand, oil is expected to account for 36.0 percent while natural gas and woodwastes will have 11.0 percent and 7.0 percent, respectively. These are brought about by significant increases in the contribution of coal and natural gas by 2025 and the subsequent reduction in oil.

Total CO_2 emission is estimated to increase nominally by an average of 6.7 percent per annum over the 1996-2025 period. Based on the projected population growth, the per capita CO_2 emission will increase from 1,200 kilograms (kg) in 1996 to 5,350 kg by 2025.

Among the different energy sources, coal shall contribute 28.5 percent to the country's total energy supply by 2025. Of this, domestic coal shall account for 6.8 percent. Though relatively cheap and geographically accessible and abundant, local coal has low heating value, carbon content, and combustion efficiency. These qualities make local coal the highest producer of CO_2 emission per unit energy supply. The dominant use of coal as a source of electric power and thermal energy can be made as the central focus of the country's attempt to reduce CO_2 emissions with emphasis on demand-side improvements in energy efficiency and application of better coal processing technologies.

3.0 CO_2 MITIGATION STUDY[1]

There have been several activities and programs that shows the country's serious commitment to address the ever-growing concern on environmental degradation and climate change. Since 1982, the Department of Energy (DOE) has implemented various foreign-assisted projects on energy efficiency and environment (see Annex, Table A.4) including the "CO_2 Mitigation Study."

3.1 Rationale of the Study

The country's present CO_2 mitigation efforts face two difficult tasks. The collection of reliable data about CO_2 emission sources and their importance as a

[1]Discussions in this section is based on the final report "CO_2 Mitigation Study," a component of the project, "Framework Convention on Climate Change: Country Study in the Philippines." The 1-year study (March 1994-February 1995) was executed by the Philippines' Department of Energy (DOE) in cooperation with Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), under the sponsorship of the Bundesministerium fur Wirtschaftliche Zusammenarbeit (BMZ) of the Federal Republic of Germany. Consulting Engineers Salzgitter (CES) was commissioned by GTZ to assist DOE in the implementation. The Manila-based Energetica International, Inc. was subcontracted by CES to work directly with DOE in the study. Results of the study, which was made possible due to the collective effort of the above institutions/agencies, were initially presented by Dr. A. Kaupp of Energetica International, Inc. during the Asia-Pacific Leaders Conference on Climate Change in February 18-20, 1995 in Manila, Philippines

potential option for economical CO_2 mitigation investments is one area of uncertainty. This study intends to address another difficult task and this involves the classification and rating of the most economical CO_2 mitigation investments and their possible impact. A basic assumption in the selection strategy for CO_2 mitigation programs is that the Philippine experiences financial constraints and future programs will compete for financial resources with other national programs with better returns and higher public acceptance.

3.2 Objectives

The aim of the study was to establish a priority list of technologies and schemes with greatest impact on emission control and CO_2 reduction in the energy sector particularly in industry and power plants. The study basically covered the preparation of impact assessment of the application of certain technologies, services or better housekeeping measures in mitigating the effects of future CO_2-emissions. It covered the comparison of technically feasible options to reduce airborne emissions at economic costs and rate them according to priority of the government. The study provided an initial list of scenarios to be considered for CO_2 mitigation in the Philippines with focus on technology-oriented classification of technically feasible scenarios in the energy sector. Scenarios about technologies which are not proven or too costly had been excluded.

3.3 Methodology

The study analyzed and compared various scenarios for consideration as CO_2 mitigation options in the Philippines. Emphasis had been given to a concise approach without the complex details on economics which do not improve the assessment due to lack of accurate and reliable input data about all effects of CO_2 mitigation projects. Options were rated according to either their long range marginal costs per ton of CO_2 saved or their relative CO_2 mitigation effect accumulated over a period of time.

Mitigation measures in the energy sector fall into two main categories: demand side and supply side measures. Mitigation options at the demand side concerns end-use efficiency improvement or energy conservation measures at the end user side. Supply-side mitigation options include fuel substitution and improving transmission and power plant efficiency. In other words, options for reducing or limiting CO_2 emissions were classified as: (1) demand side measures or end-use efficiency improvement, (2) switching/ substituting renewables and less carbon-intensive energy sources for more intensive ones, and (3) efficiency improvement at the power generation and transmission side.

3.3.1 Demand Side Management (DSM). *Energy conservation measures at the end user side.*

Commercial and Residential

- **Compact fluorescent lamps (CFL).** *A medium ambitious residential DSM program with 45 million CFL lamps sold to replace incandescent light bulbs over a 30-year period. The financial attractiveness for the* *private investor and society is only guaranteed if the local power supply becomes more stable and prolonged and low voltage conditions in the evenings are avoided. This scenario will likely take place without technical and financial assistance. However it could be accelerated.*

- **Energy-efficient air conditioners.** *To date, local efforts to introduce energy-efficient air conditioners, such as energy labelling and setting of minimum standard are among the best in the region. This residential DSM scenario which will replace existing air conditioners will likely take place with or without additional marketing efforts. Energy efficient air conditioner designs are introduced to the Philippines by automatic technology transfer to local assemblers with a time lag of 5 to 7 years.*

- **Energy-efficient refrigerators.** *Similar to the efficient air conditioners this option applies to better marketing of efficient refrigerators to replace existing refrigerators. However, cost per ton of* CO_2 *saved will always be positive because refrigerators are base load appliances, where a utility looses revenue.*

- **Improved lamp ballasts.** *This option assumes that inefficient magnetic core coil ballasts are replaced by 65 million electronic ballasts over a period of 30 years. As most DSM measures for the residential sector, this one is also financially attractive and therefore an automatic technology transfer will likely take place.*

Industrial

- **Overall improvement of energy efficiency in fuel combustion processes and electricity use in industry.** *This option assumes that each industrial firm which has committed itself to participate in a program will eventually cut specific fuel consumption by 20% and electricity use by 10%. Specific measures may include increased efficiency of motors, efficient lighting system, combustion control and monitoring, etc. The programs assumed a market penetration is 43% of all industrial energy users over a period of 30 years.*

3.3.2 Fuel switching/substitution to renewable energy and less carbon intensive energy sources. *The reduction of* CO_2 *in the country's power system relies on a shift away from high carbon fuels (coal and oil) toward low or non-carbon energy carriers such as natural gas; hydroelectric, geothermal, or nuclear generation; or renewable technologies, such as solar, biomass, or wind power.*

- **Geothermal power plants.** *Replacing fossil fueled power plants with geothermal power plants follows the official planned capacity extension until 2010. Although geothermal power may be more expensive than coal power, the* CO_2*-mitigation potential is good. This option assumes 1,657 MW in new capacity by 2025 and that*

1,057 MW of new plant capacity are in the pipeline up to the year 2010.

- **Hydro power plants.** *This option of hydroelectric power instead of fossil fueled power plants follows the official capacity extension of 2,314 MW to the year 2010 and adds another 1,000 MW to 2025. Estimated untapped resources are 15,500 MW.*

- **Natural gas combined cycle turbines.** *Natural gas has been seen as the most promising of the alternative fuels replacing fossil fuels, principally because of the gains in thermal efficiency made possible by combined cycle technology. Aside from higher plant efficiency, the lower investment costs of natural gas combined cycle power plants compared to coal fired plants is also favorable. This scenario follows the planned construction of a 3,000 MW natural gas combined cycle power plants by the turn of the century.*

Renewables, definitely, have a role to play in the future, although it is not certain whether they can provide a major part of the solution. Renewable technologies that harness natural forces or non-carbon energy sources considered in the study include:

- **Photovoltaic solar home systems (SHS).** *This scenario is extremely ambitious, because it assumes 2,000 systems sold in the first year increasing to 30,000 systems sold in the 30th year, or 226,836 systems sold over 30 years. Even the inclusion of avoided kerosene burning will not improve the marginal CO_2 mitigation effect.*

- **Wind power.** *The option of using wind power instead of small diesel engines in rural areas assumes isolated hybrid systems (wind + diesel). It is still uneconomical for a wind turbine operator to feed the electricity in the public grid. The scenario is ambitious with 436 units of 200 kW capacity each installed over 30 years. The CO_2 mitigation impact is marginal and society costs are high.*

3.3.3 Transmission and power plant efficiency improvement. *A very important option is efficiency improvement at the power generation and transmission side. This means, reduction of losses during generation, distribution, and transmission. It also includes energy conservation measures at fuel processing/refineries.*

- **Distribution and transmission efficiency improvement.** *This option, which involves the reduction of technical losses from the national electricity distribution grid, has a very high CO_2-mitigation potential, despite a conservative assumption of a 7% annual increase in electricity demand, as compared to the official 11.2%. It is argued that over a period of 20 years the present technical losses could be reduced by 40%. This measure will not only significantly reduce fossil fuel consumption, but has a macro-economic effect as well in terms of extending the technical life of all appliances and hardware* *using electric motors.*

- **Heat rate improvement of fossil fuel power plants.** *Despite all efforts to utilize renewable energy such as hydro and geothermal or low carbon fuel natural, natural gas, it is foreseen that the fossil fuel fraction of the power mix will, in the long-run, increase to 70%, and most power will be generated from coal (65%). It is unrealistic to predict a much higher combined hydro, or geothermal power fraction than 30% for the medium-term future (2025).*

3.4 Discussion of Results

Table below summarizes the preliminary results of the study showing the best options in terms of financial attractiveness and impact on CO_2 mitigation (see also Annex, Figure A.1 and Table A.5). The preliminary results confirm that, in the short run, conventional technologies (CFL, aircon, and ballasts) and fuel switching (hydro and natural gas) are the best options in terms of financial attractiveness and impact on CO_2 mitigation. It also shows that some options although extremely financially attractive, have less impact in terms of %CO_2 mitigation when compared against others. It has been also shown that most likely DSM measures on the residential consumer side, although extremely financially attractive, have less impact when compared against energy efficiency measures in industry or the power production and transmission side.

Table 1. CO_2 MITIGATION SCENARIOS

Description	% CO_2 Mitigation	CO_2 Saved million tons (@ 30 years)	LRMC CO_2 US$/ton	Effect in 30 years
1. Compact fluorescent lamps	2.34	11.70	-136	43.2 million CFL
2. Hydro power plants	6.47	31.58	-131	3,314 MW additional hydro
3. Natural gas combined cycle power plants	5.64	22.51	-78	3,000 MW installed for 20 years
4. Energy efficient aircons	1.00	4.87	-24	1.4 million efficient aircon
5. High efficiency lamp ballasts	1.31	6.70	-7	64.5 million efficient ballasts
6. Distribution and transmission efficiency improvement	19.99	112.29	13	41 % reduction of the present losses
7. Heat rate improvement	39.54	230.59	14	13.3 % fossil fuel mix savings
8. Energy efficiency improvement in industry	17.81	95.58	67	43.2 % market penetration
9. Energy efficient refrigerators	0.81	4.44	84	6.5 million efficient refrigerators
10. Geothermal power plants	4.94	19.31	127	1,657 MW additional geothermal
11. PV Solar home systems	0.12	0.66	256	226,836 units of SHS
12. Wind power (hybrid)	0.03	0.15	342	436 units of each 200 kW
TOTAL	100.00	540.38		

Source: CO_2 Mitigation Study, 1995.

4.0 BARRIERS AND ISSUES IN THE ADOPTION AND IMPLEMENTATION OF MITIGATION OPTIONS

Studies on the country's energy conservation potentials indicate that by implementing energy efficient technologies, large savings could be generated. This is consistent with the results of the CO_2 Mitigation Study, which showed that demand side energy efficiency measures are among the best options in terms of financial attractiveness and impact on CO_2 mitigation. However, the success of demand side energy efficiency programs in the country is still considered as very modest due to several constraints.

Structural

There is no specific penalty for non-compliance with certain regulation relative to the promotion of energy efficiency. With the expiration of Batas Pambansa Blg. 73 (Energy Conservation Law) in 1990, the requirement for submission of quarterly energy conservation reports and annual conservation programs of energy intensive establishments became voluntary. The DOE proposes to make the requirement mandatory again through the proposed new Energy Conservation Act. Likewise, through the Act, energy audits will also be mandatory for large establishments.

Financial

There is a need for more financial institutions and energy service companies that will provide financial support to energy efficient projects or technologies. The DOE attempts to overcome this barrier by involving financial institutions and energy service companies in the implementation of its demonstration projects. The demonstration projects aims to establish the financial viability of energy efficient technologies and through the experiences gained by these institutions, it is hoped that they will become more receptive in financing projects on energy efficiency.

Technical

Most energy efficient technologies/equipment need to be sourced from other countries. The question of after-sales service and spare parts support therefore, becomes a real concern for industrial companies that would like to adopt energy efficient technologies. While the solution for this constraint maybe long term, the creation of the market for the technologies through demonstration projects and the projected implementation of DSM programs by power utilities will eventually encourage foreign manufacturing concerns to establish local subsidiaries in the country.

Cultural

The public in general are not aware of the serious nature of the energy situation, particularly, on the complex issue on the negative effects of energy consumption on the environment. The DOE for its part, is embarking on a massive educational and information campaign on power conservation dubbed as "Power Patrol." The program is waged in three broad fronts: household and villages, commercial/industrial, and school and education sectors to inculcate the value of being efficient in electricity use. Various seminars and workshops incorporating energy efficiency technologies and environment concerns are also being conducted regularly.

Fuel switching and the introduction of renewable energy sources has also been encountering several barriers such as high capital costs. Most renewables are costlier than conventional alternatives. If they are to be pursued on a wider scale, economic incentives and technology programs will be needed.

5.0 GOVERNMENT PROGRAMS AND POLICIES TO PROMOTE THE ADOPTION OF MITIGATION OPTIONS

A continuing challenge to the energy sector is the concern for environmental protection in the light of an accelerated volume in energy production and utilization. The environmental policies and instruments are in place to formulate strategies to guarantee an integrated energy-environment approach. The following discussions are based from the 1996-2025 Philippine Energy Plan.

By the end of 1997, feasibility studies on reformulated gasoline, and ecological profiling project are targeted for completion. Emissions inventory shall also be carried out during the year. Meanwhile, the Environmental Framework for Natural Gas Development with its corresponding implementing rules and regulations is expected to be finalized by year 2000.

In the long-term, policy recommendations on environmental management including the identification of sites for possible nuclear power development option shall be in place. Power generation from nuclear energy source is envisioned to enter into the electricity generation picture by 2025. Pilot testing of methane utilization in power plants as a greenhouse gas emissions reduction strategy shall be undertaken. Within this time frame, the completion of energy accounting resources for all sectors - oil and gas, coal, and hydropower shall also be done. Lastly, greenhouse gases particularly CO_2 emissions shall reach sustainable levels through the adoption of commercially viable new and renewable energy technologies like solar, windmills, wind turbines, and mini-hydro, modernization of the mass transport system, and the implementation of appropriate technologies to improve efficiency. With the application of cleaner technologies and improvements in grade quality, coal shall be continuously utilized by the power generation and industry sectors.

5.1 Energy Efficiency and Demand Side Management (DSM)

Improving energy use efficiency has long been identified as one of the most effective ways of achieving energy and environmental goals. A number of energy efficiency programs have been carried out in the country over the last two decades, some of which are relevant to demand side management (DSM). There has been a growing interest in DSM and its relation to energy efficiency improvement and reduction in environmental impacts associated with power system operations. In particular, the implementation of DSM programs is expected to result in the deferment of additional plant capacity which shall serve the displaced peak demand. The intensified activities on energy efficiency program shall result in a cumulative energy savings of about 623 MMBFOE over the 30-year planning period. The impact of energy efficiency program shall translate to a total capacity reduction of 920 MW.

Table 2. ENERGY SAVINGS FROM ENERGY EFFICIENCY PROGRAM
(in million barrels of fuel oil equivalent, MMBFOE)

PROGRAM	1996	2000	2005	2010	2015	2020	2025
a. Energy Audit	0.04	5.08	31.87	71.22	110.57	149.92	189.27
b. Information Campaign	1.43	8.95	24.19	50.14	94.32	166.55	281.97
c. Financing Energy Conservation Program	0.03	0.90	3.38	5.93	8.48	11.03	13.58
d. System Loss Reduction	0.12	7.71	23.65	37.56	51.64	73.05	106.93
e. Energy Labelling Program for RACs	0.15	0.33	0.78	1.33	2.18	3.56	5.80
f. Vehicle Efficiency & Testing Program	0.00	0.08	0.73	2.10	4.10	7.12	11.88
g. Heat Rate Improvement	0.10	1.44	3.84	6.24	8.64	11.04	13.44
TOTAL	1.87	24.49	88.44	174.52	279.93	422.28	622.86

(Cumulative Savings)

Supplementing the power supply expansion projects are a number of demand-side management programs for the residential, commercial, and industrial sectors. These programs include interruptible and curtailable tariffs; efficiency standards for window-type airconditioners, refrigerators, electric fans, and fluorescent ballasts; energy-efficient lighting programs; standards for new commercial building construction; and use of higher efficiency electric motors.

The implementation of DSM programs shall result in a cumulative energy savings of over 15.3 MMBFOE by 2005. By 2015, cumulative savings is expected to reach 78.9 MMBFOE. At the end of the planning period, energy savings shall amount to 189.9 MMBFOE. Peak demand savings shall range from 20 MW to 450 MW in 1996 and 2005, respectively. Peak demand savings shall total 829 MW at the end of the planning period. The bulk of capacity savings shall come from interruptible and curtailable tariffs, as well as high-efficiency motórs.

Table 3. PEAK DEMAND SAVINGS FROM DSM PROGRAM
(in Megawatts, MW)

PROGRAM	1996	2000	2005	2010	2015	2020	2025
a. Interruptible/Curtailable Agreements	3	56	113	207	212	218	223
b. Motor Duty Reduction	0	19	77	199	204	209	214
c. Refrigerator Standards	0	7	38	68	70	71	73
d. Ballast Standards	0	7	51	94	96	99	101
e. Fluorescent Lamp Change-Out	0	33	69	82	84	86	88
f. Window Aircon Standards	17	42	80	82	84	86	88
g. Commercial New Construction	0	3	8	20	21	21	22
h. Fans Standards	0	2	10	16	16	17	17
i. Low Income Lighting	0	1	1	1	1	1	1
j. CFL Loans	0	9	3	0	0	0	0
TOTAL	20	179	450	769	789	808	829

(Cumulative Savings)

5.2 DSM Programs

The medium-term and long-term power planning study for the Philippines has designed the following practical and implementable DSM programs:

- Multi-Sectoral Programs

  - High Efficiency Fluorescent Lamp Program (all sectors: residential, commercial and industrial). *Since fluorescent lamps are the primary lighting source in all sectors, lamp manufacturers shall be encouraged to switch from 40-Watt and 20-Watt lamps to 36-Watt and 18-Watt lamps, respectively. As in other countries, the program is attractive to manufacturers since smaller and more efficient lamps use less material and cost less to manufacture than the traditional lamps.*

  - Low-loss Magnetic Ballasts (all sectors: residential, commercial and industrial). *Magnetic ballasts use approximately one-fifth of energy required for fluorescent lighting. The DOE through the FATL shall test ballast performances and offer to the manufacturers a voluntary labelling program such as wattage loss number printed on ballasts. Standards will likewise be attached to avoid illegally-manufactured ballasts.*

  - Window Unit Air-conditioners (residential and commercial). *The recommended program design builds on existing energy conservation efforts. The existing minimum efficiency standards and labelling programs shall be continued and extended to duty-free goods. Minimum EERs for the units shall be increased to continue the trend of market transformation and to bring the country's standards in line with other countries. Following the program, a total of 0.1 MMBFOE can be saved for the year 1995.*

  - Interruptible/Curtailable Agreements (large commercial and industrial). *The program calls for large customers to reduce load by turning on generators during peak load hours or cutting their power requirements by shifting production schedules to non-peak periods. Incentives shall be provided to customers who enter into voluntary curtailable service agreements.*

- Residential Sector Programs

  The following programs, mainly testing, labelling and standards, have been identified to promote the efficient utilization of energy for the residential sector:

  - High Efficiency Refrigerators. *Negotiations between FATL and the manufacturers on refrigerators testing and labelling program shall result in the labelling and certification of energy efficient units. Distribution utilities shall provide for the market efficient units to* *encourage manufacturers to produce efficient models.*

- High Efficiency Fans. *The project will develop a labelling program and standards to gauge the energy efficiency performance of fans. With the approval of manufacturers, energy efficiency labelling can be instituted.*

- Compact Fluorescent Lamps (CFLs). *The initial stages of the program will be focused on completing the CFL reliability testing and working with manufacturers to increase lamp reliability, after which a low-interest loan or other promotion methods will be carried out by the distribution utilities. To reduce the price of CFLs, import duty reduction for CFL components shall be pursued.*

- Low-income Incandescent Replacement with Fluorescent Lamps. *The program specifically addresses the needs of low-income customers by replacing incandescent lamps with 18-watt straight tube fluorescent lamp and low loss ballasts which will reduce the occupants' electricity consumption and distribution to the system peak demand by 60 to 75 percent.*

- Commercial Sector Program

  To complement the existing energy efficiency building code for large commercial establishments, program efforts shall be focused on institutionalizing mechanics that would ensure compliance with the code. Incentives shall be given to building owners and designers whose building designs comply with the standard Code by more than 20 percent. With the implementation of the Guidelines for Energy Conserving Design for Buildings and Utility Systems in 1994 as referral code to the National Building Code, maximum compliance by large establishments is anticipated.

- Industrial Sector Program

  The large volume of energy consumption of the industrial sector prompted the Department to develop a program that will maximize the utilization of energy such as the High Efficiency Motors and Variable speed drives. Since energy-efficient motors and variable speed drives are not available in the local market, import duty reduction from 30 to 10 percent shall be implemented. Motor efficiency criteria shall be established while the list of certified rewinding companies shall be disseminated to industrial customers.

- Public Sector Program (Street Lighting)

  Specific program for the public sector will be on high pressure sodium street lighting [replacing mercury vapor (MV) street lighting]. While street lighting consumes less than 5 percent of electricity, it nonetheless contributes to the peak demand of most grids. Improved street lighting offers a range of societal benefits not easily incorporated into a standard cost-benefit analysis: lowered maintenance costs and higher lighting levels resulting to increased safety on the streets.

6.0 SUMMARY

The growing concern on energy-environment related issues such as CO_2 emissions and its long-term consequences on global warming and climate change has imposed new dimensions on the formulation of national and international policies for security of energy supply and rational and efficient use of energy. Hence, today's planning considers the environmental dimension, formulating the right mix of policy instruments such as legislations and regulatory measures, economic and financial incentives. This brings us to a line-up of strategies or countermeasures to provide adequate and reliable energy supply with the end in view that energy will be used efficiently and in the most environmentally sustainable manner.

A more coordinated policy in the Philippine energy sector has developed significantly since the oil crisis, bringing into focus energy efficiency and environmental sustainability while maintaining security in energy supply. Starting with 92% dependency on imported oil in 1973 and bringing it down to a level of 51% in 1996 proved the effectiveness of a balanced mix of strategies mostly based on the use of domestic energy sources, new and renewable energy, and efficient utilization of energy. Long-term perspectives in energy policy paved the way to the establishment of a good domestic market, creating greater demand for energy-efficient and environmentally friendly products, equipment, and technologies.

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ANNEXES

Table A.1. CO_2 Inventory From the Burning of Fossil Fuels (1990)

Activity	CO_2 Emissions (kT)		% of Total
I. ENERGY AND TRANSFORMATION		12,115	32%
1. Power Generation	10,595		
2. Petroleum Refinery	1,520		
II. INDUSTRY		8,450	22%
1. Iron and Steel	477		
2. Chemicals	342		
3. Paper, Pulp & Prtg.	452		
4. Food, Tobacco	1,440		
5. Cement	2,106		
6. Mining	1,618		
7. Fertilizer	76		
8. Logging/Wood	180		
9. Textile Mills	383		
10. Glass Manufacturing	247		
11. Ceramics	68		
12. Rubber and Tires	77		
13. Construction	169		
14. Others	803		
III.TRANSPORTATION		10,640	28%
1. Road	9,290		
2. Domestic Marine	914		
3. Aircraft	455		
IV. AGRICULTURE		640	2%
V. COMMERCIAL		1,703	4%
VI. RESIDENTIAL		1,862	5%
VII. OTHER		2,861	7%
TOTAL		38,272	100%

Source: Francisco, R.V., PAGASA.

Table A.2. CO_2 Emission From Fossil Fuel Use for Combustion (1990)

Fuel Type	Consumption, TJ	Actual CO_2, Gg
Crude oil	460,399.41	33,425.00
Gasoline	-8,875.18	-608.90
Kerosene	0.00	0.00
Jet fuel	-14,876.96	-1,053.07
Diesel	11,908.47	873.20
Fuel Oil	22,597.33	1,730.80
LPG	7,349.26	458.86
Avgas	195.61	14.20
Bitumen	-35.59	-154.03
Sub-bituminous	49,063.35	4,619.09
Non-fuel usage	-11,259.13	-1,032.86
Total	516,466.57	38,272.29

Source: Geosphere Technolgoies, "GHG Sources and Sinks in the Philippines, 1995."

Table A.3. CO_2 Emission Outlook, 1996-2025 (Gigagrams, Gg)							
Energy Source	1996	1997	2005	2010	2015	2020	2025
Oil	46,070	61,700	73,770	97,480	123,410	162,810	203,880
Gas	50	40	7,250	13,440	19,270	33,540	49,320
Coal	12,235	26,900	42,640	65,990	123,540	176,030	226,790
Hydro	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0
Woodwaste	19,582	20,702	23,008	25,788	29,255	33,659	39,402
Municipal Waste	0	0	0	1,234	1,851	2,159	3,084
Bagasse	3,096	3,918	5,213	6,888	9,041	11,806	15,344
Coconut Residues	2,512	3,182	4,155	5,294	6,629	8,181	9,989
Rice Residues	821	1,103	1,539	2,118	2,872	3,855	5,129
Animal Manure	168	537	1,038	1,591	2,196	2,859	3,583
Black Liquor	52	55	58	61	65	68	71
Others	0	130	390	560	1,000	4,620	10,716
Nuclear	0	0	0	0	0	0	0
Total CO_2	84,590	118,280	159,070	220,440	319,130	434,600	557,290

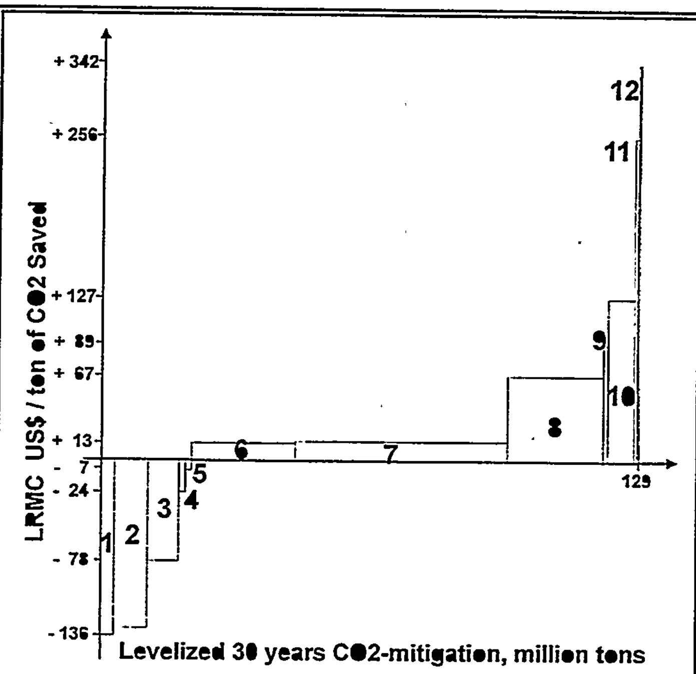
Source: Philippine Energy Plan (1996-2025)

Table A.4 COMPLETED FOREIGN-ASSISTED PROJECTS ON ENERGY EFFICIENCY AND ENVIRONMENT (1982-1995)

	Project Title	Duration	Donor Agency
1.	Industrial Energy Audits and Conservation Program for the Philippines	1982-1983	ADB
2.	Industrial Energy Management Consultancy Training (Phase I)	1983-1987	UNDP
3.	ASEAN-Australia Non-Conventional Project on Energy Conservation	1984-1987	AIDAB
4.	ASEAN-US Project on Energy Conservation in Buildings	1985-1990	USAID
5.	World Bank/TAC-SAL II	1986-1989	WB
6.	Technology Transfer for Energy Management (TTEM) Demonstration Loan Fund	1987-1990	USAID
7.	Philippine-German Rational Use of Energy	1987-1993	FRG
8.	Industrial Energy Management Consultancy Training (Phase II)	1989-1992	UNDP
9.	Industrial Combined Heat & Power Systems Development - Swedpower (Phase 1-3)	1990-1994	BITS
10.	ASEAN-Australia (P1) - Energy Conservation for Industrial Equipment & Processes	1990-1994	AIDAB
11.	ASEAN-Australia (P2) - Energy Analysis and Modelling of Buildings	1990-1994	AIDAB
12.	CO_2-Mitigation Project	1994-1995	FRG/GTZ
13.	Environmental Manual for Power Development	1994-1995	FRG/GTZ
14.	Industrial Combined Heat & Power Systems Development - Swedpower (Phase 4)	1995	BITS
15.	Highly Energy Efficient Designs for Industrial Fans and Blowers	1995	UNIDO
16.	Database Development Program	1995	NEDO

Notes: (1) ADB - Asian Development Bank; (2) AIDAB - Australian International Development Assistance Bureau; (3) BITS - Swedish Agency for International Technical and Economical Cooperation; (4) FRG - Federal Republic of Germany; (5) GTZ - Deutsche Gesellschaft fur Technische Zusammenarbeit (German Agency for Technical Cooperation); (6) NEDO - New Energy and Industrial Technology Development Organization of Japan; (7) UNDP - United Nations Development Program UNIDO - United Nations for International Development Organization; (8) USAID - United States Assistance for International Development; (9) WB - World Bank

Figure A.1: Cost Analysis for CO_2 Mitigation Scenarios



Source: CO_2 Mitigation Study.

Table A.5. RELATIVE IMPACT OF LISTED 12 SCENARIOS	
Scenario	%
Heat rate improvement in fossil fuel power mix	39.50
Improvement in distribution and transmission efficiency	20.00
Fuel and electricity savings in industry	17.90
Hydro power instead of coal power	6.50
Natural gas combined cycle instead of coal power	5.60
Geothermal power instead of coal power	4.90
Compact fluorescent lamps replace incandescent light	2.30
Efficient ballasts	1.30
Efficient air conditioners	1.00
Efficient refrigerators	0.80
Photovoltaic power	0.12
Wind power	0.03
Sum	100.00

Source: CO_2 Mitigation Study.

ISSUES IN DEVELOPING A MITIGATION STRATEGY FOR BANGLADESH

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A paper presented at the International Workshop on GHG Mitigation
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Issues In Developing A Mitigation Strategy For Bangladesh

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I. INTRODUCTION

1.1 Rationale for a Mitigation Strategy

Bangladesh, it is by now well-known, is at the receiving end, in the literal sense of the term, of the global climate change and its potential impacts. She contributes very little to the current global emission of green house gases (GHGs). The Emission Inventory under the present umbrella project, Bangladesh Climate Change Study (BCCS), has found that her annual emission of carbon has been only 3.99 mn metric tons per year. An earlier study (ADB : 1994) arrived at exactly the same figure. The figures for estimated release of methane is far less firm. The estimated methane emission in 1990 could be anywhere between 1 million and 6 million metric tons. In any case the total emission is unlikely to be more than one-half of one percent of the global total (Topping et al : 1991). On the other hand, however, she faces spectre of widespread and more frequent floods, more frequent droughts, cyclones and above all sea-level rise (SLR) which may inundate a substantial part of the country all of these bringing in immeasurable misery and destitution and loss of income, employment and growth. One would expect that in such a situation, Bangladesh's basic concern should be to prepare an appropriate adaptation startegy. This is already a major policy concern of the Government. There is, however, an increasing realisation that Bangladesh should as well emphsise an appropriate mitigation startegy (MS). There may be at least three reasons why this should be so.

The first among these is that as a signatory to the Framework Convetion on Climate Change (FCCC), the country is pledge-bound to take measures as appropriate to reduce the net release of GHGs. But more importantly and this is the second reason, as a developing country on the threshold of major growth prospects in the medium term, if not the immediate future, her consumption of energy and consequently the emission of green house gases, particularly of CO_2, is likely to increase fast. Indeed, the developing countries as a whole may account for a substantial share of the future net emission of GHGs. Third, Bangladesh depends on imports for much of its fossil fuel-based energy supply while the domestic supply of natural gas is likely to dwindle to insignificance in a matter of decades (see later). A strategy to minimise energy consumption thus serves the purpose of limiting GHG emission while conserving energy and saving at the same time scarce foreign exchange resources. On each of these three counts therefore, one should have a well-though out mitigation strategy.

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While the rationale for a well-thought mitigation strategy, on the basis of the above discussion may be accepted, the basis for such a strategy, viz., relevant, data, information and their analysis are in general lacking as there is very little by way of Bangladesh-specific studies on mitigation strategies. All the available studies on climate change in Bangladesh (ADB : 1994; Asaduzzaman : 1991; Asaduzzaman : 1995b; BCAS : 1993; BUP/CRU : 1993. Mahtab : 1989) emphasise analysis of vulnerability and an adaptation strategy. Only the Asian Development Bank study (ADB : 1994) discusses mitigation strategy in a very broad way. Even then, ADB study focussed on the estimation of emission on the basis of aggregate consumption of fuels and energy and as such was unable to specify areas with an exception or two where the mitigation attempts should be concentrated and how.

Little analysis exists on the sectoral sources of emission. Nor is the role of the structure of demand in influencing energy consumption and consequently emission has been little appreciated. The lack of these information and their analyses quite obviously mean that the evaluation of any proposed mitigation strategy is also lacking.

This paper based mainly, though not entirely, on the the data and anlysis of the on-going work on the development of a mitigation strategy for Bangladesh under the USCS Programme attempts to put together some of the salient issues that one needs to consider in the development of such a strategy. The objectives of a mitigation strategy (MS) study is to understand the prospects and consequences of a policy (or a set of policies) to limit the net release of green house gases (GHGs) into the atmosphere either through the reduction of emission or increasing the sink to absorb the gases. Any MS has to have the following as its broad essential elements:

- an analysis of sources and sinks of green house gases;
- an analysis of the technology in use in both the energy-supplying and energy-consuming sectors;
- an analysis of the costs of any proposed MS; and
- an analysis of the instruments for and obstacles to the implementation of the proposed MS.

To put the discussion in its proper perspective, therefore, one needs first to conceptualise a mitigation strategy. These are dealt with in the next section which is followed, in Section III, by an analysis of the present and future GHG emission and energy use in Bangladesh. Section IV deals with the implications of the patterns and characteristics of use and supply of energy. The implications include the costs of operationalising any MS, and of course the feasibilities of various instruments and policies.

II. PRINCIPLES OF MITIGATION

2.1 Country-specificity and Generic Response Options

The absence of a Bangladesh-specific study makes one search for analyses which focus on other, particularly developing, countries. As countries vary widely in their social, economic, political, legal and administrative structures and natural resource endowments or capability to resort to trade to ensure supply of fuels and energy, one may perhaps try to have some ideas about the mitigation strategies which are truly generic rather than country-specific. For the most recent and an authentic discussion on these issues see Jepma *et al* (1996). The first point to be noted is that there are differences in mitigation options regarding CO_2 and other GHGs in that the former is almost entirely oriented towards energy-production and/or consymption while the others are not so. In the Bangladesh context, the major GHG, apart from CO_2 is methane which is emitted mostly in course of crop and livestock production while others like land-fills are as yet minor activities. While we are focussing on energy we will later in this section briefly discuss the issue of methane.

2.2 The Nature of Sectoral Focus

We will later see that sectoral focus is a major issue. Such focus, however, may be either from the point of production or from that of consumption. Asaduzzaman (1995b), for example, has shown that on the basis of absolute emission, the following sectors are important (with percntage share of total emission due to inter-industry demand in parentheses): industries (29%), power generation (20%) and transport (37%). The average emission for the economy as a whole in production activities is 4.8 metric tons of C per million taka of value added. For the three above sectors, the estimated emission intensities are respectively 13.1 mt, 274.5 mt and 25.9 mt of C per million taka of value added. When the sectoral emissions are related to the structure of final demand it is found, however, that major emitting sectors are crops (12%), industries (15%), gas (21%), transports (24%) and construction (9%). Electricity being used mostly for intermediate production purposes power sector is not a major emitter on the basis of final demand.

What these figures indicate is that while industries, electricity generation and transport are major emitters because of the production technology in use, others like construction are major emitters because the sector has to use as inputs output from other sectors which themselves are emission-intensive (e.g. industries and transport services). A proper mitigation strategy therefore should look into both sides. Thus, the sectors which should receive attention include industries, transport and power generation in the production process of goods and services in those sectors. Additionally sectors where demand management and technological change by demanding less from emission-intensive sectors may help mitigation include crops, industries, construction, gas and transport.

2.3 Principles of Mitigation

The literature distinguishes in case of CO_2 between source-oriented measures and sink-enhancement measures. The former includes energy conservation and efficiency, fuel switching, recourse to renewable energy and nuclear energy while the latter includes capture and disposal of CO_2 and enhancing forest sink.[2] The first type of measures can be put in their context with the help of the *Kaya* identity (Yamaji *et al* : 1991). The identity is shown as

[2]Of course there are many exotic ideas regarding mitigation. These include geoengineering, orbital shades, iron fertilization, cretaing algal blooms and weathering rocks. While these are yet to be demonstrated to be practicable in large application, these are also likely to have other possibly very large and adverse environmental impacts.

$$C = (C/E) \times (E/G) \times (G/P) \times P \quad ..... \qquad (1)$$

where C = carbon, E = energy,

G = gross domestic product (GDP) , P = population,

C/E = carbon intensity of energy use/supply,

E/G = energy intensity in the economy,

G/P = per capita GDP.

Quite naturally, carbon emission can fall, among others, if any of the carbon intensity of energy, energy intensity of value added, per capita energy use or population falls while the rate of change in the emission of carbon is an additive function of the rates of change of the four components on the right hand side of the identity (1).[3] It is hardly ever likely that population will fall in a populous country such as Bangladesh although its rate of growth can be substantially slowed down. All countries, most of all developing countries, would wish a faster growth in GDP per capita. *This leaves only decarbonisation of energy production/use and lowering energy-intensity as the only major ways in which carbon emission may be reduced.*

Decarbonisation would mean switching to less carbon-intensive fossil fuels (e.g. from coal to natural gas in production processes or consumption) or to energy production processes which are carbon-free (e,g, nuclear and renewable energy including biomass where periodic consumption balances production over a given period). Only the switch to natural gas and balanced use of biomass are of relevance in the Bangladesh's present context.

Potentials for decarbonisation of energy use is often dependent on the availability of specific sources of energy in any given country. As a result, much of the attention in the literature has been given to energy-intensity which is influenced by, apart from waste reduction, two factors, viz., energy-efficiency of the technology of production, distribution and consumption and the structural shifts in the economy.

In most developed countries, there has been of late a major shift away from material production to service provision the latter being much less energy-demanding than the former. Developing countries, on the other hand, are generally in the materials production phase of the development process while many are also in the most energy-intensive industrial growth phase. Such a situation precludes a general possibility of lowering energy consumption through a structural shift in the economy. Thus, for an initial understanding of the scope for lowering energy use and mitigation in developing countries such as Bangladesh, one needs to look at energy intensity and energy efficiencies at national, sectoral and individual industry/activity levels .

Apart from the technical possibilities and their economic implications and feasibilities, one also needs to look at the institutional arrangements which a country historically has developed for managing the energy sector. For example, while price of energy is likely to exert a strong influence on its demand, one may not be able to raise or lower prices at will; nor does any such change may mean much if many of the major users are in the public sector managed under what may be called a soft budget constraint under which the additional costs to the sector may simply be absorbed by the Government thus providing no incentive to the sector to economise on energy use by cutting down on wastes or investing in more efficient technologies.

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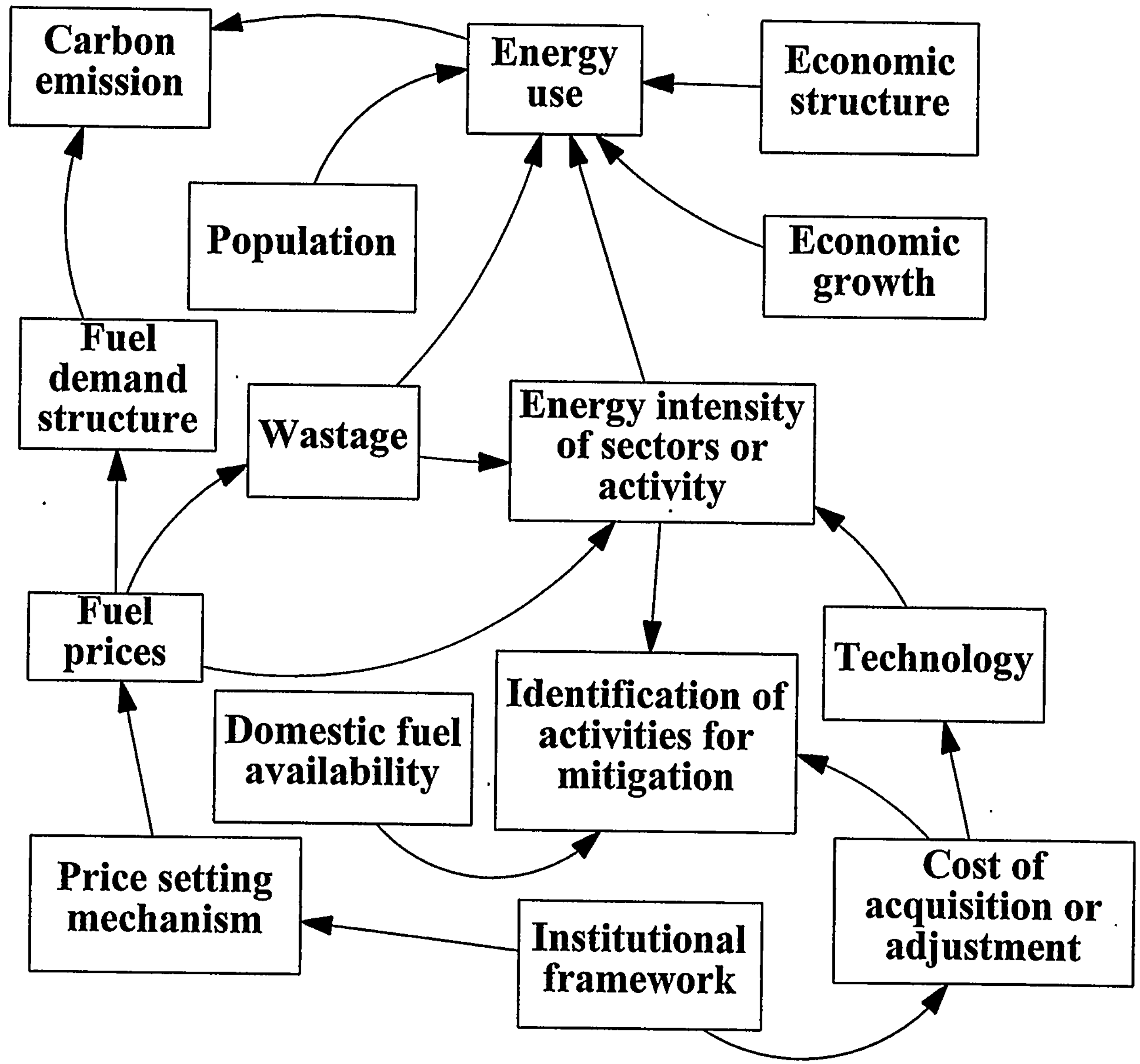
[3]This can be easily verified by taking logarithms on both sides anddifferenting with respect to C.

A mitigation strategy therefore may have look into many factors and variables. A snapshot of these variables are given in Figure 1.

Methane

In this paper we shall concentrate only on CO_2. As noted earlier, however, Bangladesh being a major rice growing country, is likely to be a major emitter of methane as the practice keeping the field in flooded condition for the cultivation of rice paddies is known to give rise to methane emission. We therefore discuss a point or two before moving on to our focus proper.

A Model of Mitigation Factors



Apart from rice paddies, other sources of methane include enteric fermentation in ruminant livestocks (cattle and buffaloes), land fills and leakage from gas pipelines or at well-heads. Anaerobic fermentation of animal waste also give rise to methane emission. Except for the emission from livestocks, other sources are likely to remain minor ones for quite some time to come. Also note that despite her being a major methane emitter does not make her a GHG emitter in aggregate of any significance. Further, there are major uncertainties regarding the emission level due to rice cultivation. The only certainty seems to be that agronomic practices do have a major bearing on these emissions. For example, experiments in Texas, USA indicate that a single draining of the rice field in the middle of rice season may lower methane emission by nearly 50% while multiple aerations may do so by 85-80% over the emission due to normal flooded conditions in the field (Sass : 1993). While the exact reduction in methane emission may vary by cultivar in use and other socio-economic and agronomic factors, such results do indicate that countering methane emission from rice fields may have to be through possible changes in agronomic practices which as yet are not known with certainty and remains to be firmed up through appropriately designed research.

Uncertainties similar in nature to that of methane emission from rice fields exist also in case of that due to enteric fermentation in ruminant livestock. Given such uncertainties, the general solution to the problem lies in increasing the productivity of these animals. This probably is more so in Bangladesh which has one of the largest concentrations of such animals compared to other countries in South and South-East Asia while the productivity are very low in terms of milk, meat and draught power services. Little Bangladesh-specific scientific information. however, exist to analyse the relevant mitigation options in this sub-sector. Experiments are therefore needed for understanding these potentials in Bangladesh's socio-economic context.

Forest as a sink

Carbon can be removed as a by-product of certain processes before it enters the atmosphere or it can be locked in sinks. Among the latter while there are other ways like weathering of rocks or iron fertilization, the major practical option and of comparative ease of application on a wide scale is forestry. The attractiveness of forestry arises from its multi-dimensional benefits (provision of food, timber, fuelwood and conservation of bio-diversity and the like) in addition to storage of carbon. While there are uncertainties in Bangladesh regarding the exact contribution of forestry as a sink in the face of widespread deforestation there probably is a substantial scope for enhancing it.

Low costs are an attractive feature of carbon squestration through forestry (Sedjo : 1995). Still, the scope for expansion of forestry is in ultimate sense limited as the opportunity costs of transferring land from other uses such as crop cultivation particularly in densely populated countries may become prohibitive after a certain level forest cover on land is reached.

2.4 Global Experiences in Energy-savings

A brief mention should be made here, to provide ourselves with a yardstick to measure the efficacy of the mitigation measures, about the actual experiences in various countries including the developing ones regarding energy savings. For details see Asaduzzaman (1995a). Over nearly two decades, 1970-1988, the world-wide use of energy-intensity has fallen by just over one-half of one percent. The experiences across countries as a whole and even for the same type of activity and between sectors within the same country have, however, generally been uneven. Rates of annual improvement in energy-intensity varied in the industrialised countries from 1.2% in Western Europe to 2.2% in Japan with the USA falling in between (1.83%). The fall in sectoral intensities has not been uniform likewise even within the same country. Thus, while refrigerators in Japan consumed only one-third as much energy in 1987 compared to 1973, the fall in case of motor cars had been 50% or so. Steel-making, one of the major energy-consuming industry, showed variable rates of improvement in the industrialised countries indicating obstacles to gains in energy-efficiency.

The developing countries experiencing energy-savings include mostly the East Asian countries of China (31% over 1970-88 mainly due to increased energy-efficiency in industry), Taiwan and South Korea (by around 40% due to increased energy efficiency). In contrast some South Asian countries (like Pakistan and India) increased their energy intensities by a quarter while Malayasia increased it by twice as much over about two decades since 1970.

A lack of cost-effective techniques is not usually, in a narrow sense of the term, a factor inhibiting energy-savings while costs are important. The total costs (including subjective costs as manifested through very high implicit discount rates in adoption of energy-efficient devices) of change and adjustment, whether private or social, may be substantial in some of the countries. One therefore should assess the mitigation options carefully.

2.5 Evaluation of Mitigation Options

There can be in general two types of assessment of any mitigation option. One may use a so-called engineering efficiency approach in which the financial costs of any given emission level is minimised. In contrast one can use a welfare-theoretic approach in which the costs of resources expended are expressed as the opportunities foregone. The information requirements for a full welfare-assessment, however, may be quite forbidding and it may not always be possible to take into account all the externalities which differentiate private (financial) costs from social (economic) costs.

A second way of looking at the assessment is the level of aggregation one may use. The most desegregated is the specific project level or option-specific assessment where either socail cost-benefit analysis or minimisation of cost is conventional. One will have to first assess, however, from an over-all perspective the desirability of accepting one over the other. More interesting from a policy perspective, therefore, is an integrated assessment which indicates the optimal mix of various response options (as to fuel-mix, technology-mix and their temporal sequence) given various constraints any given economy may face. Note that optimality here is only relative, not absolute. It has to reflect the priorities (or constraints) a nation attaches (faces) to (in) mitigation efforts in relation to other social goals (e.g. employment creation).

Both top-down and bottom-up approaches have been used in integrated assessment. While both have their strengths and weaknesses, the bottom-up approach because of its rich details of technological options for energy supply and demand and the associated emission levels are rather attractive. One of the representative studies in this tradition is Kram (1993) who reports the results of application of a particular optimisation model, MARKAL or its variants, for eight countries.[4] Others in the similar tradition include Huang *et al* (1995) for Taiwan. MARKAL is versatile enough to be applied also for specific mitigation options too. See Morris *et al* (1992).

While MARKAL or M-M is versatile, it does not answer some of the key questions that a policy planner in a developing country such as Bangladesh may ask. For example, it does not say what would be the impacts on poverty or employment, although MARKAL-MACRO (M-M, an extension of MARKAL) can give ideas about the changes in income or rather the utility derived from consumption arising out of income that is possible in a MARKALesque world. Either MARKAL or M-M therefore has to be modified to take these issues into account or supplementary analyses will have to be made for the purpose.

III. GHG EMISSION AND ENERGY USE : CURRENT SITUATION

3.1 Green House Gas Emission and Energy Use

Green house gas emission in Bangladesh in 1990 has been estimated to be 14407 Giga grams of carbon di-oxide which is the major such gas (Table 1). The next in importance is methane. Others are of little significance as yet. The source of CO_2 is mainly the use of energy in one form or other. In case of methane, however, livestock rearing and rice cultivation appear to be the main sources although biomass-burning also contributes significantly. It is of interest to note that land use changes in terms of increased forest (tree) cover may have had a net sink effect.

Table 1
GHG Emission/Absorption in Bangladesh
(1990)

Sources/ sinks	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)
Energy use	14680		165	5964	2197
-Commercial	14680		-	-	-
-Biomass	-	166.6	165	5964	2197
Cement manuf.	87		-	-	-
Energy prodn.	-	6	-	-	-
Land use change	-360	-	-	-	-
Rice fields	-	439	-	-	-
Livestock	-	526	-	-	-
Landfills	-	74.5	-	-	-
All	14407	1212.1	165	5964	2197

Source : Emission Inventory under Country Study
Note : Biomass, on balance, is assumed to give rise to no CO_2 emission.
Landfill includes waste water.

[4]The countries are Belgium, Canada,Japan,The Netherlands, Norway, Sweden, Switzerland and United States.

3.2 Characteristics of Energy Supply and Use

Concentrating now on CO_2 and its underlying causes we observe that in 1989/90, the energy supply and use has been characterised by a heavy dependence on biomass (Tables 2a and 2b). On the side of supply, 65% of the primary supply of energy has been from biomass like agricultural residues, fuel wood, animal residues and other biomass. While the primary supply of commercial energy use has been only about half as much, more than half of it had been from natural gas of which the country has a
fair amount of reserve (see later). Much of the rest of primary supply of commercial energy has been from imports of crude oil for refining and other petroleum products. There is only a little hydroelectricity production.

On the side of demand, the overall picture mirrors that regarding supply in that only a little more than a quarter of energy consumption is from commercial sources, the rest being from biomass. The latter is mainly used for cooking in the residential sector. Concentrating now on the commercial energy, it is found that, residential, industrial and transport demand dominate the use of commercial energy. Furthermore, the consumption in the agriculture sector for running irrigation machines and also for tillage purposes is not inconsiderable.

Table 2a
Energy Supply in Bangladesh
(1989/90)

(Tera joules)

Flow	Commercial	Biomass	Total
Supply			
Primary production	169.4	499.1	668.5
Import	113.8	0	113.8
Export	-6.3	0	-6.3
Stock change	-12.7	0	-12.7
Total primary supply	**264.2**	499.1	**763.3**
Transformation			
Refinery	-4.4	0	-4.4
Thermal power station	-53.7	0	-53.7
Losses and own use	-22.2	0	-22.2
Total final supply	**183.9**	499.1	**683.0**

Source : Task Force : 1991 (Vol. Three), pp. 96-97.

3.3 Natural Gas Supply and Use

3.3.1 Supply of Gas

Bangladesh has a fair amount of natural gas in 17 gas fields. Of late there had been three more discoveries including one off-shore (with a preliminary reserve estimate of 1 TCF and another in an island with a preliminary reserve estimate of 0.6 TCF. The total gas in place is 21.35 billion cubic feet of which about 60% is recoverable of which about 20% has been produced so far and the rest 80% remains to be produced. By world standards, these are certainly not very high reserves or rates of production. Yet, the consumption of gas has increased rather fast (see below) over the

Table 2b
Energy Demand in Bangladesh
(1989/90)

(Tera joules)

Sector	Commercial	Biomass	Total
Residential	37.8 (30.3)	404.6 (81.1)	442.4
Industrial	40.5 (32.4)	92.6 (18.5)	133.1
Commercial	7.1 (5.7)	1.8 (0.4)	8.9
Transport	27.6 (22.1)	0	27.6
Agriculture	11.9 (9.5)	0	11.9
Others	0.3	0	0.3
Non-energy	58.7	0	58.7
Total	**183.9 (26.9)**	**499.1 (73.1)**	**683.0**

Source : Task Force : 1991 (Vol. 3), 96-97.
Note : Figures in parenthese under the last row are percentages of total use of energy while those in other rows are percentages of total energy use in all the sectors adjusted for non-energy use.

past years, so much so that the reserve may not be expected, unless new large fields are discovered, to last beyond several decades. For example, in June 1995, the recoverable reserve has been 9959 BCF. At the rate of production existing at that period, the recoverable reserve to production ratio was 38.5 i.e. if production continues at that rate the reserves would last for more than 38 years (Table 3). By 2010, however, the level of use is expected to rise fast so much so that, by that time the reserve to production ratio would fall to 13 or so. Thus, if the demand behaves in a manner as visualised or rises faster the gas may last only 27 years or less rather than 38 years.

Table 3
Depletion of Gas Reserves
(Reference case)

Period	Gas reserves (BCF)	Reserve/ production ratio
June 1995	9959	38.5
June 2000	8517	26.6
June 2005	6798	18.3
June 2010	4923	13.1

Source : ADB : 1996.

3.3.2 Consumption of Gas

The pattern of consumption of gas in 1989/90 and in 1994/95 are shown Table 4. It shows that while in a span of five years the consumption has increased by nearly 30%, the structure of demand has remained unchanged. Nearly half of the total gas output is used for generation of electricity while more than a third is used for producing urea. Power and industries therefore together account for nearly 80% of the total use of gas while much of the rest is consumed in the homes.

3.3 Price of gas

The price of gas is a major issue of energy policy and may or may not prove to be a major instrument for mitigation depending upon how the givernment fixes the price. The current price levels are shown in Table 5.

Table 4
Consumption of Natural Gas by Sector
(million m^3)

Sectors	1989/90	1994/95
Power	2099 (46.6)	2755 (46.2)
Fertiliser	1591 (35.3)	2110 (35.4)
Other industries	453 (10.0)	572 (9.6)
Commerce	89 (2.0)	82 (1.4)
Residential	273 (6.0)	436 (7.3)
All	4505	5955

Source : BBS : 1995 and ADB ; 1995
Note : Figures in parentheses are percentages of total use

Table 5
Existing Gas Price Structure by Consumer Category
(US $ / MCF)

Consumer category	Base price	Tax	Price including tax
Residential	0.93	1.13	2.06
Commercial	1.66	2.03	3.69
Seasonal	1.27	1.56	2.83
Small industry	1.16	1.42	2,58
Large industry	1.16	1.42	2.58
Fertiliser	0.46	0.57	1.03
Power	0.54	0.65	1.19
All	0.62	0.75	1.37

Source : ADB, Gas Study (Final Report), p. 49.
Note : Tax rates are uniform at about 120%.

Two points are of note here. The first one is the wide variation in price charged to consumers. The bulk consumers like power and fertiliser sectors pay much lower prices, generally at least 50% lower than others. The second point of note is that the price differential is a reflection of the base price charged to the consumers as the tax rate is similar or the same across categories.

3.4 Electricity Generation, Supply and Consumption

3.4.1 Electricity Generation and Supply

The electricity generation in Bangladesh is mainly dependent on natural gas for fuel while the the dominant technology is steam turbine (Table 6) in terms of installed capacity or actual generation. Combined cycle, apparently the most efficient technology, is yet to be prominent. A little electricity is produced as hydroelectricity.

There are two aspects of efficiency of these technologies in use. One is the technical efficiency based on the heat rates. As Table 6 shows, the efficiency range for the various technologies in use is rather wide. For example, for steam turbines, the range is from 20% to 37%. The second point of note is that the highest efficiency of steam turbine power plants is much higher than that for the combined cycle which is usually taken to be superior and more efficient technology. Such wide variations in efficiency and the lack-lustre performance of supposedly superior technology call for an in-depth investigation of the technical, economic and institutional aspects of operation of power plants, an issue while it is very important is not within the purview of the present analysis.

Table 6
Characteristics of Power Generation

Technology type	No.	Installed capacity (MW)	Gener. Capacity (MW)	Total gener'n (GWh)	Total fuel cost (Mill. Tk)	Efficiency range (%)
Hydro	1	230 (10.3)	230 (11.3)	884.21 (11.5)		
Combined cycle (CC)	1	90 (4.1)	85 (4.2)	509.62 (6.6)	233.02 (0.46)	26.85
Combus. turbine (CT)	11	536 (24.2)	416 (20.4)	1168.98 (15.1)	1118.88 (0.96)	18.09-26.16
Steam turbine (ST)	7	1248 (56.3)	1234 (60.5)	5048.03 (65.4)	1717.96 (0.34)	20.06-37.37
Others	8	113.19 (5.1)	76.05 (3.7)	108.12 (1.4)	70.36 (0.65)	11.96-35.45

Source : ADB, Power System master Plan, 1995.
Note : Figures in parentheses are percentages of the relevant column total except in the column on fuel costs where such figures indicate cost of fuel (in taka) per kwh generated.

The second point refers to the cost of operation, particularly fuel cost. It is seen that the cost of fuel per kwh of electricity generated is the highest on the average for combustion turbine plants while it is the lowest, not surprisingly, for the steam turbines. This again strengthens the view that there is a need for a thorough investigation of the causes of differential efficiencies, be it technical or financial, of the power plants. We would later come back to this question when we judge the future prospects for increased investment in power generation.

In 1990, the gross generation was 7732 GWh while the peak demand was 1509 MW. Net generation in comparison was 7301 GWh and the corresponding peak demand was 1425 MW. In contrast, sales were just about 4405 GWh. The gap between net generation and sales is very large, just about 40% of net generation. This is often dubbed as system loss, part of which is of course unavoidable technical loss of various kinds, but, much of it is really theft without any corresponding payment to the Bangladesh Power Development Board.

3.4.2 Consumption of Electricity

The total sales of electricity over the last few years are shown in Table 7. The residential sector is a major consumer of electricity. So are those who receive power through the 11 KV bulk line, mainly large industries. Over time, however, the importance of the former has increased. Indeed, this has apparently been a long term trend in that in the late eighties, the proportion of power sold to the households had been around 25%. By 1990, it has further increased to 29% (not shown). By 1994, it has increased again to 38%. Over the same time period, the share of 11 KV consumers (mainly industries) have fallen from around 35% to 27%. This had been possible due to a fast rate of growth in domestic consumption, by 15% over 1986-94. Over the same period, sales to 11 KV consumers increased only at 4.3% per annum.

The shares of other types of consumers have remained largely unchanged although light industries have shown a rising trend. So have the share of irrigation. Indeed, while the shares had been low so far, in future these may grow to substantial proportions if the observed rates of growth over the last one decade or so, 17.5% for irrigation and 10.4% for light industries continue.

One may, in view of the very large `system loss' wonder if the above portrays a reality on the ground. To be sure the part which is used but not paid for, is being consumed by somebody somewhere and thus reflects a genuine demand. Who that consumer is remains a big question. We believe that industry (all categories together) possibly accounts for a large part of this discrepancy. We will return to this question shortly.

Table 7
Electricity Sales by Tariff Category
(Giga watt hours)

Year	Domestic	Irrigation	Lt. Indus	Commerce	11 kv Bulk	33 kv bulk	Other	Total
1990	1278.7	143.4	578.1	407.6	1550.2	171.1	275.5	4404.6
1991	1521.4	201.5	624.5	453.4	1507.4	169.7	299.4	4777.3
1992	1663.8	246.4	691.1	468.0	1560.6	166.0	289.6	5085.6
1993	2039.3	276.4	827.6	499.0	1635.4	171.6	299.1	5748.4
1994	2312.9	268.5	967.7	543.7	1657.1	175.7	216.2	6141.9

Source : ADB : 1996.

3.4.3 Electricity Tariffs

Electricity tariffs by the type of consumer are shown in the following table (Table 8). One observes that in comparison to gas, domestic prices appear to be the lowest and the industrial prices are the highest.

Table 8
Electricity Tariffs by Consumer Category

Economic sector	Low cost units (Tk.)	Next units (Tk.)	Other (Tk.)
Industrial	Off-peak	Peak	Demand charge
	1.75/kwh	4.5/kwh	35/kw
Domestic	1st 200 kwh	201-700 kwh	>700 kwh
	1.65/kwh	2.75/kwh	4.50/kwh
Commercial	Off-peak	Peak	Demand charge
	2.45/kwh	6.00/kwh	20/kw
Municipal &	All units	Demand charge	Service
Agricultural	1.75-2.60/kwh	35/kw	25-200/Mo

3.5 Supply and Demand for Petroleum Products

3.5.1 Supply

As stated earlier the petroleum products are generally imported. The country produces a little condensate and also a little oil. In 1989/90, the country imported some 948 thousand mt of crude oil. At the same time 944 thousand mt of other petroleum products were also imported. A little naptha is exported.

In 1992/93, a total of 1.31 million mt of various petroleum products were produced from the refinery (LEAP Report : 1996). The main output had been fuel oil (36%), kerosene (25%), diesel (21%) and petrol (9.7%).

3.5.2 Consumption of Petroleum Products

In 1989/90, a total of 1632 thousand mt of petroleum products were consumed. Of this, as expected, the bulk was for transportation (38%). Residential homes used another 29%. Industries and agriculture used up very similar levels of petroleum products (around 15% each).

3.6 Energy Intensities

Earlier we have discussed at length the problem of de-carbonising energy use where it has been pointed out that lowering energy intensities through raising energy efficiencies is a major way for doing so. One needs therefore to have an idea of these intensities. These information are not at all easily available and had to be culled from various sources and thus may suffer from problems of incomparability. These have been shown first in terms of aggregate sectoral intensities and then in more detail by activity by sector.

The aggregate intensities are shown Table 9. As expected, the intensity is the highest for industry. But, industries is a very heterogenous category including very large and very small and having all kinds of technologies in use. One should therefore look at the figures by activity and by individual consuming industry or where the consumer category can be made somewhat homogeneous. These are shown in Table 10.

The figures in Table 10 may not mean much unless compared with energy intensities elsewhere. For example, in Bangladesh, paper-making is one of the major energy-consuming industries where 11.7 to 18.9 million Kcal of energy is consumed for producing each mt of paper. In contrast, Japan uses only 4.5 mn Kcal, USA : 3.6-7.6 mn Kcal, China : 7.1 mn Kcal, Indonesia : 2.2-5.0 mn Kcal and Thailand : 5.5 Kcal. Only the Indian consumption is somewhat close, 10.1 mn Kcal.

Cement manufacturing similarly is rather inefficient compared to other countries. Compared to Japanese and Chinese industries, the electricity consumption is 69% and 58% higher. Fertiliser industry, in contrast, shows a dramatically different picture. Except for that in the year 1985, the average consumption of energy per mt of urea produced was either comparable to or lower than the international standard. But of late, there is a rising tendency of the energy intensity.

Table 9
Energy Intensity of GDP by Sector
(1989/90)

Sector	Comm. Energy (PJ)	GDP (mn Taka)	Intensity (GJ/mn Tk)
Industry	41.6	45927	906
Commerce	6.1	190708	32
Transport	34.9	58933	592
Agriculture	8.6	190354	45
Domestic	34.3	19.59	1.75
All	125.6	497527	252

Source : Calculated by the author
Note : Industry does not include power and gas nor has energy quivalence of gas in fertiliser been considered.
GDP under domestic row refers to million household year and thus intensity here is GJ/household.

The fertiliser industry, like power plants show a varying degree of energy intensity which is partly determined by the technology in use and other factors. While the issue like that in case of power plants demands a thorough investigation, one may note that the energy-equivalent of natural gas used per mt of urea produced varies from 25 to 66 GJ. Roughly 40-50% of this as energy. The differential therefore persists when energy consumption alone is considered.

Table 10
Energy Consumption by Sector by Fuel/Activity and Energy Intensitiies

Sector	Energy Cons. (PJ)	Energy Intensity
Agriculture	**11.707**	
Diesel tiller	0.63	0.275 GJ/ha
Diesel pump	9.58	2.812 GJ/ha
Electric pump	1.50	0.122 MWh/ha
Commercial	**8.926**	
Coal	0.351	
Gas	3.142	
Electricity	3.618	
Biomass	1.815	
Residential - Urban	**114.937**	
Cooking	*100.359*	
Biomass	81.998	4.48 GJ/person
Kerosene	8.946	4.27 GJ/HH
Natural Gas	9.415	19.52 GJ/HH
Lighting	*14.578*	
Kerosene	10.164	0.99 GJ/HH
Electricity	4.414	438 KWh/HH
Residential - Rural	**317.897**	
Cooking	*313.24*	
Biomass	313.24	4.44 GJ/Person
Lighting	*4.657*	
Kerosene	4.2	0.99 GJ/HH
Electricity	0.457	
Transport		
Car - Gasoline	1.816	1.105 PJ/bill Pass-km
Bus - Diesel	8.560	0.205 PJ/bill Pass-km
Three wheelers-Petrol	2.046	1.12 PJ/bill Pass-km
Trucks - Diesel	9.349	0.506 PJ/bill tonne-km
Rail - Diesel	1.88	3.053 PJ/bill Pass-km
IWT - Diesel	4.778	2.921 PJ/bill Pass-km
Air transport-Jet fuel	3.244	0.496 Pj/mill Pass-km

Sector	Energy Cons. (PJ)	Energy Intensity
Industry	**83.130**	
Rice mill	1.32	1.638 GJ/mt
Firewood	1.11	
Liquid fuel	0.0126	
Natural gas	0.0139	
Electrictity	0.1735	
Refinery	1.95	1.99 GJ/mt
Natural gas	1.94	
Electricity	0.000837	
Sugar	8.42	45.82 GJ/mt
Bagasse	8.37	
Electricity	0.057	
Brick	25.14	9858.82 GJ/mill. brick
Firewood	18.00	
Coal	5.48	
Natural gas	1.66	
Steel re-rolling	2.53	7.06 GJ/mt
Natural gas	2.33	
Electricity	0.20	
Paper and pulp	5.32	
Big units	4.24	63.72 GJ/mt
Natural gas	2.21	
Electricity	0.40	
Furnace oil	1.63	
Small units	1.09	20.16 GJ/mt
Natural gas	0.77	
Electricity	0.28	
Furnace oil	0.03	
Tea processing	0.89	0.02 GJ/kg
Natural gas	0.687	
Electricity	0.113	
Glass sheet etc.	0.49	0.0188 GJ/sq.ft
Natural gas	0.448	
Electricity	0.006	
Furnace oil	0.038	
Fertilizer	35.75	22.14 GJ/mt
Natural gas	22.45	
Electricity	13.31	
Cement	1.32	3.92 GJ/mt
Natural gas	0.038	
Electricity	1.28	

3.7 The Aggregate Picture of Consumption Once Again

It is by now clear that the top-down approach that has been used for the emission inventory is not really suitable for an operationally meaningful mitigation strategy. One needs a bottom-up approach in which the sectors are as further divided into their components by activity, fuel and technology for a really meaningful mitigation strategy. We therefore had to prepare a bottom-up inventory for its purpose. This proved more troublesome that had been thought initially. This is now shown as Table 11.

What the table shows is that the use of energy when all available information are utilised may have been seriously underestimated in case of industries. But in general in most other sectors too there has been some underestimation. In any case, here we see that the total energy use as estimated from a bottom-up approach in indutries is just double the estimate made from aggregate information. The total commercial energy use in 1989-90 thus goes up from 125 PJ to 172 PJ or by more than 35%.

Table 11
Comparative Top-down and Bottom-up Estimates of Final Consumption of Commercial Energy in 1989/90
(Peta joules)

Sectors	Top-down	Bottom-up
Agriculture	8.6	11.7
Commerce	6.1	7.1
Industry	41.6	83.1
Transport	34.9	31.7
Residential	34.3	37.6
All	125.6	171.2

Source : Table 2 for the Top-down column and author's estimate for the Bottom-up column

V. FUTURE ENERGY USE, SUPPLY AND INVESTMENT

5.1 Future Aggregate Energy Use

The future consumption of energy would depend on several factors including its supply, growth in income, structural change in the economy, price changes and similar other factors. However, if one considers the need for energy if the current trends continue or if certain measures towards development of energy are undertaken, then, only factors like income and structural change should perhaps be considered. The Energy Policy of the Government has recently made a projection of such future needs. These are shown in Table 12.

Two points are of immediate note from the table. First, the rate of growth of energy is faster in the reference growth scenario for which the rate of growth of GDP is somewhat higher. Yet, the energy intensity of national income rises less slowly in this case than in the low growth scenario. In both cases, however, the GDP elasticity of energy demand is assumed (?) to be changing (falling) in the same manner (not shown). While it is not clear whether this is actually an assumption or an estimate based on the projected income and energy demand, the fact remains that in the reference scenario in which the rate of growth of GDP is only slightly higher, the projected energy demand by 2020 is nearly 50% above the low growth scenario, points to the explosive nature of the demand for commercial energy. This may happen for because of rising income, rising urbanisation where supply of commercial fuels are more plentiful and assured and because of the substitution away from biomass which may be more expensive over the future.

5.2 Demand for Gas

The rate of growth of the projected demand for energy will not be the same for all types of fuels, nor is it going to be the same across sectors. This can be understood from the two tables for natural gas and electricity (Tables 13 and 14).

The demand for natural gas will rise for two reasons, an increase in the demand for final consumption and as an intermediate input mainly in industries both as fuel and as feed stock and in the power plants. And it may be seen from the Table 13 for the Reference Scenario that while it is the power generation where the consumption may be expected to be more than double over 15 years, such dynamism will also be shown by small industries and also the domestic sector both of which would show similar relative growth. Fertiliser would not consume any more than what it has been expected to consume in 1995. The Ceiling case is characterised by an upper ceiling imposed on yearly production flow from around 2005 which explains for the seeming decline. But if the economy picks up which it may, power, fertiliser and small industries as well as the households would like to consume much more so that the total demand would grow by 18 % over the possible demand for 2010 for the base case.

The issue is can this be supplied. We have earlier pointed to the reserve/production ratio which gives a rough indication that the demand may be met but the gas reserve may be exhausted nearly by 2010. Note, however, that the current producing 17 gas fields have been discovered only with 54 drilling wells, an extremely high success rate. Further, while the gas reserve per well over 1960-95 is lower than in say the major oil-producing countries such as Iran, S. Arabia or Venezuela, compared to other Asian countries these are either at par or above them. Also note that over the last several months, 3 wells, all with possible good reserves have been discovered. Thus, the demand may not simply be met, the recoverable reserve may as well go up in the future.

The further development of the present gas fields may require nearly US $ 400 mn during the next ten years or so. Another large sum of investment would be necessary for developing the transmission and distribution system ($140 mn not including taxes and other similar costs).

5.3 Demand for Power

Table 13 shows that under a reference scenario, the demand for power may rise from more than 4000 GWh to more than 29000 GWh i.e. by a factor of 6. Despite this, one sees little change in the proportions demanded by various broad consumer categories. From around the turn of the century, the share of the domestic

Table 12
Projected Demand for Energy under Alternative Scenarios of Economic Growth
(1990-2020)

Indicators	1990	1995	2000	2005	2010	2015	2020
Low growth scenario							
GDP growth rate (%)	4.4	5.3	5.2	5.2	5.2	6.6	6.7
Total energy (PJ)	256	342	512	769	1025	1537	2050
MJ/$ GNP	13	14	16	20	21	26	27
Reference growth scenario							
GDP growth rate (%)	4.5	5.4	6.4	7.2	7.7	8.2	8.7
Total energy (PJ)	256	362	531	827	1314	1979	3055
MJ/$ GNP	13	14	16	18	20	20	21

Source : GOB : 1996.

households is seen to be static at about 40% while that of industry is only somewhat higher. The rest are accounted for by commercial and other sectors.

To supply the necessary power, there will have to be adequate generation. Recent projections show that net generation may go up from more than 7 GWh to 49 GWh. Apparently, then the net generation may just keep pace with the growth in demand. Note, however, that there is a major percentage of system loss. Accounting for this loss, may leave only a hair-thin margin, if at all, of supply above demand. Gross generation in tune with net generation is expected to go up in a similar fashion.

The above only refers to the reference scenario. One may have to be ready for other eventualities too. Thus, the supply of net generation may be from 42000 GWh to 56000 GWh by 2015 depending on the growth prospects of the economy which in turn shall demand a large expansion in demand for investment in the power sector.

Projections of investment requirements indicate that over the period 1995-2005, the country may have to invest about $ 6597 mn of which $ 5283 mn will have to be in foreign exchange and the rest in local currency. Much of the investment ($ 5282 mn) will be in building generation capacity and the rest some $ 1300 mn in transmission and distribution systems.

Table 13
Projected Demand for Natural Gas under Different Scenarios
(BCF/year)

Consumer category	Reference case				Ceiling case				Optimistic			
Year	1995	2000	2005	2010	1995	2000	2005	2010	1995	2000	2005	2010
Power	108	156	195	286	108	156	195	180	108	156	199	290
Fertiliser	98	98	98	98	98	98	98	98	98	98	116	116
Large indus.	5	5	5	5	5	5	5	5	5	18	18	18
Other indus.	19	25	31	39	19	25	31	39	19	26	39	59
Seasonal	2	3	4	4	2	3	4	4	2	3	4	6
Commercial	4	5	6	8	4	5	6	8	4	5	7	10
Domestic	17	21	26	34	17	21	26	34	17	23	36	60
Losses etc.	5	6	7	9	5	6	7	7	5	7	8	11
Total	259	320	373	484	259	320	373	376	259	335	427	570

Source : ADB : 1996.

Table 14
Projected Sales of Power
(Reference scenario)

(MW.h)

Year	Domestic	Commer'l	Total Industry	Other	Total
1990	1,164,701 (29.0))	380,074 (9.5)	2,117,840 (52.8)	347,488 (8.7)	4,010,102
1995	2,273,844 (40.2)	536,805 (9.5)	2,701,032 (47.8)	341,734 (6.0)	5,653,416
2000	3,658,950 (40.7)	767,085 (8.5)	4,126,722 (45.9)	436,149 (4.8)	8,988,905
2005	5,663,616 (41.6)	1,110,745 (8.2)	6,253,224 (46.0)	556,648 (4.1)	13,584,233
2010	8,323,803 (41.5)	1,674,388 (8.4)	9,343,529 (46.6)	710,440 (3.5)	20,052,160
2015	11,835,543 (40.4)	2,541,141 (8.7)	13,979,129 (47.8)	906,722 (3.1)	29,262,535

Source : ADB : 1996.

5.4 Demand for Petroleum Products and Coal

Somewhat dated projections indicate that under a business as usual scenarion the demnd for petroleum producys may rise from 65.6 PJ in 1990 to 155.3 PJ by 2010 that is it would more than double. But obviously not all fuels would show similar rates of growth. Gasolene would probably show the highest rate of growth increasing by a factor of almost 9 over the 20 year period while the demand for kerosene would remain largely static Table 15). Indeed, because of some recent policy changes related to taxes on cars, their demand and consequently that for gasolene has increased substantially. Coal would also increase in use.

While the demand for petrolem products would grow, little prospect as yet exists that these will be indigenously supplied although crude may be imported and refined in the country. In the next five to seven years, however, the coal production would begin from new fields. Much of the coal would, however, be used for power generation.

Table 15
Projected Demand for Petroleum Products and Coal
(Tera joules)

Year	Fuel oil	Diesel	Kerosene	Jet fuel	Gasolene	Coal
1990	7980	27804	23226	3234	3276	12366
1995	11130	42294	23940	4914	4494	19710
2000	14070	48300	23100	6888	19950	49113
2005	20580	57960	21000	8820	25620	102465
2010	20790	69216	23100	11718	30492	137970

Source : Task Force : 1991.

VI. A MITIGATION STRATEGY

6.1 Areas of Focus

We have already described in the section on principles of mitigation the way one should possibly look at the issues related to mitigation. We may refer here again to Figure 1 for recapitualation. We find that while lowering of energy intensity through increased energy intensity is the core mitigation activity, its actual operationalisation depends on the identification of the sectors or the activity where one should introduce the mitigation activities. The latter shall depend ultimately on technology, costs of acquisition, domestic fuel availability.

On identification , we find from the discussion in the foregoing two sections that power generation is not simply inefficeient in general, even within the sector, there is wide variation in efficiency. Furthermore, the demand for power is going to increase fast in the future thus marking it as an area where a small percentage improvement may be much more beneficial in the aggregate than in other sectors. One can similarly identify industries, transport and the domestic sectors.

Industries is very important not simply because there is a large scope for improvement, but also because even where, the general experience is above the world average, there are wide variations in efficiency of use of feedstock. The improvement here can save natural gas, the only major indigenous fuel in the country.

6.2 Technology and Costs

Technology and the costs of its acquisition may prove to be very important. Take the case of hydropower development in Bangladesh. Adding to the existing capacity of the only hydro power station will demand an economic cost of $ 92 mn for a 100 MW plant. The present worth of the extension would be an estimated $ 99 mn. The best alternative combined turbine plant of similar capacity would require much the same amount in terms of present worth, $ 100 mn. Apparently, ther is little by way of diffrerence. But consider the fact that the economic installed cost of the latter is $62 mn. Given other things, any rational planner would go for the combined technology power plant. But, the latter is certainly less climate-friendly than a hydro power plant. The operational question at the end of the day is therfore whether anybody is willing to pick up the extra cost of $ 30 mn? AIJ may be a mechanism and needs to be considered seriously. It may be noted, however, that the concept is still evolving and its operational implications still leave many things to be clarified.

6.3 Getting the Prices Right?

One needs to have the prices right. There can be no doubt about that. Take for example, the case of gas. The present price structure has been shown earlier. This shows that power and fertiliser get gas at the lowest price and there is apparently a cross-subisdisation. Noting that there are major inefficiencies in power generation, thsi is not an acceptable situation. A more rational price structure taking the opportunity cost of the alternative fuel (tken here o be the price of Singapore fuel oil. This would increase the present average price from $1.37/MCF to $2.31/MCF i.e. by nearly 70% or so.

The question is would this be feasible and secondly would it do the trick? Price rises are always politically touchy subjects. Hence the best way is to increase it slowly and publicise the future increases so that people already take measures to such that when the actual increases come, people would not be affected much.

The second issue is very important. In a developing country, income elasticities are very large. Thus recent estimates show (Zaman : 1996) that the long term income elasticity for domestic gas is about 4.7 while for electricity the short run income elasticity is 5.2. In comparison, the price elasticities are much lower in absolute magnitudes. But, the most interesting part of it is that while the household demand for kerosene and gas is somewhat price sensitive, the demand by other sectors are not so. One possible reason is that the utilities like power and gas are in the public sector and operate under soft budget constraints such that whenever there are price rises, the additional cost is absorbed through budgetary changes thus leaving little incentive for saving energy through investment for better technology.

In the case of private industry, the costs of energy is not a large percentage of costs. Thus, price rises, unless these are very large may not have much influence on industrial energy use. Secondly, as stated earlier. Industries may be using power rather illegally to certain extent. Hence rising energy prices may not affect them that much. Such institutional peculiarities must be given attention for an operationally meaningful mitigation strategy.

6.4 The Potential Conservation

The potentials for energy conservation through improved efficiency thus may face many hurdles. And the cost of such energy-efficiency in terms of financial cost or lost output due to increased cost of production are yet to be determined. But that there is a potential for such improvements even in the present context is inescapable. This may be understood from the following estimates for power consumption savings that may take place (Table 16) through demand management. Add to this the supply management and improved technology for power generation. The savings are going to be substantial.

Table 16
Demand Side Management Potential
(%)

DSM Intervention	Intensity of Use	Technical		Behavioural	
		Reduction	2015 Penetration	Reduction	2015 Penetration
Industrial					
- EE Replacement	75	20	20.0		
- Speed Control	75	15	20.0		
- Lights	15	35	20.0	10	20.0
- Process Heat	10	5	20.0	10	20.0
Domestic Urban					
- Lights	65	35	15.3	5	10.1
- Fans	25	25	10.1		
- Others	10				
Domestic Rural					
- Lights	90	35	10.1	5	10.1
- Fans	10	25	10.1		
Commercial					
- Lights	70	35	18.9	10	18.9
- Cooling	20	25	18.9	10	18.9
- Other	10				
Other					
- Agricultural	95	25	14.7		
- Street Lights	5	40	10.5		

VII. CONCLUDING REMARKS

The foregoing discussion shows that there are substantial inefficiencies in energy production and energy consumption be it for final demand or as inputs into the production process. Further, the prices are not usually right in the sense that there are cross-subsidies and that these are much lower than the economic costs of providing energy. Third, because of high income elasticities of demand for energy in general and also for individual fuels like gas and electricity, any price effect is likely to be swamped by income effect. Then again, there are problems of technology choice, not because of their unavailability but because of their costs which often are high. Indeed the incremental costs need to be assessed very carefully and the modes of financing such costs must be found out. Further, institutional structures need to be critically examined and changed to suit the new realities.

POTENTIAL GHG MITIGATION OPTIONS

FOR AGRICULTURE IN CHINA

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Abstract

Agriculture contributes more or less to anthropogenic emissions of carbon dioxide(CO_2), methane(CH_4), and nitrous oxide(N_2O). China's agriculture accounts for about 5-15% of total emissions for these gases. Land-use changes related to agriculture are not major contributors in China.

Mitigation options are available that could result in significant decrease in CH_4 and N_2O emissions from agricultural systems. If implemented, they are likely to increase crop and animal productivity. Implementation has the potential to decrease CH_4 emissions from rice, ruminants, and animal waste by 4-40%. The key to decreasing N_2O emissions is improving the efficiency of plant utilization of fertilizer N. This could decrease N_2O emissions from agriculture by almost 20%. Using animal waste to produce CH_4 for energy and digested manure for fertilizer may at some time be cost effective. Economic analyses of options proposed should show positive economic as well as environmental benefits.

Introduction

Agriculture contributes to anthropogenic emissions of carbon dioxide(CO_2), methane(CH_4), and nitrous oxide(N_2O). There are different estimations of agricultural emissions of GHG between IPCC and past studies of China(IPCC 1990, 1992, 1996; Wang et al. 1990, 1995, Lin Erda et al. 1994, Li Yue et al., 1995). China's agriculture accounts for about 5-15% of these emissions for individual gases. Land-use changes related to agriculture are not major contributors in China.

The large influence of agriculture is traced back to its individual sources so that effective mitigation can be sought. Options such as those proposed by IPCC and others that have been proposed more recently, have been considered, which mainly include the following:

Table 1 Selected options for direct and indirect mitigation of GHG emissions from agriculture

	CO_2	CH_4	N_2O
1. Land Use			
- More intensive use of existing farmland	M	L	
- Restoring productivity of degraded soils	H	L	
2. Rice Paddies			
- New cultivars and other		-(4-26%)	L
- Nutrient management		-(5-13%)	L
- Irrigation management		-(8-10%)	
- Inhibitor use		-(9-15%?)	L
3. Animal Husbandry			
- Ammonia treatment of straw		-10%	
- Feed additives		-(10-40%)	
- Improve management		H	
4. Recycling of Livestock and Other wastes			
- Small-Scale Digesters		M	
- Middle and large digesters		L	M
5. Plant Nutrient Management			
- Improved fertilizer use efficiency		L	H
- Legume cropping to bolster system productivity			M

Note: Mitigation Potential: L = low, M = medium, H = High

The data for assessing mitigation options are mainly from : 1) observation from rice paddies from 1988 to 1995, 2) observation from cattle and sheep from 1993 to 1995, 3) China's Agricultural Year-Book 1991, 1995(1990 and 1994 's data), 4) IPCC/ OECD default data. All data more or less have some uncertainties

Enhance Soil Carbon Sinks

The estimated quantity of organic carbon in the soils for the whole of China is 183.1 billion tons(Lin Erda et al., 1996). This compares with the store of organic carbon in woody biomass of about 6.1 billion tons (Fang Jingyun et al., 1996) and the annual fixation of organic carbon in plant material of 652 million tons (Liu Yunfen, 1995). Schleping (1984) estimated global soil C stock should be 1515×10^9 tC. So China's soil C accounts for about 12% of the world. Unfortunately, there are not available dada for estimating additional annual sequestration rates at present.

Comparing the estimates of agricultural soil carbon shows that a half of soil carbon have stored in crop-lands and grasslands used for agriculture and animal production. The management of soils and crops can have a positive or negative effect on the amount of organic carbon retained in the soil. An increase in soil carbon can only come about through a buildup of vegetative matter, either added to the soil from outside (crop residues or animal wastes) or from the maintenance of in *situ* plant biomass. This case would enhance the soil sink of carbon greenhouse gases. If crop residues are regularly removed, or practices are undertaken which encourage the breakdown of organic soil carbon, carbon will be lost from soil, partly through carbon greenhouse gas emissions.

Most temperate agriculture soils have been cultivated in China, and soil C is probably decreasing slightly in some regions. However, soil organic C in permanently cropped fields can be increased through a number of management practices, including greater returns of organic materials to soil, decreased periods of fallow, use of perennial and winter cover crops, recycling of organic wastes, reduced tillage, erosion control, and agroforestry. The on going Fertilized Soil Program in China is probably increasing soil C slightly due to increased productivity and hence greater organic fertilizer, crop residue and green manure inputs, improved residue management, and reduced tillage. So the sink of C could be enhanced under this program, but no available data can be used for estimation of its potential now.

The larger difference in CH_4 oxidation in natural grasslands has been observed in Tibet and Inner Mongolia of China. When they are converted to agricultural use, the CH_4 oxidation could be decreased. Insufficient information is currently available to recommend agricultural practices to increase the oxidation of CH_4 in cultivated soils.

Mitigate Sources of CH_4

Flooded rice fields, domestic ruminants and anaerobic animal waste processing are the principal sources of CH_4 from agriculture. An aerobic soil sink of 10-20% of CH_4 emissions is now evident in China(Lin Erda et al., 1996).

Rice fields

Tracegas emissions from rice fields are governed by a complex set of parameters including the physical and biological characteristics of flooded soil environments with specific agricultural management practices. Rice plants influence CH_4 emissions by providing substrata for root oxidation and decay. Planting new cultivars with lower emission rate and higher productivity, as some research results showed that CH_4 emissions can be decreased by applying digested hybrid rice varieties, could decrease CH_4 emissions (Wang et al. 1995). Other cultivation practices, such as a new technique of seeding on dry nursery and thinning planting which has been expanding in China can also decrease 2-6% of the emission. The largest potential of these options could be 20-30% of decessed (Lin Erda, 1993, 1994). Refuse instead of organic fertilizer (0.91-2.1Tg) or adding inhibitors in germicide-type and fertilizer-type (9-15%) can also decrease emissions (Lin Erda et al., 1994).

Experiments showed that draining rice field at specific times decreased CH_4 production by 10-37%(Lin Erda et al, 1994) without decreasing rice yield but could increase N_2O emission during that time. The ability to control flooding and drainage based on demands will be available to no more than 70% of the total rice paddies.

Several nutrient management techniques have proved highly effective for reducing CH_4 emission. The application of nitrogen fertilizer, for example, appears to reduce methane emissions relative to unfertilized fields and fields fertilized with organic material. But according to our experiments of 1992, heavy nitrogen fertilizer be used that appeared to enhance methane emissions in dollop. If manure is fermented in biogas generator pit, methane emission from the fields with residue can be reduced greatly when it is used as fertilizer. If all of the residue (15 million tones, see the description below) produced by biogas plants are applied to rice fields (2.5 tones per ha.), 1/5 of rice paddies can decrease 24-63% of CH_4 emission (Tao Zhan, 1993), so 5-13% of CH_4 emission might be reduced at most in China. It is possible to counteract the effect of increased application of nitrogen fertilizers and manure.

Ruminant animals:

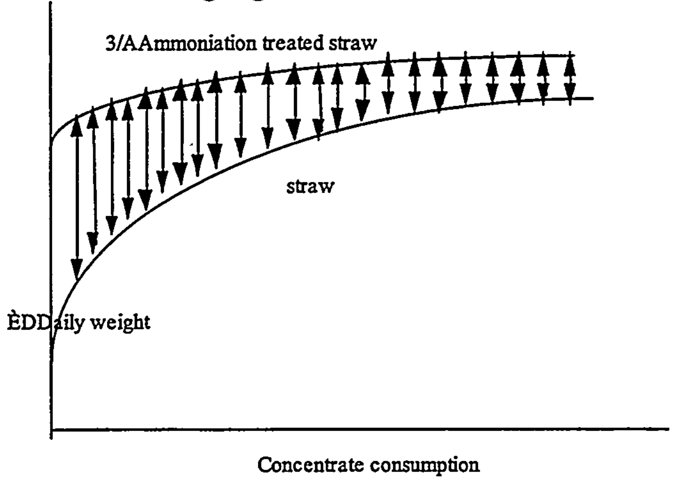
Although the animal productivity have been improved in past 10 years, low off-take rate and beef productivity results in large population of animal in China . In 1992, beef production per cattle are 17.0 kg/cattle in China, 84.9 kg/cattle in developed country, 37.2 kg/cattle all over world. The technologies to increase per animal productivity are effective mitigation options.

A. Ammonia treatment of straw:

Ammonia treatment of straw is the most feasible technology in China. The technique of ammonia treatment of straws has been expanding since 1987. About 5 percent of the annual straw production of 500 million tons was being treated in 1995. For the largest potential of animals, it is estimated that the treated straw will be 15% per percent of the annual straw production.

Ammonia treatment of straw can increase the digestibility and energy intake. It was estimated that about 10% of methane emission per unit of production could be reduced by use of this technique (EPA, 1993). The experiment in Henan Province shows that the weight gain per day increased 30~80% and the ratio of weight to feed increased 20~40% for cattle fed on ammonia treatment straw. Fig.1 express the results of the effect on cattle weight gain of Ammonia treatment of straw in China (Guo, 1995).

Fig 1 The effect on cattle weight gain of ammonia treatment of straw in China



The main sources of ammonia treated straw are Urea, Liquid ammonia, Ammonium hydrogencarbinate. Table 2. express the cost of different ammonia sources for treating straw. The costs of weight gain per kilogram was about 2~3 and 3~5 yuan for the cattle fed with ammonia straw and straw respectively (Guo, 1995).

Table 2. The cost of different ammonia sources for treating straw

Ammonia sources	Nitrogen content (%)	Amount of ammonia (%)	Cost of ammonia sources (yuan/kg)	Cost of treated straw (yuan/kg)
Urea	46.67	4.5	1.10	0.050
Liquid ammonia	82.35	3.0	1.30	0.039
Ammonium hydrogencarbinate	17.72	10.0	0.30	0.030

Note: Cost of equipment treating straws not included in cost of treated straw

B. Feed additives:

Feed additives (e.g., NPN, Molasses/ Urea multi-nutrient Blocks(MUB), bypass protein) can increase growth rate and increase the feed efficiency of dairy caw, beef cattle and sheep, resulting in 10-40% less methane emission per unit of products. The weight gain per day increases about 15-30%. The cost of weight gain per kilogram was decreased about 10% for NPN multi-nutrient Blocks (Zhang, Z.W et al., 1993).

C. Management to increase animal productivity:

Reductions of methane emission from ruminant animals rises with increasing animal productivity. About 99.30 million of yellow cattle were raised in China in 1994, and most of yellow cattle are used for draft power by individual farmer. With the development of mechanization , the number of draft cattle will decrease and it should be replaced by crossbreeding beef and dairy cattle which have high productivity. Crossbreeding program provide the opportunity to reduce the population of animal used for given product and reduce the total CH_4 emissions. In addition, controlling diseases and parasites and applying intensive feeding system are the suitable technologies to improve livestock production and reduce CH_4 productions.

Animal Waste

According to IPCC report, methane emissions from livestock manure of the world is 14 (10-18)Tg. With current technology, CH_4 emissions from animal waste can be reduced by 25 to 80%(IPCC, 1996). The methane emission from manure management system in China was estimated to be 1.25 Tg using IPCC methodology(Li Yue, et.al.,1995). The popular technologies for recovering methane from manure management system in China include:

A. Small- Scale Digesters:

These digesters are designed to decompose the organic materials in livestock manure for CH_4 recovery. It is easy to use and the input is small. It is suitable for Chinese condition because about 80% of animals, especially swine, are fed by individual farmers. About 5.43 million such biogas digesters were in use in China at the end of 1994, handling about 15 million tones of organic waste per year with 1.345 billion m^3 of biogas production. The cost of $15m^3$ digester and conveyance system is about 2000~3000 yuan RMB and the payback period is about 3-5 years(Si, Y.S., 1995).

B. Middle and Large Scale Digesters:

Middle and larger digesters are more complicated to build and operate. They were used in large livestock farms and wineries. The number of these kind digesters was about 583(Zhang Y.X.,1995), handling more thane 5 million tones of industrial waste water and livestock manure with 36.78 million m^3 36.78 of annual biogas supplication (Yan.L.,1996). The CH_4 content in biogas was 55~70%. Table 3 presents the biogas projects and biogas production in 1994.

Table 3. The biogas projects and biogas production in China in 1994(Yao Aili, 1995)

		1985	1990	1994
Family scale	No. (million)		4.853	5.43
	Biogas production (m^3)		$1.2x10^9$	$1.35x10^9$
Middle and large scale	No.		200	583
	Total volume (m^3)			$22x10^4$
	Annual biogas production (m^3)			$3.58x10^7$
	Annual methane production(m^3)			$2.15x10^7$
	Families use biogas (1000)		50	83
	Electricity generation (KW/h)	$442x10^4$		$275x10^4$
Biogas power plant		44		138
Total power (W)				$2.64x10^6$

The cost-benefit analysis is related to many factors such as the input and output of the project, running efficiency, environmental and social benefits. Currently the data are insufficient to do the economic analysis, the reasons as: 1) the project can not run perfectly because the conveyance system are not complete, the pipe blocked up or raw material are not sufficient. The running time can not meet the designed targets; 2) although the biogas can run perfectly, the side product of the biogas can not be comprehensively utilized. Table 4 is just a example of the economic analysis for several demonstration projects, that can be used for a case study.

Table 4 Economic analysis for 4 demonstration projects in Suzhou city (Qian, 1995)

		Experimental Swine Farm	Livestock Farm	Putian Swine Farm	Bingxi Livestock Farm
Population	Swine	10,000	10,000	10,000	1,000
	Chicken	80,000	1,000		30,000
Volume (m^3)		700	960	520	250
Investment (1000 yuan)		350	220	500	250
Biogas production rate($m^3/m^3/d$)		0.5	0.15	0.5	0.6
Use time (days)		95	100	95	95
Total gas production (1000 m^3)		122.5	52.5	85	50
Usage of the biogas	Used for daily life (No. of people)	60	40	263	90 families
	used for process	process	process	process	
Benefit	Direct (1000 yuan)	60	25	34	30
	Indirect (1000 yuan)	20	15	20	5
Payback period (year)		4.5	5.5	9.2	7.1

C. The implementation activity

A tentative plan on rural biogas development has proposed as:

1. Energy construction project: The comprehensive energy construction in 100 counties in China. The focus of the energy construction is to extend the biogas digesters.
2. Implementation of two engineering:

   * During the period of the Ninth-five plan:

   Select 200 intensive livestock farm to build the biogas generators ;

   Expand 3 million families to utilize the biogas and side products comprehensive in southern China;

   Build 50 thousand lagoons to process municipal waste water by 2000.

* Through the implementation of the tentative plan, their will be 7.55 million families

used biogas (include the centralized biogas supplication families) by the end of 2000. The biogas production will reach 2.26 billion m^3. It may be instead of 1.695 million tones standards coal. The methane recovery is 1.243 to 1.582 billion m^3.

Table 5 summarize the above discussions and give a brief description for various mitigation options, from which some new techniques can developed.

Table 5. Comparison of methane mitigation options

Sources	Criteria / Options	Does the mitigation options reduce emissions	Is the mitigation option feasible in China	Is the mitigation option consistent with the trends in the develop-ment of agriculture	Can mitigation option operated profitably on the large numbers of farmers	Additional costs/ Emission reduction
	New cultivars	Yes	Yes	Yes	Yes	Smaller
Rice field	Nutrient management	Yes	Yes	Yes	Yes	Smaller
	Irrigation management	Yes	partly	Yes	Partly	Larger
	Inhibitor	Yes	Not sure	Not sure	No	larger
Enteric fermen-tation	Ammonia treatment of straw	Yes	Yes	Yes	Yes	Smaller
	Feed supplements	Yes	Yes	Yes	Yes	Middle
	Raising management level	Yes	Yes	Yes	Yes	Middle
Livestock	Small scale digesters	Yes	Yes	Yes	Yes	Smaller
Manure	Middle and large scale digesters	Yes	Partly	Yes	Not sure	Middle

Mitigate Sources and Enhance Sinks of N_2O

In agricultural systems N_2O is produced primarily by microbial processes, nitrification and denitrification in the soil (Bouwman, 1990). Anthropogenic emission of N_2O occurs as a result of land conversion to agriculture and is likely to be most intensive in agricultural systems that have high N input. Because the interactions among the physical, chemical and biological variables, like N supply, temperature, pH and soil moisture, that control N_2O production are complex, N_2O fluxes from agricultural systems are highly variable in both time and space(McTaggart et al., 1994)

N_2O emissions derived from agriculture are >75% of the anthropogenic sources, but prediction of N_2O emissions associated with a unit of N applied to a specific field or fixed by legumes is not yet reliable. If some combination of agricultural management practices, such as match N supply with crop demand, tighten N flow cycles, use advanced fertilization techniques, optimize tillage irrigation, and drainage, were adopted, the emissions can significantly decrease by almost 20%(IPCC, 1996).

Recent developments suggest that nitrous oxide emissions are spatially and temporally highly variable and therefore have been underestimated in rice soils. Chen Guangxung et al.(1996) found that rice fields emitted or consumed little N_2O while the fields were flooded but when fields were drained substantial N_2O was emitted. On an annual basis only 0.04kg N_2O ha^{-1} was emitted while fields were flooded compared to 1.7kg N_2O ha^{-1} during non-flooded periods. So it can not overestimate the effect of intermittent draining of rice fields, even though draining the field at specific times decreased CH_4 production by 88% without decreasing rice yield(Sass et al., 1992)

Conclusions and Limitations

Mitigation options are available that could result in significant decrease in CH_4 and N_2O emissions from agricultural systems. If implemented, they are likely to increase rather than decrease crop and animal productivity. Implementation has the potential to decrease CH_4 emissions from rice, ruminants, and animal waste respectively by 4-40%(see Table 1). The key to decreasing N_2O emissions is improving the efficiency of plant utilization of fertilizer N. This could decrease N_2O emissions from agriculture by almost 20%. Using animal waste to produce CH_4 for energy and digested manure for fertilizer may at some time be cost effective. Economic analyses of options proposed should show positive economic as well as environmental benefits.

Uncertainties in present assessment stem from two main sources; 1) the inherent unpredictability of future conditions that are controlled primarily by social, economic, and political forces; 2) deficiencies in present scientific understanding of GHG processes, as well as inadequacies in the information base needed to apply the knowledge that we do have. Both of these sources point to future research needed for improving our assessment of mitigation options.

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PRIORITY MITIGATION MEASURES IN NON-ENERGY SECTOR IN KAZAKSTAN

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Abstract

Fulfilling the Commitments on UNFCC through the U.S. Country Studies Program, Kazakstan has developed the national GHG Inventory, vulnerability and adaptation assessment and estimated the possibility of mitigation measures in certain sectors. Next step is developing National Climate Change Action Plan. That process includes such major steps as setting priorities in mitigation measures and technologies, their comprehensive evaluation, preparation implementation strategies, developing the procedure of incorporation of the National Action Plan into other development plans and programs.

This paper presents programs and measures that can reduce GHG emissions in non-energy sector. Measures in land-use change and forestry, agriculture and coal mining are considered. Current situation in non-energy sector of Kazakstan is discussed.

The amount of GHG emissions reduction and cost analysis presented in this paper was developed with the use of IPCC recommendations.

Introduction

With already extremely vulnerable ecosystems, Kazakstan finds the need to address climate change issues particularly urgent, and its current policies will continue to focus primarily on solving the severe economic problems. Nevertheless there are a number of programs in agricultural and environmental policy and forestry sector, which include measures that have mitigation effect. Therefore to be successful Climate Change Action Plan must be integrated with other national sustainable development plans and programs.

According to recent GHG emission inventory non-energy sector emitted about 13 MMTCE in 1990 (*Monocrovich et. al.*, 1996). Agricultural activities produce 5 MMTCE, or approximately 8 percent of total GHG emissions in Kazakstan. Methane (CH_4) makes up the largest percentage of total GHG emissions due to agricultural activities. Other GHG emissions from the agricultural sector include nitrous oxide (N_2O) totaled about 1.1 Gg and nitrogen dioxide (NO_2) totaled 10 Gg. Another methane emissions source is coal mines: CH_4 emissions in 1990 accounted for 751 Gg (or about 5 MMTCE) that was about 49% of total methane emissions in Kazakstan. The net carbon dioxide flux from land-use and forest management was estimated to have been an uptake 1.1 MMTCE. This amounts to approximately 2% of the total CO_2 emitted, or approximately 1.7% of the total GHG emissions in Kazakstan.

An objective of this paper is to present programs and measures that can reduce GHG emissions in non-energy sector and to evaluate measures in land-use change and forestry, agriculture and coal mining.

Methods and Approaches

The national programs and strategies in agriculture and forestry sectors and in environment protection from the point of view of possible reduction of greenhouse gas emissions in non-energy sector of Kazakstan were examined. As the result of the reviewing we selected the following programs to be integrated in National Climate Change Action Plan:

1. "Conceptual Program of Development of Agricultural and Industrial Complex of Kazakstan until the Year 2000";
2. National Program "Forests of Kazakstan";

In the field of coal mining we selected to reduce methane emissions scientific and technical program "Methane-Acetilene-Artificial Liquid Fuel". This technology was developed in Combustion Problem Institute of the Republic of Kazakstan to create an equipment for complex processing of natural gas (methane).

The mitigation effect of measures and technologies was assessed with the use of IPCC recommendations (*IPCC/OECD,* 1994).

Results

Kazakstan covers an area of approximately 270 million ha. Its climate is arid, with extreme temperatures in summer and winter. About 40 percent of Kazakstan is made up of desert land. Forest-steppe and steppe lands occupy about 27 percent, semi-desert - 22 percent and mountains are amounted to 11 percent of the remaining territory. Diverse soil types, climates and vegetation cover greatly influence agricultural production.

Despite its great continental territory is so large, main changes in storage of GHG due to land-use change and forestry are supposed to be in the area between 51 and 57°N latitude. The area of cultivation useful lands is about 40 millions in this belt. Low productive pastures and grasslands are situated between 45 and 51°N latitude, totaled 182 million ha. Sheep breeding, supported by vast expanses of both desert and semi-desert pastures, is the leading branch of animal husbandry in Kazakstan. Cattle livestock and pig, camel and horse breeding also contribute to the agricultural industry in Kazakstan.

Land Use Change and Forestry

According to the strategy of development of agricultural and industrial complex of Kazakstan until the year 2000 and conception of forestry development considerable changes in planted area structure, livestock population and amount of phitomeliorative works should be done. Measures and technologies offered in these programs allow to calculate mitigation effect directly.

Crop Land Abandonment

A special attention in the "Conceptual Program..." is payed to scenarios of wheat planting area reduction. Kazakstan has six natural and economic regions based on soil type, climate and economic conditions (*Abugaliev*, 1985). Two of these regions are important in wheat production: semi-arid and arid steppe zones.

After soil protection measures were implemented in North Kazakstan, the average wheat yield at scientific institutes amounted to 1.6-1.7 Mg ha^{-1} compared with 0.5-0.6 Mg ha^{-1} when the soil was first developed in 1964. Recently, however, the average wheat yield has been 0.92 Mg ha^{-1} because of economic conditions.

In some regions wheat is grown not only in the steppe and arid-steppe zones, but even in the desert-steppe zone on light-chestnut and gray-brown desert soils. The soil and climate of that area allow a wheat yield of no more than 0.5-0.6 Mg ha^{-1}. According to the Kazak Agricultural Academy of Science research results areas that now give low yields will no longer support crops.

Under these consideration five scenarios of low wheat-productive land reduction are proposed in "Conceptual Program...". The most acceptable scenarios exclude from cultivation land with wheat productivity of 5-6 mg per hectare. The most acceptable intensive wheat production scenario (usage of fertilizes, herbicides, seed improvement etc.) will exclude from cultivation land with wheat productivity of 7 mg per hectare. The cost of wheat production in Kazakstan is currently $130/ha. Under measures (fertilizers, pesticides, weed control, etc.) to increase wheat yield to 1.49 Mg ha^{-1}, the cost will increase to $160/ha. This figure was calculated on the basis of the cost of fertilizers, pesticides, workers' salaries, etc. Critical wheat yields that ensure a given profitable level were defined for different areas. The critical wheat yields are 0.8 Mg ha^{-1} with current farming technology and practice and 1.0 Mg ha^{-1} under intensive technology and advanced management practice (assuming the price of wheat is about $160 mg). Therefore wheat production is profitable under the all options (Table 1).

The available areas should be planted in perennial grassy and bushy vegetation for 7 or 8 years. After that carbon will be re-accumulated in the soil. Because abandonment lands are to be regenerated from crop lands to grasslands, the default assumption is that no significant changes in aboveground biomass will occur. The results of calculations of annual carbon re-accumulated in soils under the five scenarios are presented in Table 1. These calculation were made with assumption that the abandoned croplands will not to degrade and with the use of crude defaults soil carbon for temperate grasslands (70 t C/ha) (*IPCC/OECD...*, 1994).

Table 1. Changes in wheat planting area structure

Option	Planted Area, 1000s ha	Planted Area Reduction, 1000s ha	Wheat Yield, mg/ha	Total Wheat Yield, million t	Wheat Production Cost, million $	Profitability ,%	Annual Re-accumulated carbon, Gg
on excluding areas with average wheat yield:							
1. < 5 mg/ha	18,343.1	4,410.5	14.2	26,054.3	2,998.9	34.7	308.7
2. < 6 mg/ha	16,275.8	6,477.8	14.9	24,200.8	2,666.8	40.7	453.4
3. < 7 mg/ha	13,111.7	9,641.9	16.2	21,223.6	2,169.2	51.7	674.9
differentiating by regions:							
4. < 5 and 6 mg/ha	18,370.5	4,383.1	14.2	26,012.6	2,990.2	34.8	306.8
5. < 5, 6 and 7 mg/ha	17,044.7	5,708.9	14.4	24,266.9	2,786.2	36.1	399.6

Amount of carbon re-accumulated in soil varies from 308.7 Gg under first option to 674.9 Gg under the third one. Decrease of planting areas by 9,6 ha (third option) is most favorable from the point of view its profitability and amount of re-accumulated carbon, but total wheat yield would be less than this one under all the other scenarios. It seems that most acceptable scenario could be the second because of its averaged parameters of total wheat yield, profitability and re-accumulated carbon.

Forestry

Among the options in the non-energy sector related to forestry, the most promising mitigation measure is increase of carbon absorption by expanding the planted area and preserving existing forest sink capacity. Currently forest area totals about 3.7% (9.6 million ha) of the Kazakstan territory. Based on data of 1990 annual CO_2 uptake from forest exploitation was evaluated as 4,627 Gg CO_2. Taking into account the CO_2 emissions from forest fires, the net CO_2 flux in 1990 from land-use change and forest management activities was estimated to have been a sequestration of 4,011 Gg CO_2.

Studies of the Kazak Scientific and Research Institute of Forestry showed that, on the basis of natural and economic conditions and the depleted condition of land, the optimal share of forested territory for Kazakstan is 5.1 percent. According to the Program "Forests of Kazakstan" the forest area of the country should be increased up to 4.6% of the whole Kazakstan territory by 2010 and up to 5.1% - by 2020. The areas (about 3.8 million hectare) are to be planted mostly with mixed softwoods forest. According to the IPCC recommendations annual increment in biomass should be taken as 14.5 tonnes/ha. Taking into account that carbon fraction of dry matter is equal 0.45 (*IPCC/OECD...*, 1994), annual carbon uptake increase is equal to 2,140 Gg/year. Because of the uncertainty about the magnitude and direction of the soil carbon change in plantation systems, this is ignored in our calculations. This analysis is to be done in further investigation.

Therefore if the forested area increases to 5.1 percent of the territory of Kazakstan, the CO_2 uptake by forests will increase from 1.7 to about 2.7 percent of the total CO_2 emissions. The cost of implementation of this option is assessed as $3.5 billion. To implement such measures foreign investments are necessary.

Agriculture

According to National GHG inventory assessment in 1990 agricultural activities are responsible for emissions of 5.564 MMTCE, or approximately 8% of Kazakstan's total emissions. The most significant gas emitted by agricultural activities is CH_4. The agriculture sector produces more that 45% of total CH_4 emissions in Kazakstan, from sources such as domestic livestock, manure management, and rice cultivation.

Livestock

The results of calculation of methane emissions from domestic livestock for 1990 are given in Table 2. Data on the number of animals of each livestock type are taken from an agriculture census in Kazakstan and are included in State Statistic Accounts *(Kazakstan...,* 1991). The amount of methane depends upon the type, age and productivity of the animals. Methane from the management of animal manure occurs as the result of its decomposition under anaerobic conditions.The emissions factors for enteric fermentation and manure management are the same as those proposed by IPCC Guidelines for GHG Inventory for developing countries and temperate regions because livestock complexes in Kazakstan is situated at the west and north parts of the country. Note, that the main livestock region is the Northern Kazakstan, where average annual air temperatures is about 1-2 ^{0}C.
As can be seen from Table 2, the total methane emissions from all animal types were 774.5 Gg in 1990. Thus, domestic livestock and manure management together were responsible for 93 percent of methane emissions from agricultural activities. In domestic livestock, methane produced by enteric fermentation accounted for 89 percent of the total CH_4 emissions from agriculture and share of methane from the management of animal manure was 11 percent.

Table 2. Methane emissions from domestic livestock: 1990

Animals	Population (1000s)	Enteric Fermentation Emissions (Gg/year)	Manure Management Emissions (Gg/year)	Total Emissions (Gg/year)
Non-Dairy Cattle	6,491.6	285.6	6.5	292.1
Dairy Cattle	3,326.8	186.3	53.2	239.5
Sheep and goats	36,223.0	181.1	5.8	186.9
Pigs	3,262.3	3.3	13.0	16.3
Horses	1,618.8	29.1	2.6	31.7
Camels	142.5	6.6	0.3	6.9
Poultry	59,300.0	0.0	1.1	1.1
TOTAL		**692.0**	**82.5**	**774.5**

Two livestock population change scenarios were developed in the Conceptual Program of development of agricultural and industrial complex. According to this program it is planned the livestock population to be reduced while increasing its productivity.

In Table 3 the scenarios of domestic livestock populations change and respect methane emissions projections are presented.

Table 3. Methane emissions projections from domestic livestock under developed options: 2000

Options	Animal Population (1000s)	Enteric Fermentation Emissions (Gg/year)	Manure Management Emissions (Gg/year)	Total Emissions (Gg/year)
		Non-Dairy Cattle		
1	5,719.0	251.6	5.7	257.3
2	5,445.0	239.6	5.5	245.1
		Dairy Cattle		
1	2,309.0	129.3	36.9	166.2
2	2,289.0	128.2	36.6	164.8
		Sheep and goats		
1	31,000.0	155.0	5.0	160.0
2	26,200.0	131.0	4.2	164.8
		Pigs		
1	1,500.0	1.5	6.0	7.5
		Horses		
1	2,000.0	36.0	3.2	39.2
2	2,200.0	39.5	3.5	43.0
		Camels		
1	200.0	9.3	0.42	9.7
2	220.0	10.2	0.5	10.7
		TOTAL		
1		**582.7**	**57.2**	**639.9**
2		**548.5**	**50.3**	**628.4**

As it can be seen from Table 3, methane emissions suppose to decrease to 630-640 Gg Me/year under both scenarios. Thus, the emissions reduction can be amounted to 134.6 Gg Me/year and 146.1 Gg/year under proposed options.

We do not assess emission reduction for poultry because of its insignificant contribution in total agriculture methane emissions (Table 2) and a lack of reliable data.

Rice

Methane emissions from rice cultivation make a relatively small contribution to total CH_4 agricultural emissions, representing approximately 5.7 percent. The aggregate emissions factor from Kazakstan rice fields, based on the average temperature of the growing season and irrigated regimes, is equal to 4.22 kg/ha/day. The total area of harvested rice was about 120,000 ha in 1990. The average duration of a growing season for all rice species cultivated in Kazakstan is about 115 days (*Kazakstan...*, 1991). Thus, annual methane emission from flooded rice fields in 1991 was calculated as follows:

$$4.22 \times 120{,}000 \times 115 = 57{,}459{,}520 \text{ kg} = 57{,}46 \text{ Gg}$$

Total annual rice yield amounted to 260,000-300,000 t in 1990, and rice crop demand for the republic is only 120,000 t. At the same time excessive intensification of rice production effects unfavourably on ecology situation in the South Kazakstan. Water consumption negatively effects on water inflow into Aral Sea and Balhash Lake. Unreasonable fertilizes using especially nitric ones have leaded to exceeding limiting value of irrigation and underground water pollution. To reduce irrevocable water consumption it is necessary to decrease rice planting area.

Table 4: Methane emissions from rice plantations

Oblast	Area of harvested rice systems, 1000s ha	% of rice satiation at the area	Area of harvested rice, 1000s ha	Rice yield, Mg ha^{-1}	Total Rice Yield, 1000s t	CH_4 emission, Gg
			Rice production in 1991			
Kzylorda	189.0	43.4	83.0	43.6	357.6	39.79
South Kazakstan	34.0	58.5	20.5	48.0	95.6	9.66
Almaty	28.0	43.9	12.3	41.0	50.6	5.97
Taldy-Korgan	10.0	42.0	4.2	41.1	17.2	2.04
TOTAL	261.0	45.4	120.0	44.0	521.0	**57.46**
			Under the recommended option			
Kzylorda	189.0	37.5	70.8	45.0	318.5	34.36
South Kazakstan	34.0	37.5	12.8	55.0	70.4	6.21
Almaty	28.0	42.6	11.9	45.0	53.6	5.78
Taldy-Korgan	10.0	33.2	3.3	45.0	14.9	1.6
TOTAL	261.0	37.9	98.8	46.3	457.4	**47.95**

Thus, it was proposed in the "*Conceptual Program...*" to reduce rice sowing area, but this process should be carried out carefully because of the following reasons:

- Rice irrigation systems are very special and expensive constructions;
- Soils under rice plantations are saline. Therefore, on restricting surface water inflow to rice system secondary salinization process will occur.

Under these considerations it was proposed in the *"Conceptual Program..."* to reduce rice sowing area from 120,000 to 98,800 ha. Table 4 presents recommended options, changes in planted area, crop yield and methane emissions. It can be seen, that in 2000 CH_4 emissions reduction suppose to be about 10 Gg/year or 17% of total emissions from rice plantation in 1990.

Methane Emissions from Coal Mining

The extraction of the coal in the country is about of 114 million tonnes/year, while the deposit of coal are assessed as 64 billion tonnes. The fugitive methane emissions from coal mines and refinery enterprises were evaluated using the data about the coal, oil, and gas extraction and the IPCC emission factors (*IPCC/OECD*, 1994). Methane emissions from coal mines in 1990 accounted for 751 Gg (or more than 5 MMTCE) that was about 49% of total methane emissions in Kazakstan. The mitigation option from coalbed methane utilization may be very attractive from the viewpoint of criteria of consistency with national environment goals and indirect economic impacts.

Methane supplies in Kazakstan are significant. Every year about 200 million m^3 of methane are extracted by degasation in the mines of Karagandy coal basin, 12-15 million m^3 of which are utilized in boilers to generate heat. The rest of methane goes irretrievably into the atmosphere thus polluting it. Emissions of 170-180 million m^3 Me are equal to 240,0 tonnes CO_2.

At present methane practically is not used as a feedstock for oil industry but is burnt out in various energetic installations. Being a secondary power resource in the processing of coal layers, methane can be used both as an power supply source and as a feedstock for chemical industry.

That is why developing new technologies of methane processing into valuable chemical compounds is of great scientific, practical, economic and ecological importance.

There are not any sustainable programs on coalbed methane utilization in Kazakstan. However, a number of well developed technologies and pilot projects are exist. For example there are the scientific and technical program "Methane-Acetilene-Artificial Liquid Fuel" developed in Institute for Combustion Research of the Republic of Kazakstan. The project aim is to create an equipment for complex processing of natural gas (methane) to obtain valuable compounds for chemical industry. The project budget is to be $ 400,000. Successful implementation of the project will allow to decrease significantly coalbed methane emissions in Karagandy basin.

Current Situation

All the mentioned above programs related to agriculture, forest and environment protection were developed in 1993-1994. Measures and options were evaluated based on analysis of country economic situations in 1992-1993. However in 1995-1996 economic conditions in Kazakstan has became worse. As the result the GHG emissions in non-energy sector has been changed as follows:

- Not only wheat planting, but the whole arable area has decreased. According to the State Committee on Land Resources of the Republic of Kazakstan of January 01, 1996 planted area amounts to 23,2 million ha, 17 million ha of available for cultivation land are abandonment. Thus, soil began to re-accumulate carbon even now and the annual amount increase of re-accumulated carbon is 1,190.0 Gg.

- Rice planting area has been reduced from 120,0 ha to about 70,0 ha. Current annual methane emissions from rice plantations are about 33.5 Gg.
- Drastic livestock reduction takes place currently. Cattle population has been decreased by 30-40% and population of sheeps has been reduced by 50% by January 1, 1996. This resulted in about 45 % reduction of methane emissions from livestock comparing to the base year. The annual CH_4 emissions for different kind of animals are presented in Table 5.

Table 5. Methane emissions from domestic livestock in 1996

Animals	Population (1000s)	Enteric Fermentation Emissions (Gg/year)	Manure Management Emissions (Gg/year)	Total Emissions (Gg/year)
Non-Dairy Cattle	3,570.4	157.1	3.6	160.7
Dairy Cattle	1,829.7	102.5	29.3	131.7
Sheep and goats	1,8111.5	90.6	2.9	93.5
Pigs	1,957.4	2.0	7.8	9.8
Horses	1,537.9	27.6	2.5	30.1
Camels	128.5	5.9	3.0	6.2
TOTAL		**385.7**	**49.1**	**432.0**

There are a number of GHG emission reduction options, such as concerned to changes in soil management, fertilizers using and so on in the "*Conceptual Program...*". These options are not discussed in this paper because of lack of reliable data. Separate amount of manure can be worked into biogas and used in agriculture at the site of processing. The potential agricultural methane emissions reduction in this case is 5-6 percent of the base year emissions, but this estimation is rough and preliminary.

Conclusions remarks

The implementation of the National Climate Change Action Plan integrated with conceptions of agriculture, industry and forestry development, with National Action Program on Desertification prevention in Kazakstan and National Action Program on biovariety saving will allow to reduce considerably GHG emissions in non-energy sector in Kazakstan.

There are some environment programs that have not been considered in this study including the "National Action Program on Desertification prevention in Kazakstan" and "National Action Program on biovariety saving". They will not lead to GHG emissions reduction directly, but measures and activities these programs foreseen will allow to reduce CO_2 emissions caused by CO_2 absorption by rehabilitated vegetation and to re-accumulate carbon dioxide in soils. Nevertheless a comprehensive evaluation of such measures should be done in further work.

Coalbed methane utilization option has a great GHG mitigation potential in Kazakstan, but there are not any sustainable programs on coalbed methane utilization in Kazakstan.

Implementation of options is very difficult under Kazakstan economic condition. To carry out mentioned above options and measures foreign investments and mobilization of country resources are needed.

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UNDERSTANDING THE NATURE OF METHANE EMISSION FROM RICE ECOSYSTEMS AS BASIS OF MITIGATION STRATEGIES

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Abstract

Methane is considered as an important greenhouse gas and rice fields are one of the major atmospheric methane source. The paper aims to develop sampling strategies and formulate mitigation options based on diel (day and night) and seasonal pattern of methane emission. The study was conducted in 4 countries to measure methane flux using an automatic closed chamber system. A 24-hour bihourly methane emissions were continuously obtained during the whole growing season. Daily and seasonal pattern of methane fluxes from different rice ecosystems were evaluated.

Diel pattern of methane emission from irrigated rice fields, in all sites, displayed similar pattern from planting to flowering. Fluxes at 0600, 1200, and 1800 h were important components of the total diel flux. A proposed sampling frequency to accurately estimate methane emission within the growing season was designed based on the magnitude of daily flux variation.

Total methane emission from different ecosystems follow the order: deepwater rice > irrigated rice > rainfed rice. Application of pig manure increased total emission by 10 times of that without manure. Green manure application increased emission by 49% of that applied only with inorganic fertilizer. Removal of floodwater at 10DAP and 35 DAP, within a period of 4 days, inhibited production and emission of methane. The level of variation in daily methane emission and seasonal emission pattern provides useful information for accurate determination of methane fluxes. Characterization of seasonal emission pattern as to ecologies, fertilizer amendments, and water management gives an idea of where to focus mitigation strategies for sustainable rice production.

Introduction

Methane is considered as an important greenhouse gas and rice fields are one of the major atmospheric methane sources (Neue et al., 1990). The increase of methane in the atmosphere contributes to global warming (Ramanathan et al., 1985) and affects the chemistry of the atmosphere (Bolle et al, 1986; Rasmussen and Kahlil, 1986). Global annual methane emissions from rice fields were estimated to range from 25 to 100 Tg (IPCC, 1992).

Projected global population levels indicate that the demand for rice will increase by 65% over the next 30 years, from 460 million t/yr to 760 million t/yr in the year 2020 (IRRI, 1989). The growing demand is most likely to be met by the existing cultivated wetland rice area through intensifying rice production in all rice ecologies, mainly in irrigated and rainfed rice. Coupled with existing rice production technologies, global methane emissions from wetland rice agriculture are likely to increase. In promoting sustainable rice farming strategies, the combined effect of various factors on rice ecology should be identified and assessed to ensure harmony with the environment.

The Intergovernmental Panel on Climate Change (IPCC) concluded that a 10 to 15% reduction in total methane emissions would stabilize concentrations in the atmosphere. These reductions may be achieved through identification of potential methods to reduce methane emissions from rice cultivation while maintaining or increasing productivity. Identification of abatement strategies require an establishment of preferred methods which promote consistency in the techniques used for different investigations and sites. Mitigation strategies may only be accepted if the methane source strength of rice fields is reliably identified and discriminated according to the various ecologies and production systems. To date, the best time to sample methane emissions (using closed chamber) from different rice ecosystems is not yet established. The International Atomic Energy Agency (IAEA, 1992) recommends gas collection intervals at midnight, 0600, 1200, and 1800 h for 2 hour sampling (i.e. after covering, and again after 1 and 2 h). Parashar et al (1994) used a sampling combination of 1000 and 1600 h for 30 min (0, 15, 30 min). The Rice Cultivation and Trace Gas Exchange Activity (RICE) of the International Global Atmospheric Chemistry (IGAC) Project suggests that flux should be determined 6 to 12 times within a 24 hour period for at least three times during the season: during the late vegetative stage, during the reproductive stage (possibly near heading), and during the ripening stage. On other days, sampling for mean diel flux is recommended during the early morning (6-8 A.M.) and during the early afternoon (1-3 P.M.).

The paper evaluates and characterizes the pattern of methane emission from various rice ecosystems within a 24-hour period and within the growing season. It aims to develop an appropriate sampling strategies and formulate mitigation options in accordance with diel and seasonal patterns of methane emission.

Objectives

The general objective of the project is to evaluate and characterize the diel (day and night) and seasonal pattern of methane emission from various rice ecologies and production systems. Specifically, it aims to 1) design sporadic sampling strategies for accurate determination of methane emission by closed chamber method; and 2) formulate mitigation strategies on the basis of diel or seasonal emission pattern and effects of modifying treatments.

Methodology

Field experiments in China, Indonesia, Philippines, and Thailand were conducted from 1993-1995 to measure bihourly methane emissions using an automatic closed chamber system (Table 1). Experiments were designed to discriminate the effects of water regime, organic and inorganic amendments, cultivar, and crop establishments on methane emission at different rice ecologies. The sites are part of the IRRI-UNDP Project on Interregional Research Program on Methane Emission from Rice Fields.

Table 1. Sites of IRRI-UNDP Project on Methane Emission from Rice fields, 1993-95.

COUNTRY	LOCATION	ECOSYSTEM
China	Beijing	Irrigated
	Hangzhou	Irrigated
Indonesia	Jakenan, Central Java	Rainfed/Irrigated
Philippines	IRRI-Farm, Los Banos	Irrigated/Rainfed
	PhilRice, Maligaya	Irrigated
Thailand	Bansang, Prachinburi	Deep water/Irrigated

The technical details of the system used in CH_4 measurements were described by Wassmann (in *International Atomic Energy Agency* (IAEA) [1992]). The sampling principles and analytical procedures were given by Schutz et al. (1989). The automatic system consists of two major parts: sampling component and analytical component. The sampling component consists of chambers connected to tube/valve system and regulated by multiport valve to gas chromatograph (GC). The analytical components are a GC equipped with two flame ionization detector (FID) channels and an integrator. The system is calibrated from a tank (connected to the sample loop) filled with compressed air of a known CH4 concentration. Sampling of gases from the chambers is done in a 2-hour cycle allowing 4 measurements of the methane mixing ratio inside each chamber. All sampling operations and data acquisition were regulated by a computer equipped with timing device.

Methane emission rate per treatment per replication was calculated by regressing the four methane fluxes obtained during each closing period. A 24-hour bihourly methane emissions (12 readings) were continuously obtained during the whole growing season.

The whole season 12 bihourly fluxes were grouped as to irrigated and rainfed collected emissions. Fluxes obtained from China, a temperate country, were treated separately from fluxes collected from tropical countries: Indonesia, the Philippines, and Thailand. Methane emissions were further subdivided as to growth stages: pre-planting, planting to panicle initiation (PI), PI to flowering, flowering to harvest, and post-harvest. Mean diel (day and night) fluxes were computed from the 12 bihourly methane emissions. Deviation from the mean of bihourly fluxes within a 24-hour period and the deviation of diel fluxes from the mean within a particular growth stage were computed and evaluated. Frequency of measurement within a day and within the growing season was established based on the outcome of variation coefficient. The optimum sampling interval or the best sampling time within a day was designed using multiple regression technique.

Seasonal pattern of diel fluxes from different ecosystems were graphed and evaluated. The effects of fertilizer materials and water regime on seasonal pattern of methane emissions were compared. Abatement strategies were assessed based on seasonal pattern of methane emissions.

Results and Discussion

Diel Pattern of Methane Emission

A typical diel and seasonal pattern of methane emission from irrigated rice field at different stages of growth is shown in Figure 1. Diel pattern of methane emission from irrigated rice fields in all sites displayed similar pattern from planting to panicle initiation. Emissions tended to increase rapidly after sunrise, peaked in the early afternoon, then declined gradually until they leveled off at night (Fig. 2 and 3). The diel pattern of methane fluxes correlates with the pattern of air, floodwater, and soil temperatures. From panicle initiation to flowering, diel pattern of bihourly fluxes flattened considerably and the influence of temperature was dominated by other controlling factors associated with crop development stage. Diel pattern recommenced in shape, similar to early growth stage, from flowering to harvest for bihourly fluxes obtained in Indonesia, Philippines, and Thailand. For China, however, emissions decreased gradually after sunrise, peaked during the late afternoon, then gradually decreased and then form a second peak after midnight. Low temperature during rice maturity stage in China affected the diel pattern of bihourly fluxes.

Similar diel pattern of bihourly fluxes from planting to harvest was observed in rainfed and deepwater rice fields.

Figure 4 shows the variation of bihourly methane emission from rice field at different growth stages. Low level of variation (18%) in bihourly fluxes within a day is obtained from panicle initiation to flowering. Other stages gave coefficient of variation of bihourly fluxes ranging from 28% to 53%.

The total diel flux (dependent variable), which is the sum of 12 bihourly fluxes (independent variable), was regressed with the later. The t-stat value in parenthesis was noted to determine the significance of the true value of the regression coefficient. Table 2 shows that fluxes at 0600, 1200, and 1800 h are important components of the total diel flux for all stages of growth. Changes in total diel flux can be explained by these 3 fluxes with 99% accuracy. For tropical countries, flux at 0600h carries more weight than flux at 1200 and 1800h. The weight contribution of flux at 0600h tends to increase towards maturity stage of rice. Low variation in bihourly emission from panicle initiation to flowering allowed the flux at 0600h to estimate total diel flux with percent reliability. For temperate areas like China (Beijing in particular), flux at 0600h carries more weight but the contribution tends to decrease towards harvest due to lowering temperature. Flux at 1800h carries more weight from flowering to harvest while the contribution of flux at 1200h becomes insignificant.

Daily Pattern of Methane Emission

Daily methane emission from irrigated and deepwater rice fields at pre-planting to early panicle initiation exhibited high deviation from the mean daily flux. Low variation in daily emission is observed from panicle initiation to early flowering while high variation resumed from flowering to post-harvest. Similar magnitude of variation in daily flux is observed from rainfed rice field. Variation of daily emission was higher in magnitude, however, from rainfed than from irrigated rice.

The level of variation in daily methane emission at different stages of growth is an indication of the frequency of flux measurement within a particular growth stage. Frequent sampling is required for periods when variation in daily methane emission is high. From panicle initiation to flowering, less intensive sampling is required to accurately determine the total diel flux. Figure 5 presents a proposed sampling frequency to estimate methane emission for the whole growing season.

Table 2. Regression and correlation analysis between total flux (Ft) and 12 bihourly fluxes (where Ft, F0, F2..., F22 are total flux, flux at 0000h, flux at 0200h, etc.).

Indonesia, Philippines, and Thailand	China (Beijing)
A. Planting to Panicle Initiation	
Ft = 5.18F6 + 2.5 F12 + 3.7F18 ; R^2=0.99 (24) (24) (26)	Ft = 7.4F6 + 3.4F12 + 1.4F18 ; R^2 = 0.99 (27) (27) (15)
B. Panicle Initiation to Flowering	
Ft = 5.4F6 + 2.8F12 + 3.7F18 ; R^2 = 0.99 (31) (21) (23)	Ft = 6.9F6 + 1.3F12 + 3.4F18 ; R^2 = 0.99 (21) (14) (14)
Ft = 12.8F6 ; R^2 = 0.99 (172)	Ft = 13F6 ; R^2 = 0.98 (97)
C. Flowering to Harvest	
Ft = 6.6F6 + 2.3F12 + 3.6F18 ; R^2 = 0.99 (29) (20) (28)	Ft = 4.0F6 + 1.4F12 + 5.3F18 ; R^2 = 0.96 (13) (1.7) (7.4)

Seasonal Pattern of Methane Emission

By Rice Ecosystem

The seasonal patterns of methane emission from different rice ecosystems are presented in Figure 6. Irrigated rice has the potential for producing more methane because water supply is assured. The assured supply and control of water, the intensive soil preparation, combined with improved growth of rice favor methane production and emission and mediate methane flux to the atmosphere. The potential for methane production in rainfed rice widely varies in time and space because its floodwater regime depends primarily on rainfall. Total methane emission is much lower in rainfed rice because of drought periods during the growing season and the poorer growth of rice. Upland rice is considered not a source of methane because it is never flooded for a significant period of time.

Deepwater rice showed similar seasonal pattern as irrigated rice. Daily emission rates are higher from deepwater rice and total methane emission is much higher because of longer growing period. Overall, based on recent experimental results, methane emission per m^2 per year from different ecosystems follow the order: deepwater rice > irrigated rice > rainfed rice (Wassmann, 1995). Based on percent global distribution of rice area, however, irrigated rice is clearly the largest source of methane of all rice ecologies.

By Type of Fertilizer Materials

Figure 7 presents the seasonal pattern of methane emission from irrigated rice fields as influenced by different fertilizer materials. In Beijing, rice field applied with pig manure gave an early release of methane fluxes which can be associated with easily decomposable properties of the organic material. About 86% of the seasonal CH_4 emission was released to atmosphere from planting to panicle initiation. Methane emission peaked at tillering stage. Aside from the effect of water regime, methane emission from panicle initiation to harvest gradually decreased due to lowering temperature. Methane emission from rice field applied with green manure (milk vetch) in Hangzhou, China formed a peak at panicle initiation stage. Emission, with reference to growth stage, was a bit late as compared to rice field applied with pig manure. This may be attributed to the readily mineralizable carbon content of organic material that influences methane production and emission. Rice field applied with inorganic fertilizer (urea) gave a seasonal flux pattern that increases gradually from planting to maturity. Unless floodwater removal is done, methane emission continues to increase and emission peaks from flowering to heading.

Application of organic amendment to flooded soils increases methane production and emission by enhancing soil reduction and providing carbon source (Schutz et al 1989, Yagi and Minami 1990, Sass et al 1991, Cicerone et al 1992, Neue et al 1994). The application of pig manure in Beijing's irrigated rice field increased seasonal methane emission by 10 times of rice field without pig manure. In Hangzhou, green manure application increased methane emission by 49% of the emission from rice field applied only with inorganic fertilizer. However, more data are still required to fully assess the effect of increasing rate and time of inorganic fertilizer application on methane emission.

By Water Regime

The effect of water regime on the seasonal pattern of methane emission is earlier shown in Figures 6a and 7c. The drying condition of the rainfed rice field in Jakenan, Indonesia gradually reduced the production and emission of methane towards maturity. Removal of floodwater at 2 weeks before harvest from irrigated rice field at PhilRice, Maligaya abruptly changed the pattern of methane emission.

Figure 8 is a detailed presentation of Figure 7b which shows the effect of water regime on seasonal emission pattern. The removal of floodwater, at 10 days after planting (DAP) and 35 DAP (early tillering), within a period of 4 days inhibited the production and emission of methane. The application of irrigation water thereafter enhanced CH_4 emission until the next drying period. However, doubling the duration of drying from 4 to 8 days greatly reduced methane emission (Figure 8a). Emission rate started to recover after the application of water but the magnitude was almost reduced by 75% until harvest.

Figure 8b presents the significant effect of water regime on cumulative methane emission. Drying the field for 8 days during late tillering (60 DAP) leveled off methane emission to almost constant rate. Water regimes, however, did not significantly affect rice biomass and grain yields. Mean grain yield was 6.6 tons per ha while mean biomass yield was 14.7 tons per ha.

Conclusion and Recommendation

Variation of daily methane emission and the seasonal emission pattern indicate the frequency of flux measurement that should be done for a particular rice ecology with known modifying treatments. The variation and pattern imply that an accurate determination of diel flux may be obtained with least number of sampling frequency possible. For areas where automatic sampling is not possible, due to its availability and cost, and where estimate of methane is necessary for extrapolation, the proposed sporadic sampling strategies may be adopted for manual sampling with high level of accuracy. Occurrence of low and high variation in daily methane emission within the growing season indicate the role of rice in transporting methane from soil to the atmosphere. It would be interesting for rice breeder to determine the cause of low variation in bihourly and daily methane emission from panicle initiation to flowering which in effect limits the flushing of very high emission.

The characterization of seasonal emission pattern according to ecologies, fertilizer amendments, and water management provides focus for mitigation strategies. In areas where rice fields are mostly irrigated or high amount of organic amendments is applied, more efforts should be done to develop and apply technologies that will abate methane emission. Promising mitigation candidates are water management, organic amendments, and fertilization. Present knowledge of processes controlling methane emission provides useful information to develop abatement strategies in accord with sustainable rice production. An understanding of diel and seasonal variation of methane emission from various rice ecologies poses a new challenge for both agricultural and atmospheric researches to promote cultivation with moderate methane emission at sustainable yield level.

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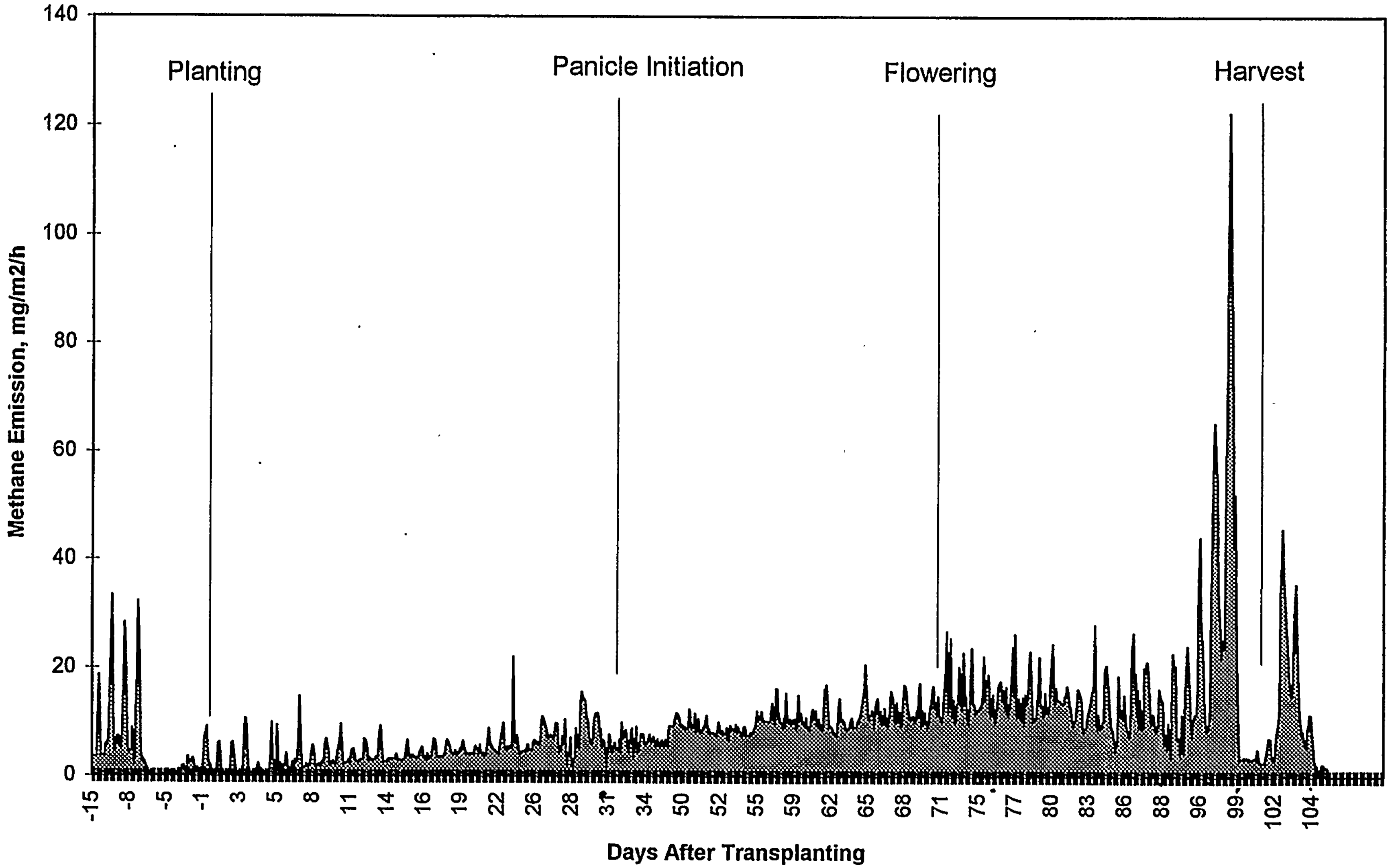
Figure 1. Bihourly methane emission from irrigated rice field at different stages of growth



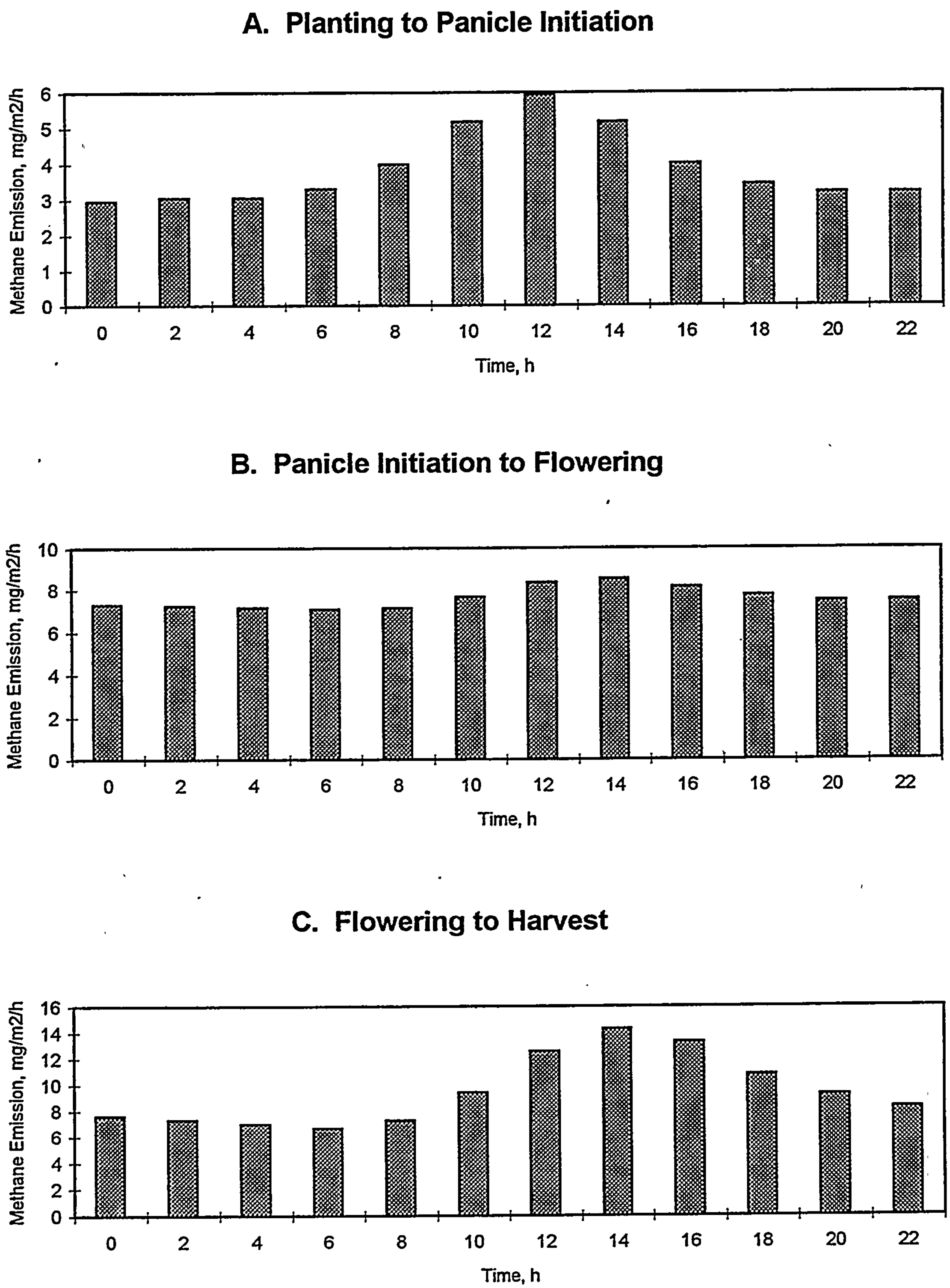


Figure 2. Diel pattern of bihourly methane emission from irrigated rice fields in Indonesia, the Philippines, and Thailand (1994-1995).

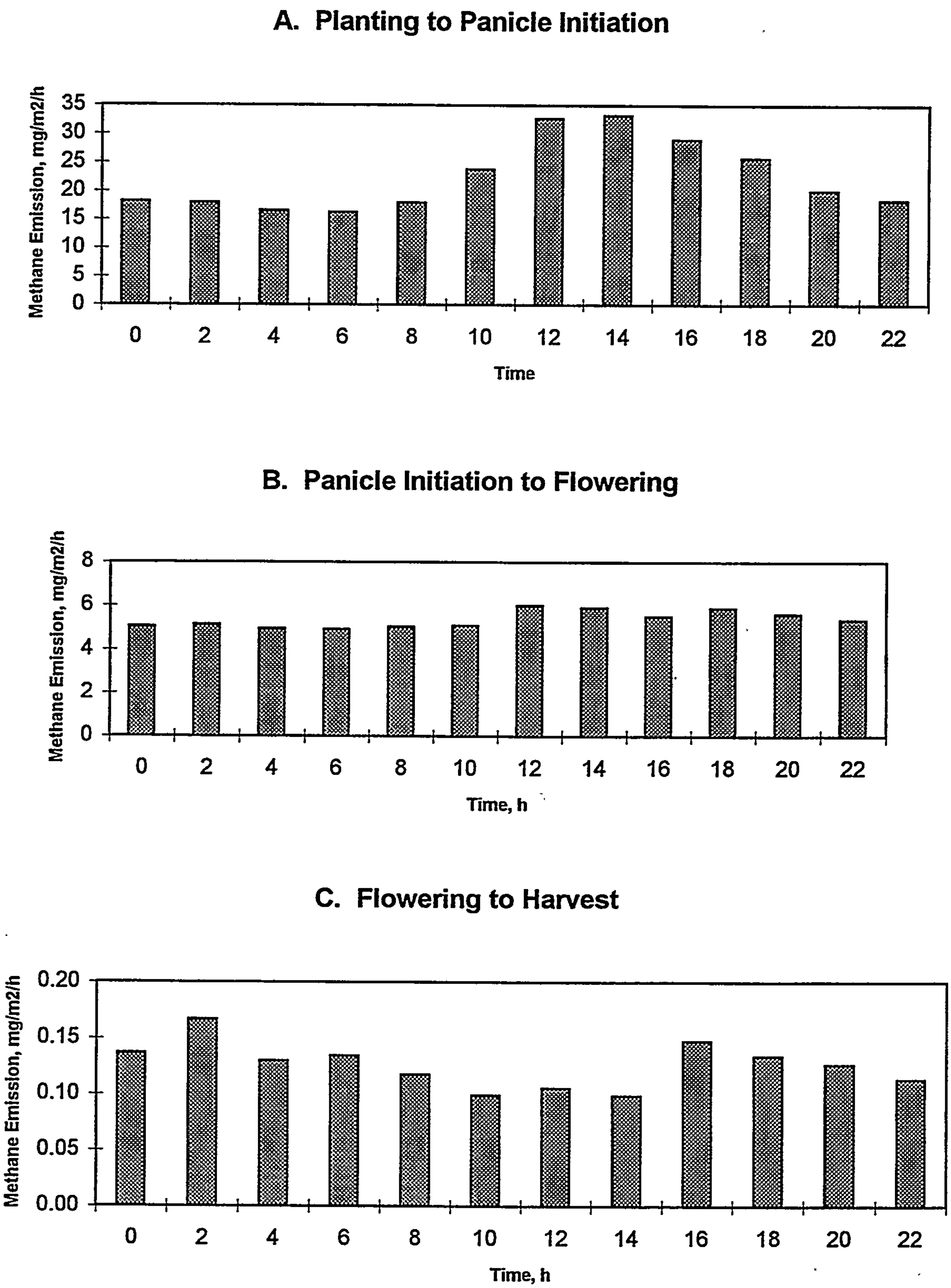
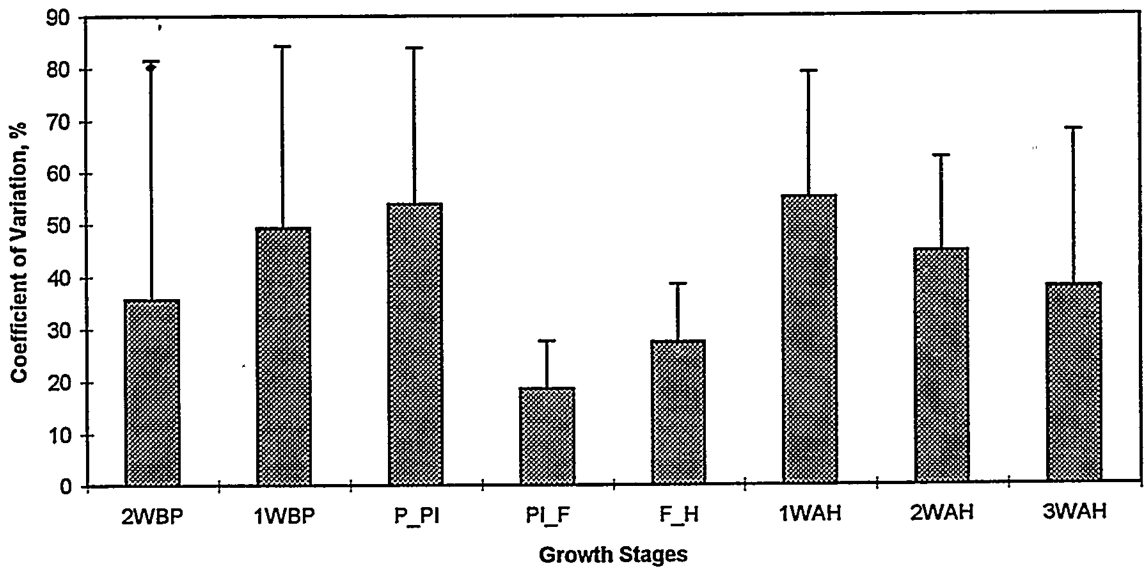


Figure 3. Diel pattern of bihourly methane emission from irrigated ricefield at Beijing, China during the 1995 crop season.

A. Bihourly methane emission



B. Daily methane emission

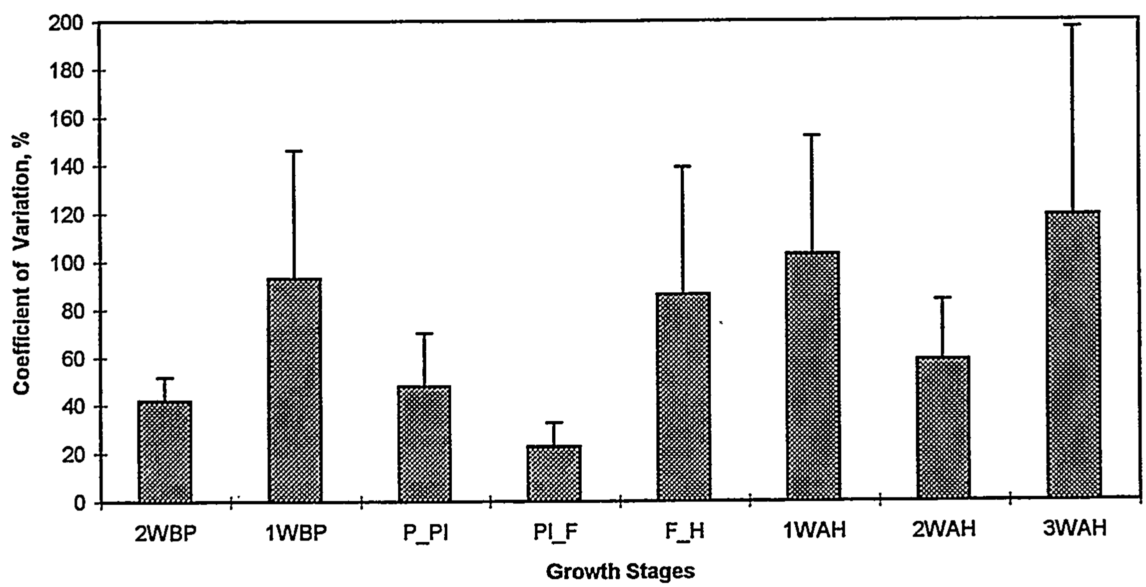
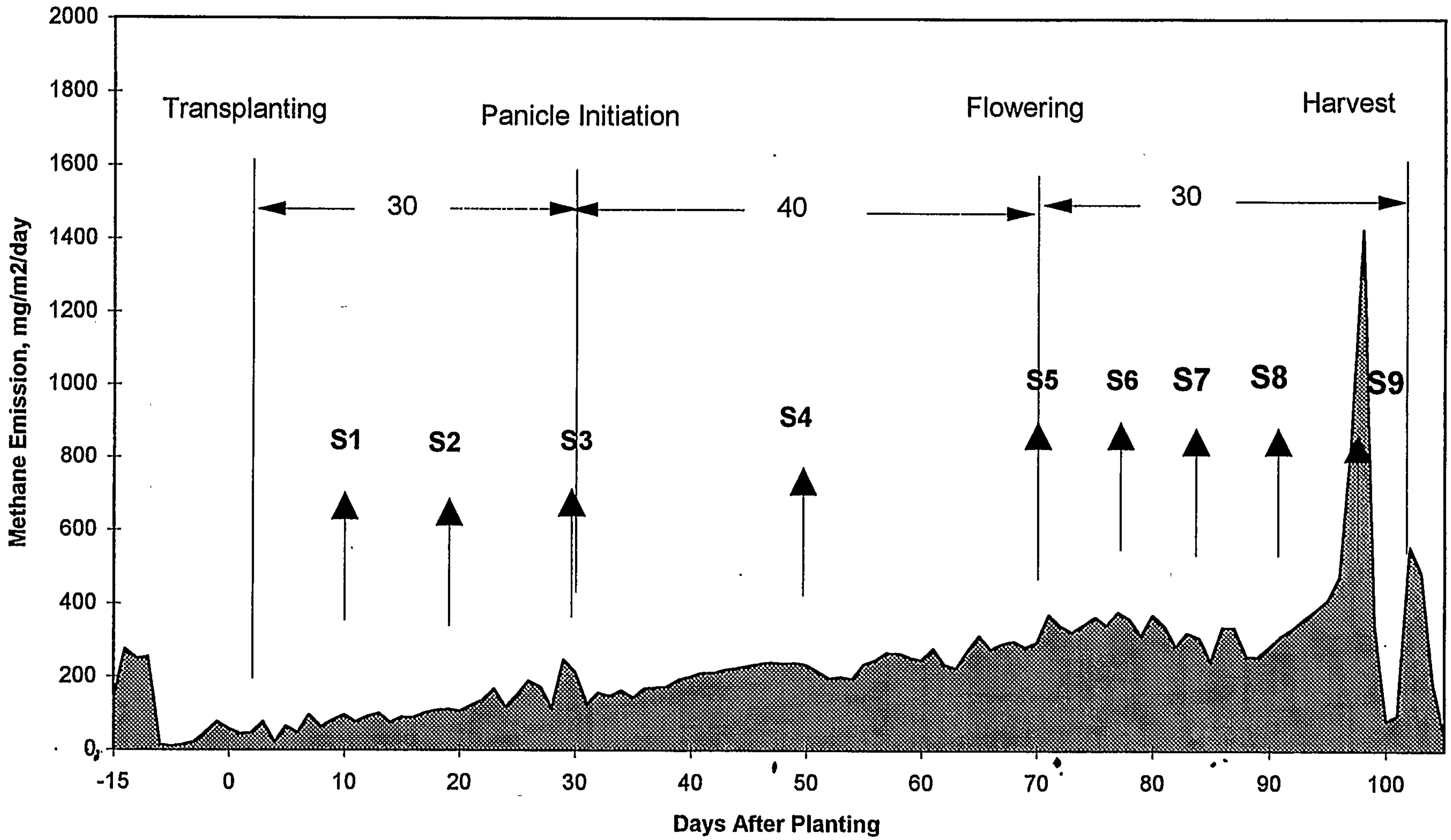
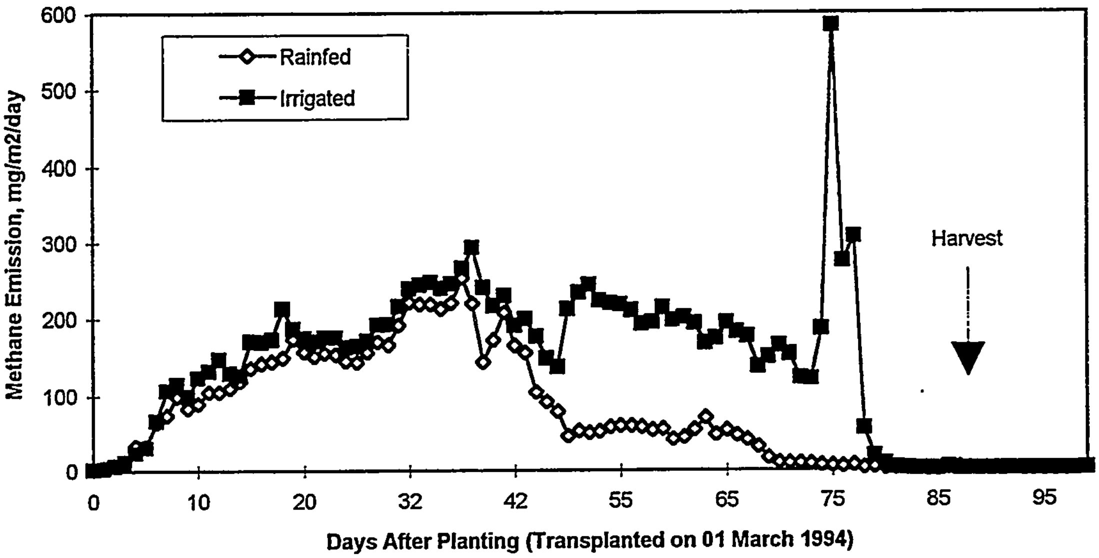


Figure 4. Coefficient of variation of bihourly and daily methane emissions from irrigated and rainfed rice fields at different stages of growth.

Figure 5. Sampling frequency to estimate methane emission from irrigated ricefield at different stages of growth



A. Irrigated vs. Rainfed



B. Irrigated vs. Deep Water

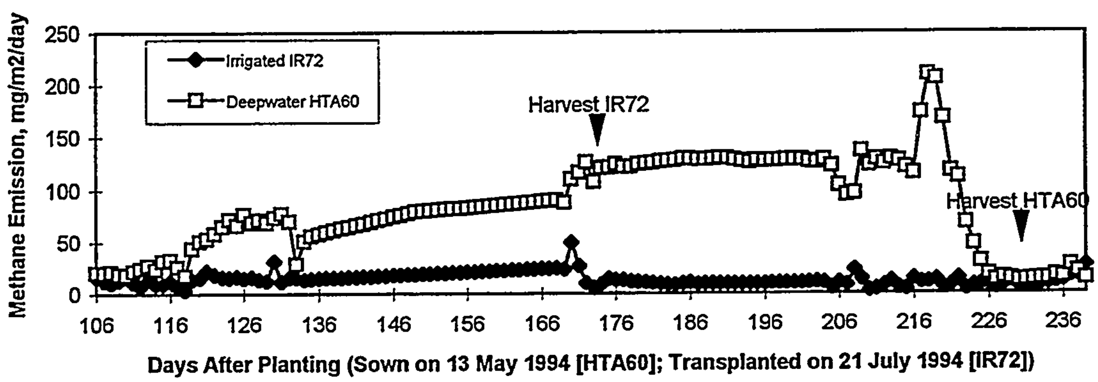


Figure 6. Seasonal pattern of methane emission from different rice ecosystems.

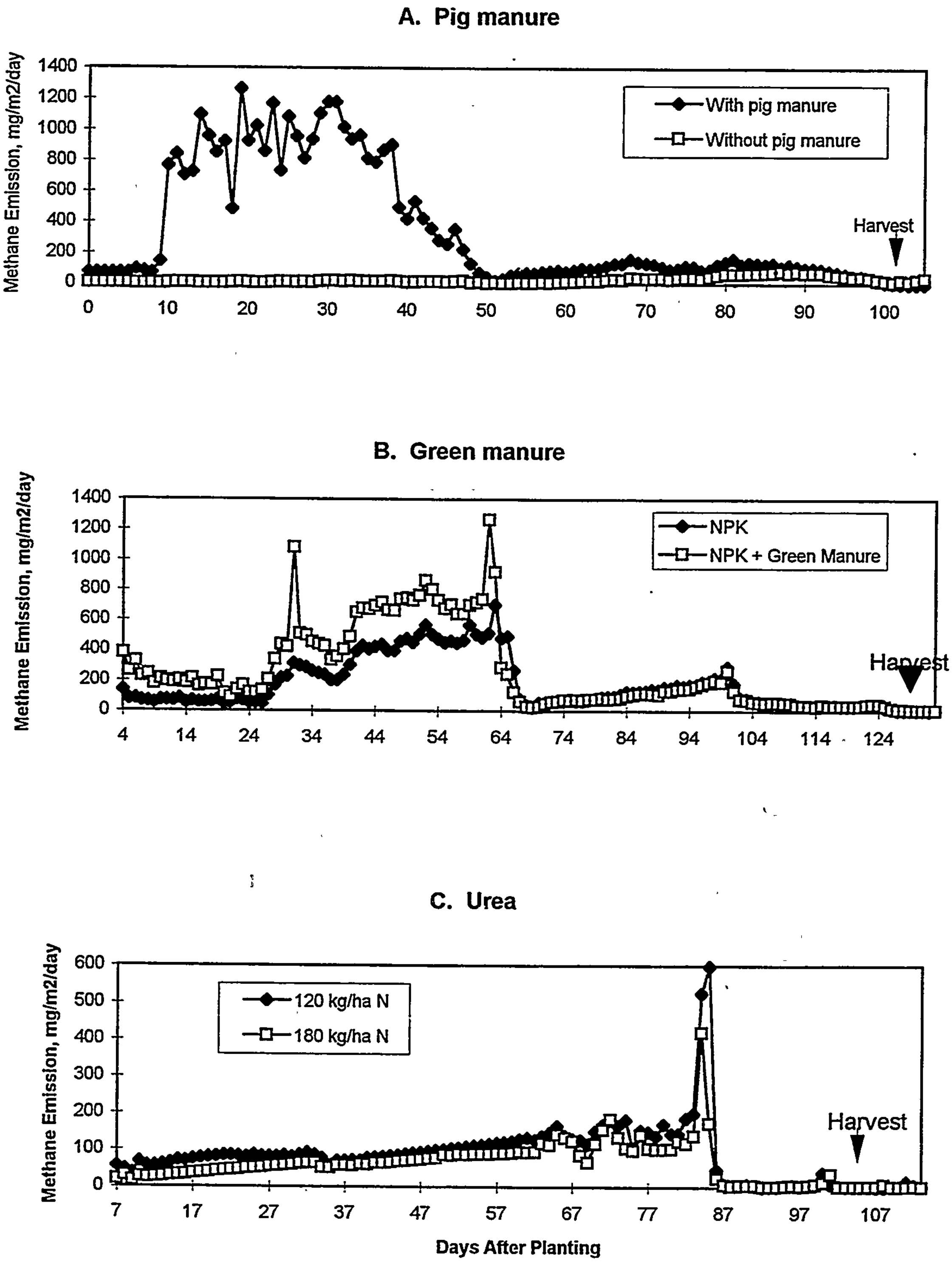


Figure 7. Seasonal pattern of methane emission from irrigated ricefields as affected by type of fertilizer material.

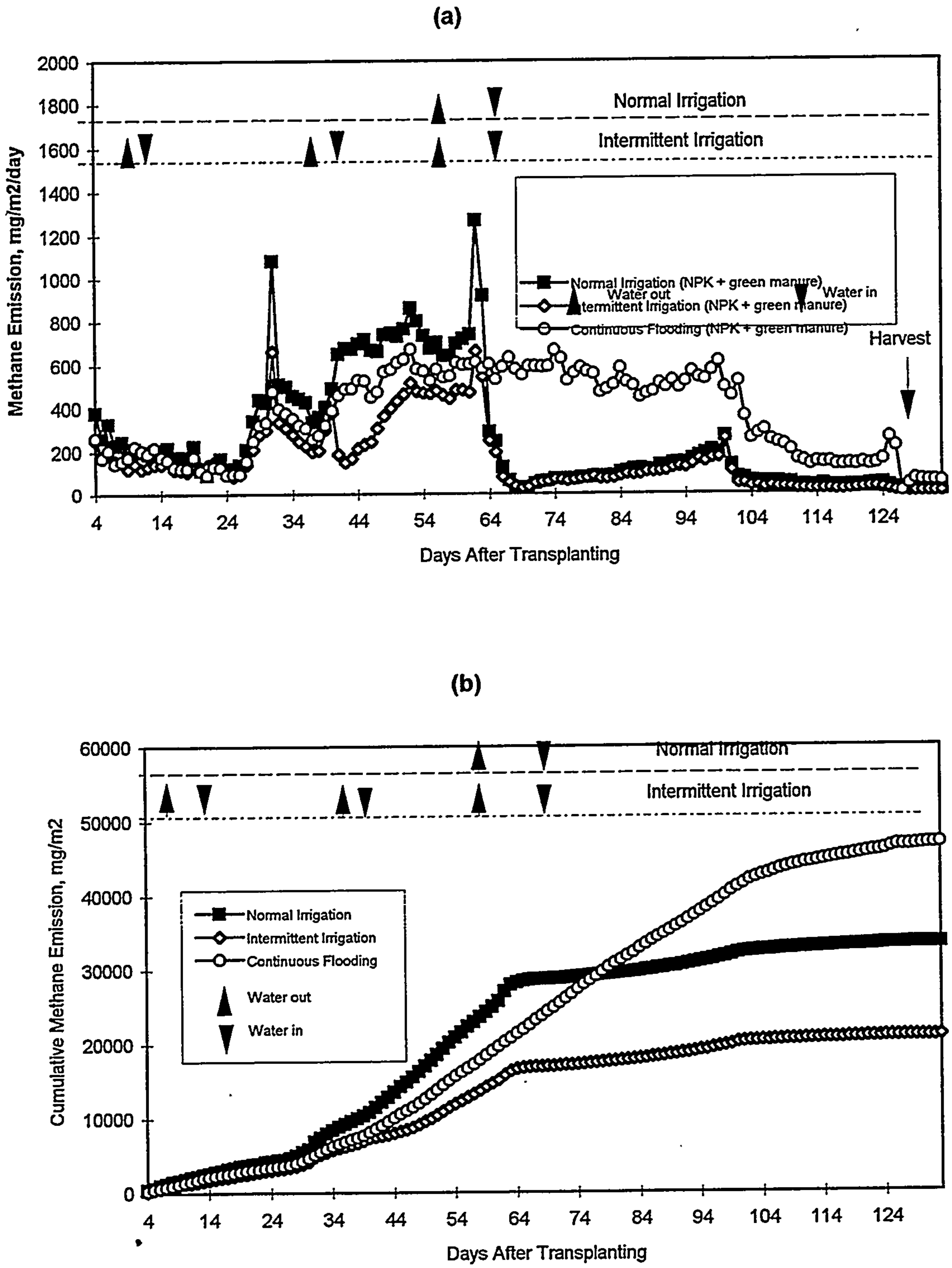


Figure 8. Effect of water regime on methane emission from rice field at Hangzhou, China during the 1995 crop season.

Evaluation of Methane Emissions of Some Rice Cultivars of Sri Lanka

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Summary

A field experiment on three local rice cultivars, namely BG 300, BG 304 and AT 303, showed no statistically significant difference ($p<0.05$) among them with respect to the methane flux emitted. The methane flux profiles of all three varieties indicated a more or less constant emission during the vegetative and reproductive periods, a peak emission during late flowering/early ripening stage and a dramatic increase in the flux during the late ripening period. The seasonal methane flux of BG 300, BG 304 and AT 303 were 200 ± 48, 156 ± 52 and 129 ± 40 g m^{-2}, respectively for a 92 day cropping period.

Introduction

Methane is a greenhouse gas implicated in global warming and stratospheric ozone chemistry (Thompson and Cicerone, 1986). Rice paddies have been identified to be one of the major methane emitters to the atmosphere (Neue, 1993). More than two-thirds of the world rice production is from tropical and subtropical countries. Therefore, a significant portion of the world's rice methane comes from these countries (Bachelet and Neue, 1993) even though the estimates of the magnitude are yet debatable due to limited availability of flux data from actual field measurements. However, the global methane flux from the rice paddies is still increasing as a result of the expansion of rice growing area in some parts of the world (Khalil et al. 1991). This emphasizes the necessity of developing mitigation technologies for curtailing methane flux while maintaining the same rice yield or improving it.

The Sri Lankan picture with regard to the extent of rice cultivation is, however, different. Since 1990, the area under rice cultivation did not increase significantly due to such factors as the limitation of uncultivated arable land and the changes in land use patterns. At present, about 570,000 ha and 350,000 ha are under rice cultivation in two annual cropping seasons, *Maha (November to April)* and *Yala (May to October)*, respectively (Central Bank, 1996). The estimated methane flux from the local rice fields is 0.407 Tg CH_4 in 1990 (Ratnasiri, 1993).

Methane is produced in the soil under flooded conditions due to microbial methanogenasis of organic matter when oxygen content of the soil is depleted. The microbiological process depends on several factors like the water depth, the soil organic matter content, the redox potential and the temperature (Neue, 1990). The methane produced in non-vegetated soil is released to the atmosphere by two processes, ebullition and molecular diffusion through water-air interface.

The rice plant is believed to enhance the emission by a third process which involves absorption of methane into the roots from the rhizosphere, diffusive transport to the shoots and eventual release into the atmosphere via stomata and micropores in leaf sheath (Nouchi et al., 1990). Apparently, the rice plant physiology plays an important role in this process. Some studies have, in fact, shown the methane flux patterns of different rice cultivars to vary widely under the same soil and other conditions (Adhya et al., 1994; Lantin et al., 1996). Therefore, the correct choice of the rice variety may be a good option for mitigating methane flux of the rice fields. This should not, however, affect the rice yield significantly. The need of studying emissions of different cultivars over an entire growing season, while keeping all other variables constant, has been emphasized (OECD, 1991).

In Sri Lanka, about 15 major rice varieties, most of them developed or improved locally, are in use, and, as such, there is some room for selection of varieties low in methane flux and satisfactory in yield. In this work, methane mitigation aspects of three popular local rice varieties were studied in a statistically significant manner. Furthermore, this paper, for the first time, reports experimentally determined methane emission factors of some local rice varieties.

Materials and Methods

A rice field located at Gelioya of the Kandy district of Sri Lanka was selected for the field experiment of this study. The rice field was divided into three blocks of equal size (i.e. 20 m x 4 m) and each block was further subdivided into four plots (5m x 4m each) by randomized complete block design. The plots were prepared for rice transplanting according to the International Global Atmospheric Chemistry (IGAC, 1994) project guidelines. Three locally developed short aged rice varieties, viz. BG 300, BG 304 and AT 303, were assigned to the plots of each block randomly such that each variety occupied only one plot of the block. The remaining plot of each block was maintained uncultivated throughout the rice cropping season. Rice plants about 21 days old were removed from the nurseries and transplanted in the appropriate plots of each block (ie. altogether three replicate plots per variety) such that three seedlings per setting are distributed in a 20 cm x 20 cm square grid array of spacing. The water depth was maintained at 5 cm level in all plots including those unplanted throughout the cropping season as recommended by the IGAC (1994) project guidelines. Fertilizer was applied as recommended by the Department of Agriculture, Sri Lanka, (1990). The first application made at the time of transplanting contained a mixture of 32.6 kg/ha Urea, 25 kg/ha P_2O_5 and 20 kg/ha K_2O. After six weeks, urea was applied again at a level of 65.2 kg/ha. Weeding was done manually and Quinalphos (ie. Ekalux EC 25 %) was applied at seedling and ripening stages to control thrips and paddy bug attacks, respectively. This study was conducted in the *Yala* season (i.e. July to October) of 1995.

Static closed chamber method (FAO/IAEA, 1992) was used for gas sample collection from rice plots. The collection systems were locally fabricated and each comprised of a 60 x 38 x 12 cm aluminum base and a 54 x 32 x 70 cm flexiglass chamber (with aluminum supports on edges) fitted with a small fan, an injection port and a thermometer. The collection systems were made airtight by sealing all joints with silicone gum. The bases were placed permanently in the plots (one each per plot including the unplanted plots) as recommended by the IGAC (1994) project before rice seedlings were transplanted. Each base placed in the vegetated plots enclosed six rice plant hills.

Gas samples from the four plots of a block were collected simultaneously within 12 minutes. All three blocks were sampled within 45 minutes on each sampling day. The sample collection was carried out twice a week on Tuesdays and Fridays at 6.00 a.m and 12 noon. For collection of gas samples from a plot, rice plants within the base were covered by resting the open end of the chamber on the channel of the base and the air inside the chamber was isolated from outside atmosphere by applying water into the channel. Four gas samples (16 ml each) were collected from the chamber at fixed time intervals of 0, 4, 8 and 12 minutes by a syringe and stored in pre-evacuated gas tight vials (Supelco Inc., USA) having self sealing silicone septa and brought to the laboratory within two hours for analysis. (Preliminary experiments showed that the vials are gas tight at least for 6 hours). The air inside the chamber was mixed before gas sampling by operating the fan for 10 seconds. The inside and outside temperatures were recorded.

Methane contents of the gas samples were determined by a gas chromatographic system (Shimadzu, Model 9AM) equipped with a molecular sieve (5A°) column and a flame ionization detector (FAO/IAEA, 1992). Nitrogen was used as the carrier gas at a flow rate of 30 ml/min. The injector, the column and the detector were maintained at 250°C, 50°C and 250°C respectively. A primary methane standard (2.6 ppmv) donated by the National Physical Laboratory, India was used to calibrate the analytical system prior to and in between gas sample analysis. The coefficient of variation of the peak area of the standard (9 replicates) and the minimum detection limit were 4.2% and 0.20 ppmv, respectively. The methane content in the chamber was calculated by taking the inside/outside temperatures of the chamber and the atmospheric pressure of the site (718 mm Hg) into account. The methane flux of each plot was determined from the slope of the regression line between methane content and elapsed time. Only sets of data having correlation coefficients better than 0.95 were used for flux calculations.

Daily methane flux at different growth stages were calculated using the formulae developed by Buendia et al. (1996). The methane fluxes at 6.00 pm were estimated from the diurnal patterns studied at respective stages.

(a) Transplanting to panicle initiation

$$F_t = 2 \times (5.18\, F_6 + 2.5\, F_{12} + 3.7\, F_{18})$$

(b) Panicle initiation to flowering

$F_t = 25.6\ F_6$

(c) Flowering to harvest
$F_t = 2 \times (6.6\ F_6 + 2.3\ F_{12} + 3.6\ F_{18})$

where F_t = total daily flux, (mg m^{-2} d^{-1})
F_6, F_{12}, F_{18} = hourly fluxes at 6.00, 12.00 and 18.00 hours, respectively

The temperature, the pH and the dissolved methane content of water and the temperature of the soil were measured on each sampling day. Agronomic data of the rice plant, viz plant height, tiller number, below and above ground biomass (both fresh and dry) and leaf area index were also measured regularly. The rice yields were estimated from those of one square meter area.

In addition, the rice soil was characterized by standard soil analysis techniques (Page et al. 1982). The soil was a reddish brown latosol with a silt loam texture and clay, sand and silt contents of 12.7%, 24.2% and 63.1%, respectively. The other chemical characteristics of the soil were pH, 4.99; cation exchange capacity, 10.0 meq $100g^{-1}$; organic carbon, 4.19%; P (available), 5.86 ppm; N (available), 154 ppm. The exchangeable Zn, Mg, Ca and K contents were 4.66, 1.82, 1.65 and 0.12 meq $100g^{-1}$, respectively.

Results and Discussion

Figure 1 shows the seasonal variation of the methane flux of BG 300, BG 304 and AT 303 rice varieties and Table 1 presents their mean fluxes at different growth stages. During vegetative (i.e. up to 30 days after transplanting) and reproductive (i.e. 30 - 60 days after transplanting) periods,respectively, all three rice varieties indicated a more or less similar and stable emission of methane into the atmosphere. The mean daily emissions during the vegetative stage was between 0.348 ± 0.047 and 0.400 ± 0.084 g m^{-2} d^{-1} whereas during the reproductive stage, it was between 0.419 ± 0.024 and 0.598 ± 0.025 g m^{-2} d^{-1} . The methane fluxes of vegetated rice plots showed one fold enhancement over unplanted plots. At late flowering /early ripening stage between 60-80 days after transplanting prominent peak emissions were noted for BG 304 and AT 303 while BG 300 produced a less prominent peak emission. As ripening stage proceeded, methane flux of all three varieties increased substantially. This is the normal pattern of emission for the rice fields treated with inorganic fertilizers (Buendia et al., 1996). In particular, BG 300 showed a very high emission at this growth period with an abnormally high emission of 19.9 g m^{-2} d^{-1} on the 99th day after transplanting.
The emissions during vegetative and reproductive stages were similar to those reported in many studies (e.g. Sass et. al., 1990). High daily emissions up to 5 g m^{-2} d^{-1} have been reported for some rice fields (Cicerone et al., 1983) but emissions of the local varieties, particularly of BG 300, at the late ripening stage was more prominent. On average, BG 300, BG 304 and AT 303 released 4.60 ± 1.02, $3.34 \pm$

1.20 and 2.77 ± 0.930 g CH_4 m^{-2} d^{-1}, respectively during the ripening stage of growth. Table 1 shows that, in all three varieties, the emission at the ripening stage was significantly higher ($p<0.05$) than those of the vegetative and reproductive stages but there was no difference between the latter two stages.

The peak emissions observed in this study during the late flowering/early ripening stage in all three varieties may have been due to root exudation whereas the high fluxes at the late ripening stage may have been produced by the degradation of dying tillers and root matter. The soil of this field contains high organic carbon content (4.19% org. C) and does not totally dry out throughout the year due to ready availability of water. Therefore, the soil may be under reduced condition all the time favoring continuous production of methane from the highly organic soil. In fact, during the latter part of the cropping season, intensive ebullition from the flooded soil. The formation of high methane contents in the soil of this rice field at the ripening stage is also evident from the dissolved methane concentration as well (Figure 2). About 5 fold increase in the dissolved methane content (i.e. from 0.2mg/ml to 1mg/ml) was observed during this period. The seasonal variation of the dissolved methane content was somewhat similar for all three rice varieties. Furthermore, statistical analysis indicated a significant difference ($p<0.05$) between the methane fluxes of the transplanted and unplanted plots. The methane flux of the transplanted plots were about 1-2 times larger than that of the unplanted fields. This emphasizes the involvement of the rice plant in the methane releasing process.

The mean daily methane flux of the rice plots cultivated with the three rice varieties for the entire cropping season were 2.20 ± 0.53, 1.70 ± 0.57 and 1.40 ± 0.44 gm^{-2} d^{-1}, respectively, for BG 300, BG 304 and AT 303. Due to high day to day variation in the methane flux of rice fields, the total seasonal flux may be a more useful parameter for the estimation of the methane flux and for comparing the methane emission potentials of different field locations. Figure 3 shows the cumulative methane fluxes of the rice varieties studied in this work. According to the Figure, the seasonal methane flux of the rice varieties were BG 300, 202 ± 48 g m^{-2}, BG 304, 156 ± 52 g m^{-2} and AT 303, 129 ± 40 g m^{-2} for a 92 day measurement period. This rice field is located at an altitude of about 500m (atmospheric pressure, 718 mm Hg) with a seasonal temperature between 19-27°C and was maintained at 5 cm water depth during the cropping season. A majority of the irrigated rice fields are, however, located in the dry zone of the country where different soil characteristics, weather conditions and crop management practices prevail. Furthermore, another significant portion is cultivated with rainfed water and, as such, may produce a substantially lower methane flux. Therefore, methane fluxes of the present study can not be extrapolated to estimate methane flux of the entire rice cultivation of the country.

Table 1 presents the statistical analysis of flux data with respect to the variety at each growth stage as well as for the whole cropping period. In general, rice cultivars may differ in methane emission due to two factors, the gas transport potential and the level of root exudation (OECD, 1991). However, the fluxes of the rice varieties of this study were not significantly different ($p<0.05$) at all three growth stages as well as during the whole cropping season. Therefore, there is not enough evidence to suggest a significant flux variation ($p<0.05$) among the rice varieties. The rice yields of the varieties (i.e. 1228, 1311 and 1653 kg/ha, respectively, for BG 300, BG 304 and At 303) were also not significantly different ($p<0.05$). Therefore, with respect the rice yield and the methane flux, all three varieties seems to perform similarly.

The possible correlations between the methane flux and some of the physico chemical parameters of the soil and the water of the rice field as well as the physiological attributes of rice plants were investigated. The correlation coefficients of the statistical analysis are summarized in Table 2. Plant height and dissolved methane correlated with the methane flux significantly ($p<0.05$) for all rice varieties. In general, below and above ground biomass showed significant correlations at $p<0.05$ or $p<0.10$ level. Other parameters, namely tiller number, leaf area index, water temperature, soil temperature and water pH did not indicate good correlations with the methane flux. The correlation analysis was repeated for the physico chemical parameters of soil and water using data gathered for short periods in order to minimize the effect of plant growth on the methane emission but no more significant relationships were observed.

Conclusions

The study suggests that BG 300, BG 304 and AT 303 rice varieties do not differ significantly ($p<0.05$) with respect to their methane releasing potential. Further studies on other popular local rice varieties are needed to identify cultivars that generate low methane fluxes.

Acknowledgements

The authors are grateful to the United States Country Studies Program and the Ministry of Transport, Environment and Women's Affairs, Sri Lanka for financial support for this study. They thank Dr. W.M.W. Weerakone of the Rice Research and Development Institute , Sri Lanka and Dr. R.O. Thattil of the University of Peradeniya, Sri Lanka for their advice on local rice cultivation techniques and statistical design of the field, respectively. Technical and field assistance of Messers P.C.P. Kurukulasooriya and M.U. Dias is also acknowledged. Ms. Jeeva Kasthuri assisted in typing the manuscript.

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Table 1 A summary of mean daily methane flux (g CH_4 m^{-2} d^{-1}) data of BG 300, BG 304 and AT 303 and their statistical analysis.

Growth Stage	Variety		
	BG 300	BG 304	AT 303
Vegetative	$0.400 \pm 0.084^{a,1}$	$0.348 \pm 0.047^{a,1}$	$0.363 \pm 0.027^{a,1}$
Reproductive	$0.461 \pm 0.071^{a,1}$	$0.598 \pm 0.025^{a,1}$	$0.419 \pm 0.024^{a,1}$
Ripening	$4.60 \pm 1.02^{a,2}$	$3.34 \pm 1.20^{a,2}$	$2.77 \pm 0.930^{a,2}$
Cropping season	2.20 ± 0.53^{a}	1.70 ± 0.57^{a}	1.40 ± 0.44^{a}

Note: Means followed by the same letters in a row and the same numbers in a column are not significantly different at $p<0.05$
(Number of data points per variety vegetative 15, reproductive 24; ripening 36)
Vegetative - up to 30 days after transplanting , Coefficient of variation = 23.8%
Reproductive - between 30 - 60 days after transplanting, Coefficient of variation = 8.6%
Ripening - between 60 - 102 days after transplanting, Coefficient of variation = 40%

Table 2 Correlation coefficients (r) for linear relationships between methane flux and field parameters

Variety	DM	PT	TN	LAI	WT	ST	WPH	AGFB	BGFB	AGDB	BGDB
BG 300	0.92*	0.77*	0.38	0.48	0.57**	0.34	0.45**	0.90**	0.90**	0.96*	0.94**
BG 304	0.63*	0.71*	0.36	0.53	0.33	0.10	0.43	0.98*	0.97*	0.99*	0.94**
AT 303	0.76*	0.62*	0.38	0.39	0.14	0.08	0.23	0.77	0.92**	0.95**	0.76

Key:
DM - Dissolved methane
TN - Tiller Number
WT - Water Temperature
WPH - Water pH
PT - Plant height
LAI - Leaf area index
ST - Soil Temperature
AGFB - Above ground fresh biomass
BGFB - Below ground fresh biomass
AGDB - Above ground dry biomass
BGDB - Below ground dry biomass
* denotes statistical significance at $p<0.05$
** denotes statistical significance at $p<0.10$

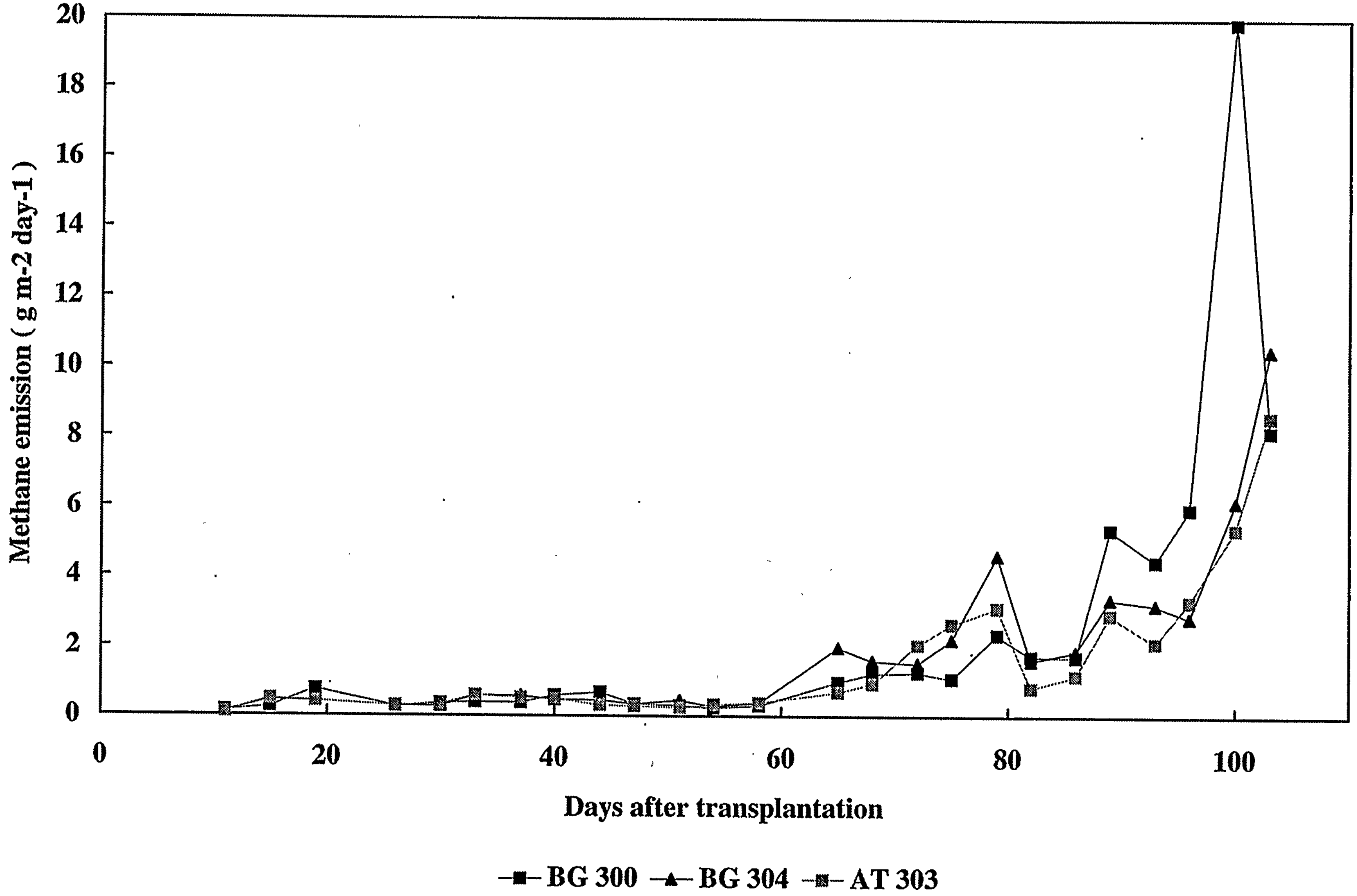

Figure 1 :- Seasonal methane emission of rice varieties

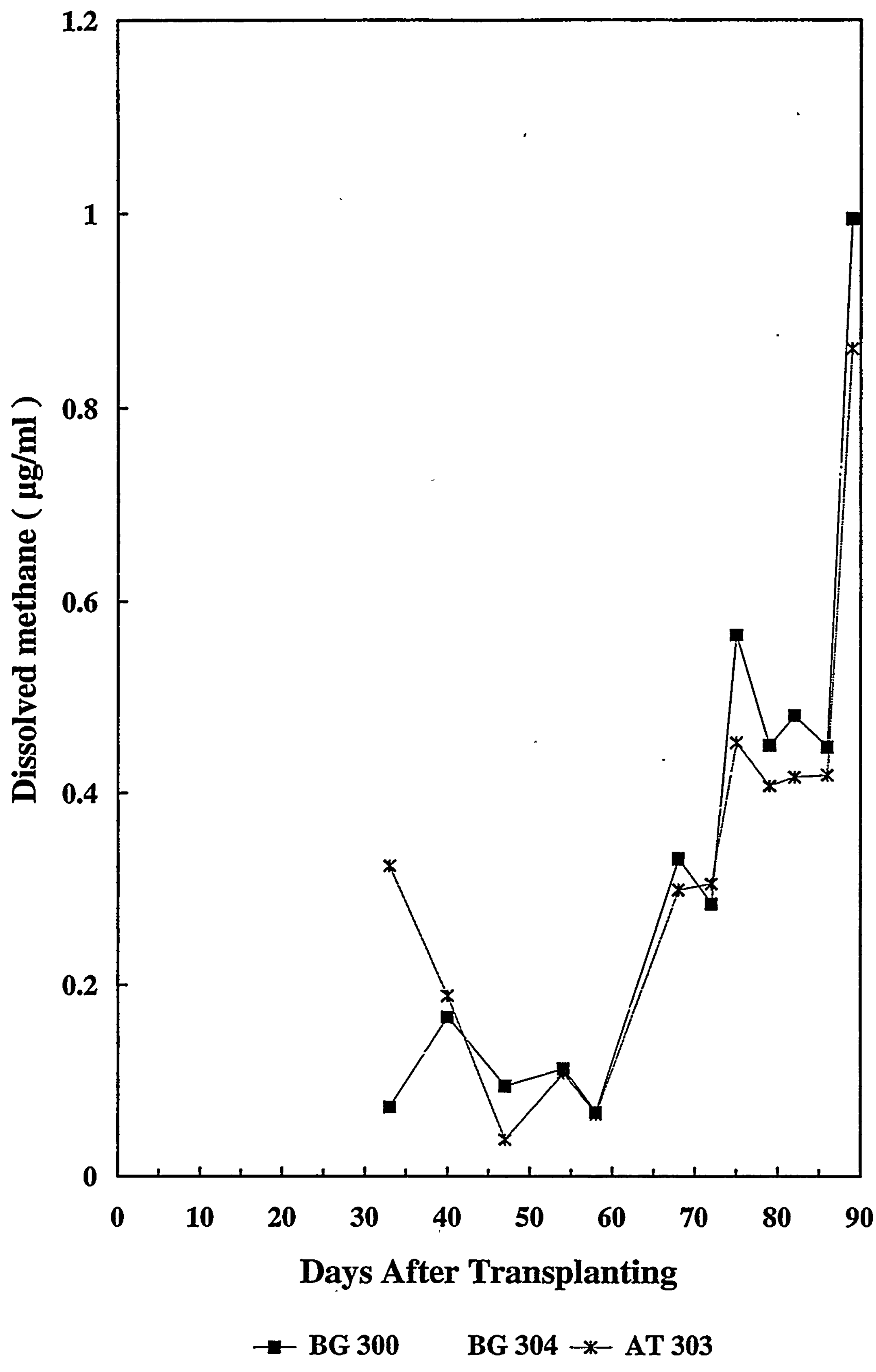

Figure 2 :- Seasonal variation of the dissolved methane content of the rice plots cultivated with

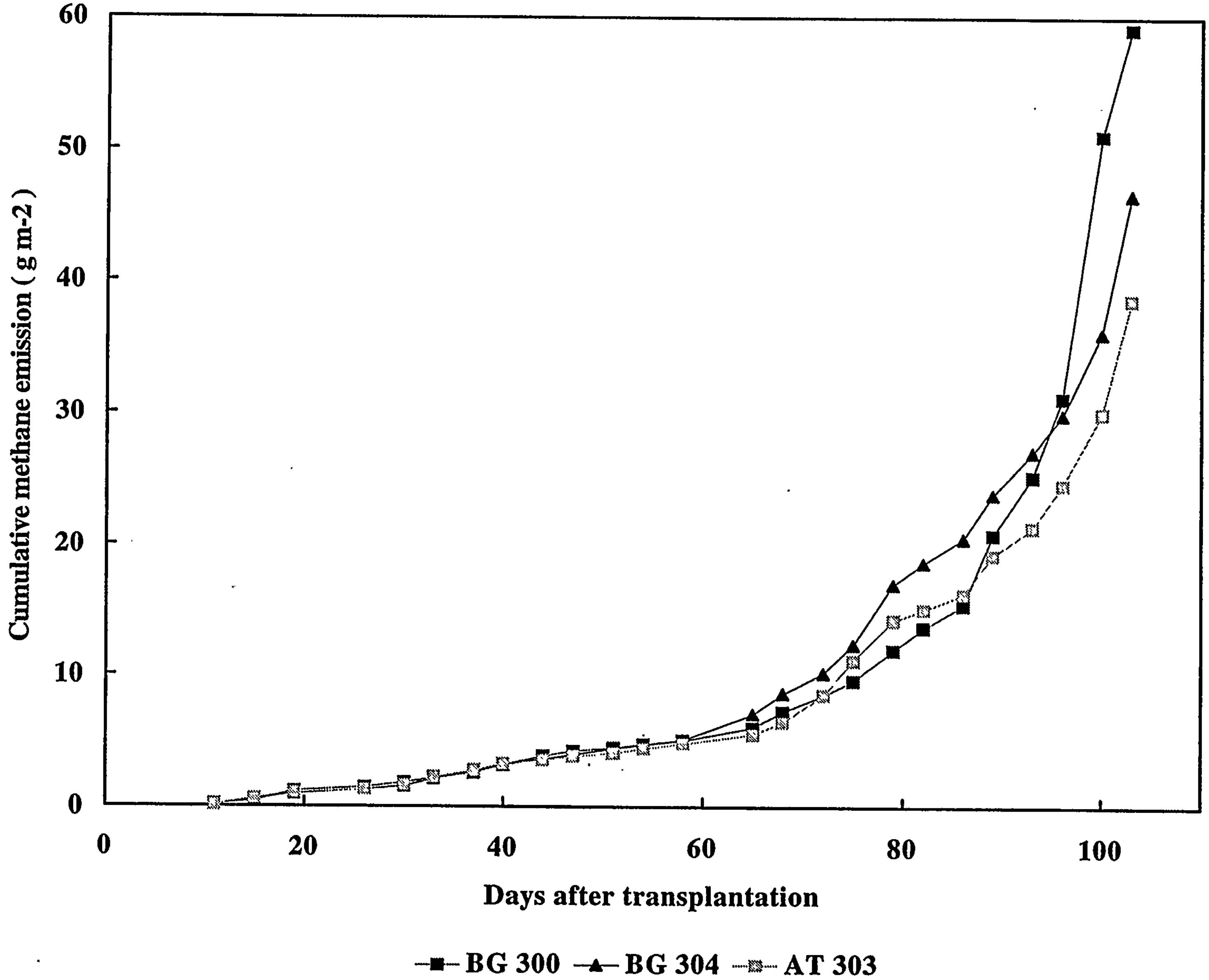

Figure 3 :- Cumulative methane emission of rice varieties

Scenarios of forestry carbon sequestration measures in the Russian Federation and priorities for Action Plan.

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Development of forestry mitigation strategy under Russian transition economy conditions has many difficulties and specific features. The most important factors are: shortage in funds; absence of well defined legislation, rules and standards; absence of adequate control systems; weak transport infrastructure and export problems. Assessment of economic possibilities, potential, short- and middle-term measures show that strategies have to be focused on improvement and promotion of current carbon sequestration activity.

Five baseline forestry scenario (#1) and four other scenarios (#2 - #5) for 2000-2040 were developed. Each scenario covers all forested area but provides separate analysis of 30 "forestry ecoregions. Three types of forestry management were included in scenarios: clear-cut logging and reforestation (by scenarios #2 and #3); selective logging and thinning (#4); measures to prevent and manage fires (#5).

The baseline scenario results in a constant net-sink of about 150 MtC/yr. An increase in clear-cut logging on the basis of current forestry practice will cause a rapid drop of net-sink. Implementation of a modest increase in clear-cut logging with active forest fire and selective logging measures could provide with a slight increase of net-sink.

Consideration of scenarios helps identify regional forestry priorities for Russian Climate Change Action Plan. The priorities by region include: European-Ural: 1) creation of economy mechanism to increase forestry effectiveness on the same cutting areas, 2) assistance to natural reforestation. Central and North-East Siberia: promotion of forest fire protection system. South Siberia and Primorie and Priamurie: limit of clear-cut logging and creation market situation for better forestry efficiency. The proposed Joint Implementation Vologda reforestation project which is being considered now by special bodies of the USA and the Russian Federation is in good agreement with these priorities.

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Scenarios of forestry carbon sequestration measures in the Russian Federation and priorities for Action Plan.

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General approach and state of affairs with forestry mitigation options.

Development of mitigation strategy under Russian transition economy conditions has many specific features in forestry as well as in other sectors of the national economy. The most important factors for forestry sector are shortage in funds; absence of well defined legislation, rules and standards; absence of adequate control systems; weak transport infrastructure and export problems (*Nilsson et.al.,1994; Strakhov et.al.,1995; Vinson et.al., 1996*). Considering mitigation activity under the Russian Country Study Program one can see the following main steps:

1. Collecting of basic data on forestry development before 1990s including regional features and sharing of funds and resources;
2. Collection of data on crisis events of 1990s;
3. Consideration of potential possibilities of carbon sequestration;
4. Consideration of real carbon sequestration possibilities in short- and medium-term scales;
5. Developing of national and regional scenarios of forestry mitigation activity in 1997-2040 and calculation of carbon sinks or emissions on the base of carbon cycle model;
6. Determination of priorities for Climate Change Action Plan

In this way such six subtasks are linked to inventory/vulnerability results completed just recently and Climate Change Action Plan preparation which has been started in spring, 1996. Mitigation works considered here have to provide us with detail basis for Action Plan preparation in 1997 and its future implementation. The Joint Implementation (JI) activity is one of important elements for Action Plan. The first JI RUSAFOR project is under implementation, (*Vinson et.al., 1996*) and the second VOLOGDA reforestation project is under Russian Government's consideration now.

Background information obtained by first and second subtasks and potential and possible short- and medium-term measures were reported before in Warsaw Mitigation Workshop in June, 1996 and were published later in "Environmental Management" Journal (*Kokorin et.al.,1996; Vinson et.al., 1996*).

Therefore the specific goals of this paper are 1) considering of national and regional scenarios of forestry mitigation activity and 2) identification of related priorities for Action Plan. The main points of

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potential and possible short- and medium-term measures are briefly described before as introductory basis.

Brief review of potential short- and medium-term measures.

General examination of carbon sequestration potential shows that a carbon sink can be increased by several times above their current level but mostly by involving of difficult to access huge areas of Siberia and Far East in to active forestry. Possible specific values of carbon sequestration (per area unit) can not be high (many times smaller than in tropical or even in temperate zone), (*Vompersky and Utkin 1988; Isaev et.al., 1993; Dixon et.al., 1994; Kokorin et.al., 1996; Vinson et.al., 1996).*

According to Russian Federal Forestry Service, it is possible to increase the forested area by 80—100 Mha. Changes in age distribution of forests can give us large CO_2 sink too. We have also more than 200 Mha of overmature (very old) forests in the Asian part of the country (*Nilsson et.al., 1994; Handbook on Forest Fund, 1995*). The natural fall in these forests is much higher than the growth. The increase in forest density (number of trees per ha) is one more potential mitigation option. The excess of humidity is a limiting factor for improving the quality and density on 40% of all Russian forest lands (*Bazilevich, 1993*). The drainage measures can be useful. There are great possibilities to improve forest fire protection; cutting technology and transportation (*Strakhov et.al., 1995*). Increase in duration of forestry cycle due to replace of some deciduous species by coniferous is also possible over about 120—140 Mha. Thus Russian forests have a large CO_2 sinking potential which is estimated as from 200 to 400 MtC/yr and sometimes even as high as 1000 MtC/yr (*Dixon et.al.,1993; Krankina and Dixon, 1994; Kokorin et.al., 1996; Vinson et.al., 1996).*

In some reports one can see consideration of different short- and medium-term forestry measures in Russia and related calculation of possible carbon sequestration effects (*Krankina and Dixon, 1994; Kolchugina et.al., 1995; Kokorin et.al., 1996; Vinson et.al., 1996).* Measures include, *inter alia*, afforestation of about 5 Mha, enhanced forest productivity on 10 Mha, establishment of land-protective forest strands on 4 Mha, increased forest fire control and suppression of fires on 30-50% of annual crown fire area, increase in efficiency of wood utilization and age of the final harvest on 50% of clear-cuts, and etc. The total carbon sequestration effect could be estimated at 60 MtC/yr.

However these measures were considered mostly as additional steps in an Action Plan. However the transition economic crisis in forestry sector lead to an another question: what is way to restore forestry as a sector of economy with effective carbon sequestration, if possible on new technology level (*Shvidenko and Nilsson, 1994; Strakhov et.al.,1995*). This question is the main issue for Action Plan preparation. So it is more important to consider scenarios of forestry development without planning of special "climate change" measures and determine the most important points for influence on future development. After that, in 1997, "additional" measures should be considered again but in the context of forestry development as a whole and with more details.

Scenarios of forestry mitigation activity and related changes in CO_2 sinks or emissions.

The baseline forestry scenario (#1) and four other scenarios (#2 - #5) of forestry activity in 2000-2040 were considered. Every scenario covers all forested area of the Russian Federation but provides separate analysis of 30 "forestry ecoregions" grouped in 6 geographical or climate condition regions. Such fine consideration is necessary for taking into account all local features and possibility to go down to concrete projects or local measures. The same subdivision were used before for prognoses in vulnerability/adaptation works (*Kokorin et.al., 1995; Kokorin and Nazarov 1995*), where prognoses were based upon so-called "baseline forestry scenario #1" with different climate change scenarios. In this work we have taken the opposite approach: "baseline climate change scenario", which is in full accordance with middle IPCC climate change scenario (*Climate Change.,*1996), plus different forestry mitigation scenarios. The same carbon cycle model reported previously, (*Kokorin et.al., 1995; Kokorin and Nazarov 1995; Kokorin et.al.,* 1996) was used in the both: climate change and mitigation calculations.

Three types of forestry management activity were included in scenarios: clear-cut logging; selective logging and thinning; forest fire control, including measures to prevent fires or to limit area burned out. We took into account current and past volumes of these measures in the different administrative units of the Former USSR, tree species and natural zone distribution data (*Molchanov, 1977; Basilevich, 1993; Isaev et.al., 1993; Handbook on Forest Fund, 1995*). Economic problems listed in the beginning of the report led us to focus on, first of all, improvement and promotion of current activity. Calculation scenarios were constructed on the basis of data obtained by Federal Forestry Service which are considered in the Final Report of the Russian Country Study (*Handbook on Forest Fund, 1995; Final Report, 1997*).

Baseline forestry management scenarios suggest slow but stable linear growth of forestry as a sector of national economy in 1997-2010. The scenario is "restoration" of forestry to 1990 level. Actually before 2010 this scenario is only reflection of 1990-1995 data. However, in significantly longer time range 1997-2010.

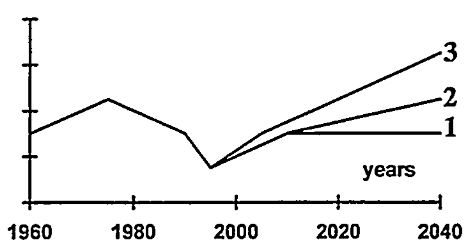
Considering the years 2010-2040 we suggest that forestry activity will be fixed at a constant level of 1990/2010. This level includes not only very large increase in logging with timber export followed but also wide-spread reforestation and expensive forest fire control measures with use of aircraft and helicopters (*Nilsson et.al.,1994; Final Report, 1997*). Thus it is reasonable to forecast that Russia will have some part of global wood product market. However situation will not allow us to expand wood trade and therefore logging will be on constant level. This scenario can be described as "modest forestry growth".

The second scenario can be named as "intensive logging growth". It suggests that clear-cut logging will increase significantly in 2010-2040 up to maximum value observed in 1980s or 1970s, except South Far East: Primorie and Priamurie (Amur River basin) region where 1990 was the most active year and increase by 50% is suggested for 2010-2040.

The third scenario reflect the greatest and very intensive growth of clear-cut logging: Years 2010 and 2040 of the second scenario were replaced here by 2005 and 2020 with linear extrapolation of the growth in 2020-2040, see Figure 1.

Figure 1
Approximate scheme of forestry activity under the different clear-cut logging scenarios

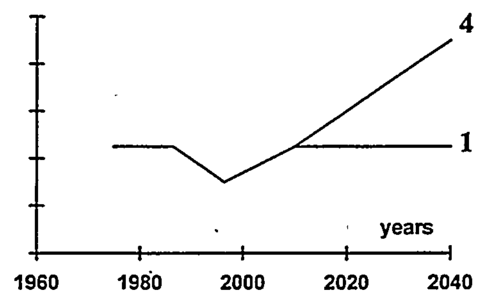
Area of clear cuttings in relative units



#1 - baseline scenario with "modest forestry growth";
#2 - intensive logging growth;
#3 - the most intensive growth of clear-cut logging.

Figure 2
General scheme of forestry activity under the different non-clear-cut logging (selected logging and thinning) scenarios

Volume of harvesting by non-clear-cut logging in relative units



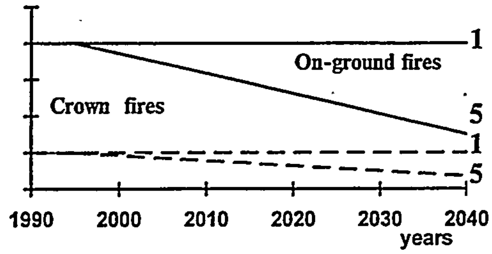
#1 - baseline scenario with "modest forestry growth";
#4 - "sustainable forestry" scenario where increase in harvesting is provided by non-clear-cut logging only

Scenarios #4 and #5 deal with other types of forest management other than clear-cut logging. The fourth scenario differs from baseline #1 by another volumes of selected logging and thinning after 2000. In this case increase in alternative type of harvesting reflect so-called "sustainable forestry management", Figure 2. Actually in this scenario we tried to estimate the effect of possible measures related to this direction of forestry after 2000. Harvesting (m^3) has significantly more volume than in the baseline scenario. However, the decrease in CO_2 sink is almost the same.

The fifth scenario deals with forest fire control measures starting in 2000. They provide a linear decrease in areas of anthropogenic fires (separately for ground and crown fires). The decrease depends on the place considered. In general, we suggest a 2-fold decrease in areas for far and low populated regions of East Siberia and Far East and, 3 or 4-fold decrease in other places, Figure 3.

Figure 3
Approximate scheme of forestry activity under the different forest fire control scenarios

Areas of anthropogenic forest fires in relative units



#1 - baseline scenario with "modest forestry growth";
#5 - "forest fire control" scenario: decrease in areas is generally 2-fold in hard accessible regions and 3 or 4-fold in other parts of the country.

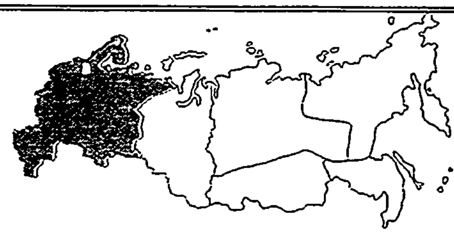
Consideration of Russian forests as a whole does not allow to determine regional priorities required for Action Plan. So it is necessary to observe regions step by step, at least briefly, with focus on the main forestry areas right where first projects are under draft planning now.

European-Ural region. According to all scenarios, a decrease in net CO_2 sink is predicted due to a shift in age distribution ("growing older") of forests. Age distribution of forests observed now is a result of wide-spread logging not only in 1960s- 1980s but also in the past including the beginning of the century. They caused "an excess" of young forests and consequently net-sink (difference between sinks and emissions in a forest carbon cycle, where sinks are more than emissions). However, these forests are becoming older with a smaller annual net-sink. For example, coniferous mature forest (100 years old) is 2-3 times smaller sink than middle-age (60 years), so-called overmature forest (>140 years) where decomposition processes exceed growth are already a net-source. This feature is the main modeling factor but dependence on logging scenario is also important, Figure 4.

Scenario #2 assumes a 5-10% increase in harvested wood in 2010-2030 but non-proportional decrease in sink. This response can be explained by depletion of forest resources after 2010-2015 and smaller harvesting on the same area. Scenario #3 leads to rapid depletion of forests. So there is no practical possibility (from both ecological and market economy points of view) to implement this scenario. Notice that we consider not only intensive logging but also complete reforestation of cutting areas in several years after clear cut (imitation of activity of 1980s).

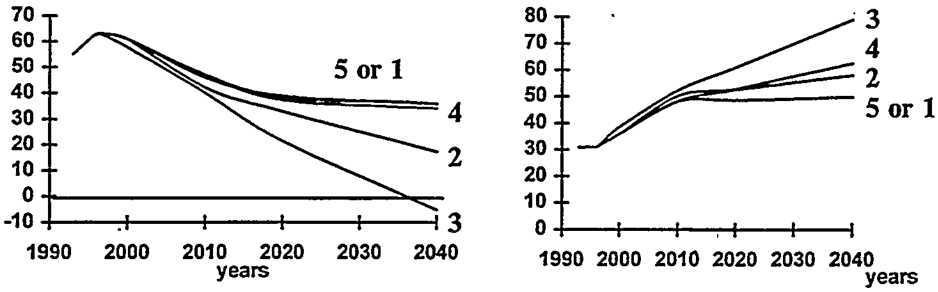
On the other hand, forest fire emission is not significant in the carbon balance of the European-Ural region. Therefore possible contribution of forest fire control measures is smaller than contribution of other measures in region considered.

Figure 4
Prognoses for the European-Ural part of the Russian Federation under the different scenarios.



Carbon net-sink in MtC/yr

Prognoses of wood harvested and removed from forest MtC/yr (1 tC is equal around 4 m³ of wood)



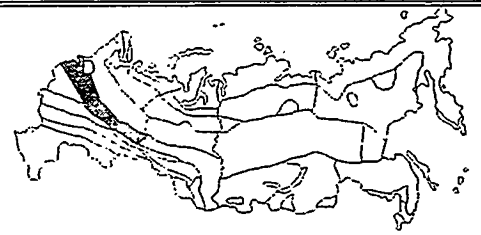
#1 - baseline scenario - "modest forestry growth";
#2 - intensive clear-cut logging growth;
#3 - the most intensive growth of clear-cut logging.
#4 - baseline scenario plus increase in harvesting provided by non-clear-cut logging only;
#5 - "forest fire control" scenario: baseline scenario plus decrease in on-ground fire areas by 40% and crown fire areas by 5 times.

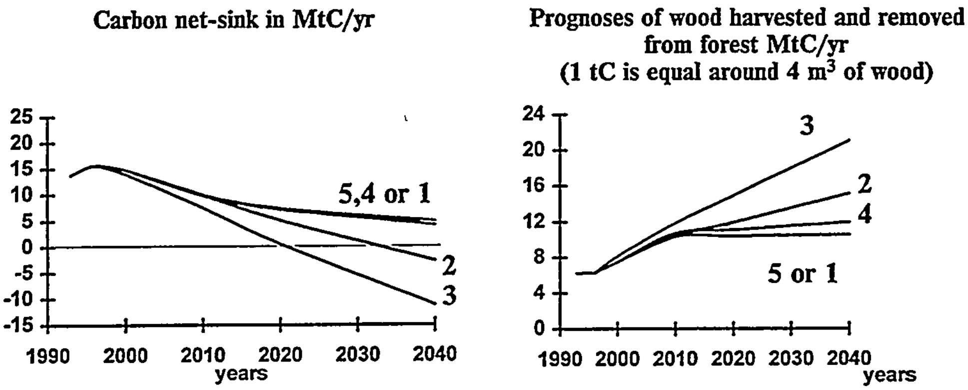
Replace of non-clear-cut logging by selected logging could give us very significant effect. In comparison with scenario #2, scenario #4 will be able to provide the same volume of wood harvested in 2020 and more wood in 2040 with minimum decrease in carbon sink. So this scenario could illustrate importance of a "sustainable forestry" concept and implementation.

In this way it is very important to consider south taiga zone of European-Ural part, Figure 5. This is the most important forestry "belt" which covers mostly Novgorod, Vologda, Yaroslavl' and Vyatka oblasts and usually considered as first place for mitigation measures. The proposed Russian - US JI forestry project is also in this zone (Vologda reforestation project). The zone contains good quality pine and fir forests, relatively satisfactory road structure, stable market economy policy of local authorities and positive public opinion related considered problems.

In this South Taiga belt decrease in carbon sink after 2000 is unavoidable but rate of decrease strongly depends on volumes of clear-cut logging. Logging of about 10 MtC/yr on 170000 ha (level of 1990) causes slow decrease in sink, but logging of additional 5 MtC/yr on additional 70000 ha (level of some years of 1970-1980s) could lead to fast depletion of forests and net-emission after 2030. So forestry management can play a key role for "carbon sink protection". Complete reforestation on clear-cut areas is considered in each region. However there are a lot of additional free lands for reforestation, mostly for natural reforestation which is usually very successful and inexpensive here.

Figure 5
Prognoses for the South Taiga zone of European-Ural part of the Russian Federation under the different scenarios.





#1 - baseline scenario - "modest forestry growth";
#2 - intensive clear-cut logging growth;
#3 - the most intensive growth of clear-cut logging.
#4 - baseline scenario plus increase in harvesting provided by non-clear-cut logging only;
#5 - "forest fire control" scenario: baseline scenario plus decrease in on-ground fire areas by 40% and crown fire areas by 5 times.

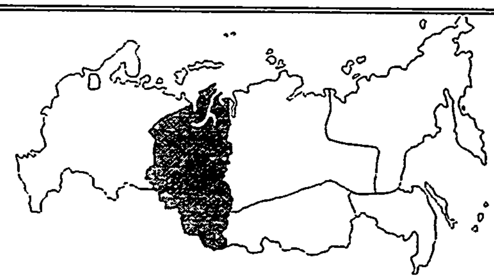
Action Plan priorities for the European-Ural zone is: 1) creating of economy mechanism for increase of forestry effectiveness on the same cutting areas, including full reforestation on clear-cut areas and 2) assistance to natural reforestation on currently non-forested lands.

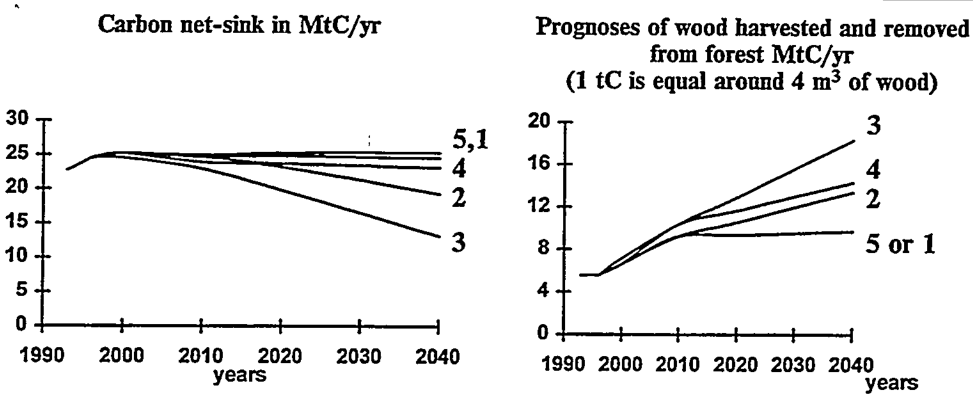
Under the Country Study Program we prepared similar analysis for 30 forestry ecoregions of Russia including 8 in European-Ural part. The results are summarized below.

West Siberia. According to baseline scenario #1, we could expect a very stable net-sink. Possible positive influences of non-clear-cut logging and even forest fire control measures are very small here, Figure 6.. Possible level of thinning and other selected harvesting is limited because almost all forested territory of the region is hard accessible. Typical level of forest fires in West Siberia is significantly smaller than in East Siberia or in Far East.

Only a large increase in clear-cut logging (up to harvesting of 12-14 MtC/yr on about 200,000 ha or more than 2-fold increase of current level) could cause fast decrease in net-sink after 2010. Consequently, contribution of possible measures in West Siberia is less then in other regions. However, in general, implementation of improved forestry practice is also very important for full-scale restore of forestry as a sector of economy.

Figure 6
Prognoses for the West Siberia forest of the Russian Federation under the different scenarios.



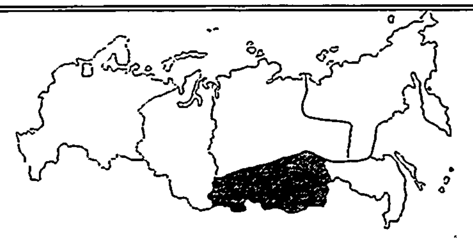


#1 - baseline scenario - "modest forestry growth";
#2 - intensive clear-cut logging growth;
#3 - the most intensive growth of clear-cut logging.
#4 - baseline scenario plus increase in harvesting provided by non-clear-cut logging only;
#5 - "forest fire control" scenario: baseline scenario plus decrease in on-ground fire areas by two third and crown fire areas by 4 times.

The next region South Siberia has a great importance for carbon sequestration. According to inventory data this region provides one third of a total net-sink, Figures 7 and 8.

Restoration of logging wood volumes of 1980s and 1970s could cause fast drop of CO_2 net-sink in this region. In this case any forest fire control measures or modest replace of clear-cut logging by selective harvesting can not compensate for this effect. It means that logging levels of the past are too large for South Siberia and it is impossible to continue such practice in future and also mountain the current CO_2 sink. The level of annual harvesting of about 15 MtC/yr on approximately 250,000 ha is maximum possible level without becoming a net source.

Figure 7
Prognoses for the South Siberia forests of the Russian Federation under the different scenarios.



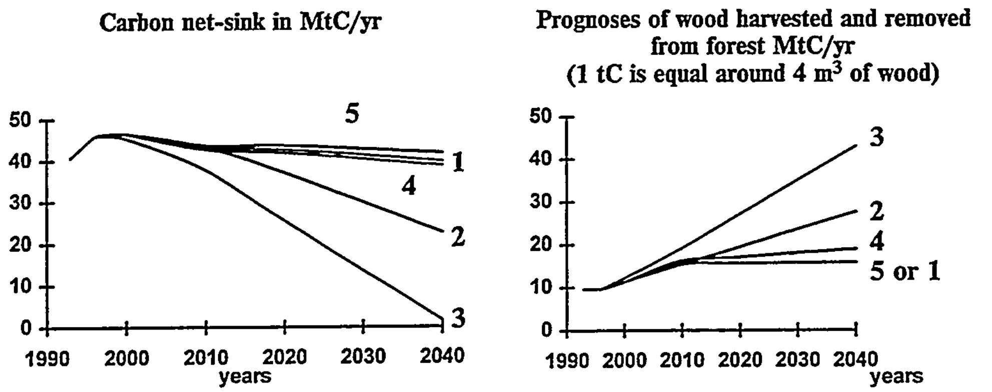
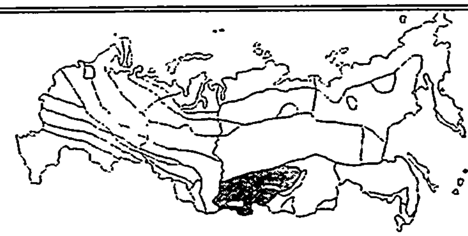
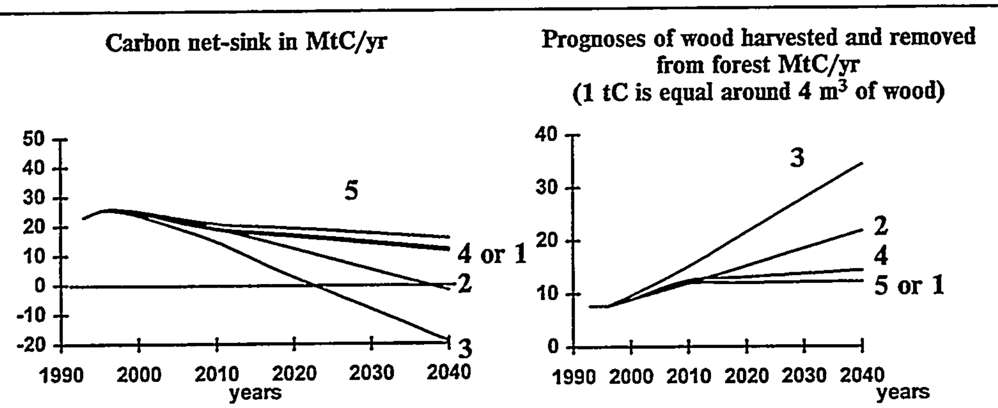


Figure 8
Prognoses for South Taiga forests of South Siberia under the different scenarios.





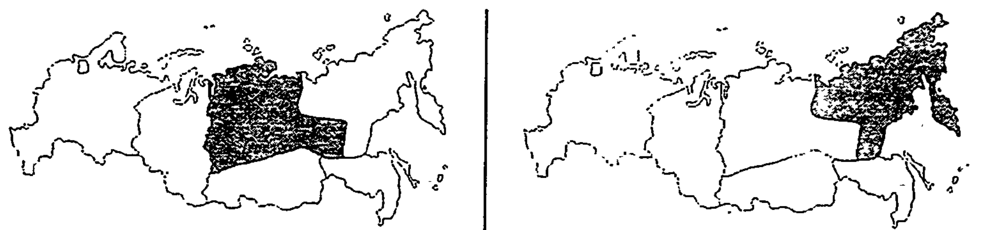
#1 - baseline scenario - "modest forestry growth";
#2 - intensive clear-cut logging growth;
#3 - the most intensive growth of clear-out logging.
#4 - baseline scenario plus increase in harvesting provided by non-clear-cut logging only;
#5 - "forest fire control" scenario: baseline scenario plus decrease in on-ground fire areas by 2.5 times in taiga forests and by 40% in deciduous forests; decrease in crown fire areas by 40-50% from average annual level of two last decades.

According to recent vulnerability investigation of South Siberia forests (*Kokorin and Nazarov 1995*), we could expect that a positive influence of warming and growth of CO_2 concentration will be more than negative influence of tropospheric ozone and some other external factors. Therefore positive net-effect could help us to keep net-sink on almost constant level. However, it requires limiting of logging in 1995-2010 on modest level and no increase in logging after 2010 (baseline scenario #1).

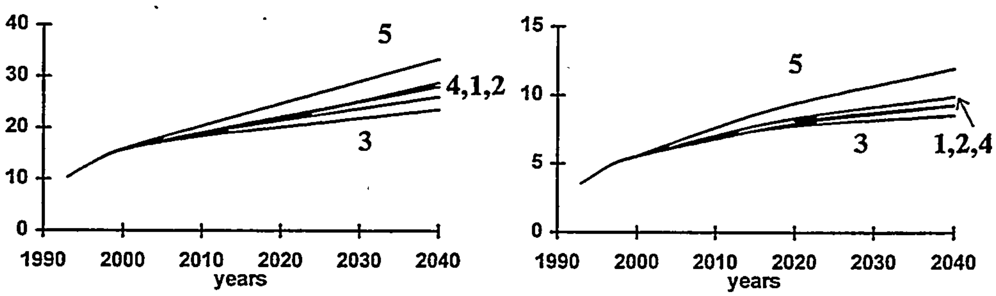
So priority for Action Plan is limitation of clear-cut areas. Increase in forestry efficiency on these areas have a key importance. Effect is especially sharp in South Taiga zone of South Siberia where the main forestry enterprises of Irkutsk oblast and Krasnoyarskii krai are harvesting high quality pine, fir and Siberian cedar forests (Figure 8). Only stabilization of harvesting level as 10-12 MtC/yr on less than 200,000 ha could provide satisfactory compensation of decrease in net-sink caused by "growing older" process.

Central Siberia. and North-East Siberia regions cover huge hard accessible territories with similar type of prognoses, Figure 9. In theses regions projections are strongly different from projections for regions considered in the above.

Figure 9
Prognoses for Central and North-East West Siberia forests under the different scenarios.



Carbon net-sink in MtC/yr
(logging levels is very small and there are no reasons to wait for increase in the next decades)



#1 - baseline scenario - "modest forestry growth";
#2 - intensive clear-cut logging growth;
#3 - the most intensive growth of clear-cut logging.
#4 - baseline scenario plus increase in harvesting provided by non-clear-cut logging only (minor influence in considered regions;
#5 - "forest fire control" scenario: baseline scenario plus decrease in on-ground as well as crown fire areas by 40% from average annual level of two last decades.

The baseline scenario #1 gives us increase in net CO_2 sink due to climate change influence. In contrast with other regions considered before, forest fire control has a greatest importance. Notice that only a part of regions is covered now by regular observations of fires (including aircraft observations). Logging possibilities are strongly limited by hard accessibility of the main part of the regions. So logging levels always were small and there are no reasons to expect an increase in the next decades. The similar reason determines also low possible level of selected logging and thinning.

Establishment of forest fire observation and control system can be considered as a priority measure in North-East Siberia, as well as in Central Siberia. Several years ago Federal Forestry Service has developed plan to organizing forest fire observation and protection system on almost all these territories to 2010-2020 problems (*Nilsson et.al.,1994*). However currently there are no funds for implementation as well as for support of arctic zone economy as a whole. Generally the solution strategy is wood market mechanisms and new forestry regulation but now and in the next decades there are no market possibilities in considered regions. So "Action Plan path" is 1) market forestry policy in other regions with sharp economy of federal subsidies and after 2) use of funds released for fire control system in East Siberia and Far East.

Primorie and Priamurie.

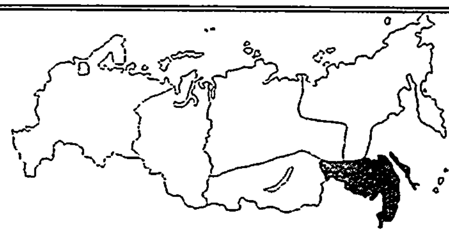
According to calculations, possible CO_2 net-sink dynamics is generally close to projections for South Siberia. Similarly overlogging can cause a sharp decrease in sink. Forest fire control measures are not insignificant but clear-cut logging level plays a key role, Figure 10. It is important to underline two features of the region: 1) good export possibilities due to suitable geographical position and relatively small transport expenses and 2) almost all logging is located in coniferous forests of taiga while these forests are only a current weak carbon net-sink.

According to inventory data, taiga forest covers about two third of forested area but provides only about 40% of net-sink. Consequently even modest increase in wood trade and logging by current practice will cause net-emission in this zone, Figure 11. According to our scenarios, an increase in logging is projected and it is possible to stabilize net-emission near zero level if logging is 10-12 MtC/yr on about 200,000 ha annually. More intensive logging can cause fast increase of net-emission after 2010.

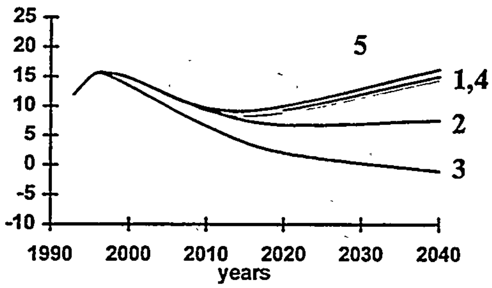
Thus Action Plan priority is control of clear-cut logging with establishment of regulation and creating market situation for better efficiency of forestry. The economic situation in Primorie is worse than in Russia as a whole. So it is possible to plan only measures with great socioeconomic effect, creating of new jobs or/and infrastructure. Developing of possible proposals is not easy task and in this way related Project "Russian Far East Sustainable Natural Resources Management Program" is undertaken by Federal Forestry Service, Pacific Institute of

Geography, local authorities of Primorski and Khabarovski Krais from Russian side and US AID, Wildlife Foundation from the US side.

Figure 10
Prognoses for Primorie and Priamurie forests under the different scenarios.



Carbon net-sink in MtC/yr



Prognoses of wood harvested and removed from forest MtC/yr (1 tC is equal around 4 m^3 of wood)

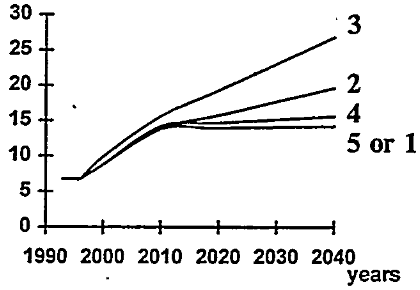
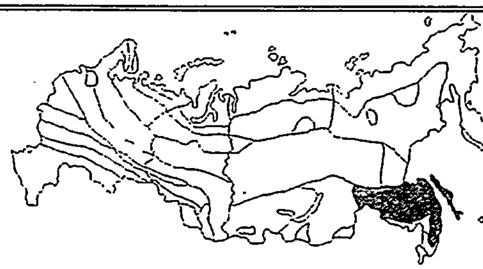
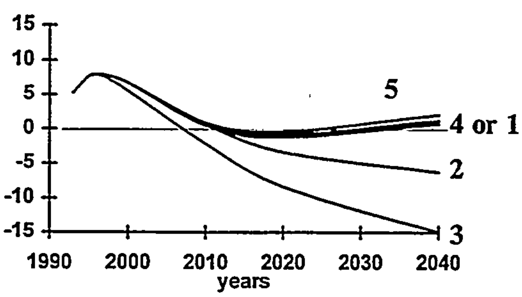


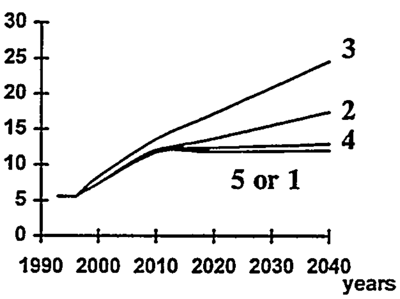
Figure 11
Prognoses for South Taiga forests of for Primorie and Priamurie region under the different scenarios.



Carbon net-sink in MtC/yr



Prognoses of wood harvested and removed from forest MtC/yr (1 tC is equal around 4 m^3 of wood)

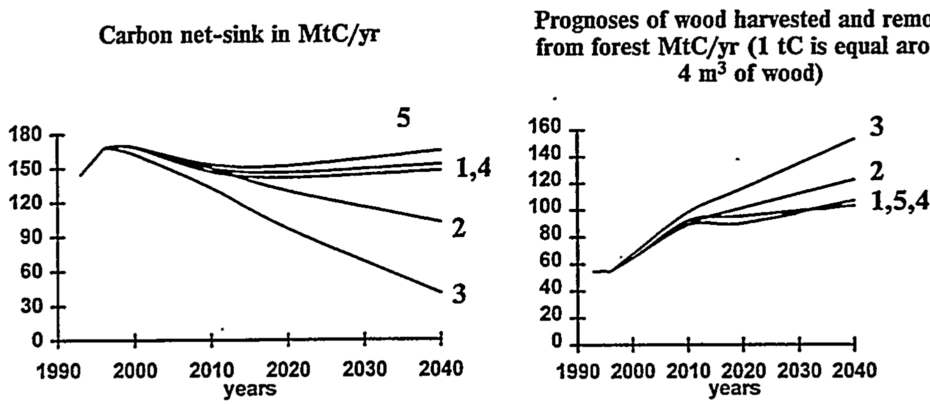


#1 - baseline scenario - "modest forestry growth";
#2 - intensive clear-cut logging growth;
#3 - the most intensive growth of clear-cut logging.
#4 - baseline scenario plus increase in harvesting provided by non-clear-cut logging only;
#5 - "forest fire control" scenario: baseline scenario plus decrease in on-ground fire areas as well as crown fire areas by 2.5 times in taiga forests and by 40% in other forests.

After separate consideration of regional forestry scenarios, <u>country-scale scenarios</u> are considered usually. However Action Plan forestry priorities of different regions are absolutely different and country-scale figures mask problems. Growth of net-sink in Central and North-East Siberia could compensate its decrease in European part and Primorie, and etc. Therefore it is reasonable to consider consolidated estimate very briefly.

Baseline scenario provide with almost constant level of net-sink which is approximately 150 MtC/yr; decrease in European-Ural region and South Siberia could be compensated by increase in Central and North-East Siberia. An increase in clear-cut logging on the basis of current forestry practice can cause fast decrease in net-sink after 2010 up to 2-fold drop in 2010-2040 under the "most extensive clear-cut logging" scenario with logging volume of 1970s in 2020, Figure 12.

Figure 12
Prognoses for the Russian Federation as a whole under the different scenarios.



#1 - baseline scenario - "modest forestry growth";
#2 - intensive clear-cut logging growth;
#3 - the most intensive growth of clear-cut logging.
#4 - baseline scenario plus increase in harvesting provided by non-clear-cut logging only;
#5 - "forest fire control" scenario: decrease in areas is generally 2-fold in hard accessible regions and 3 or 4-fold in other parts of the country..

Only composition of a modest (baseline) increase in clear-cut logging with active forest fire control measures (mostly in Siberia and Far East) and increase in selective logging and thinning could provide slight growth of net-sink. However these scenarios (#4 and #5) can be implemented under new forestry regulations only.

In this way it is necessary to underline that a new document titled "Forest Code" which was prepared recently by Federal Forestry Service and was passed by Russian State Duma (parlament) in July, 1996. The main points of a new law are the following. 1) All forests are Federal property (except forests on territories of cities, villages or other settlements). There are no private forests now in Russia. So this point is only validation of de-facto situation. 2) Change in land use on forested lands is forbidden. 3) New market economy terms are introduced: forest concession; rent a forest area, establishment of secondary market of forestry land use. 4) Thinnings and reforestation works always will be built-in element of land-use concession contract.

It is quiet clear that new Forest Code is, first of all, directed to restoration of Russian forestry as a sector of economy. However, secondary climate change effect of new Forest Code is positive and in full agreement with priorities of Action Plan activity. Consequently there are evident goals of Action Plan works 1) calculation of carbon sink/emission effect of new Forest Code; 2) support of related measures to implement new code into usual business; 3) developing of additional measures of the Action Plan to enhance positive effect of new code from carbon sequestration point of view.

Conclusion

In conclusion, the main regional forestry priorities for Action Plan are:

European-Ural part of the country: 1) creation of economy mechanism to increase forestry effectiveness on the same cutting areas, including full reforestation on clear-cut areas and 2) assistance to natural reforestation on currently non-forested lands of Forest Fund.

Central and North-East Siberia: establishment of forest fire observation and protection system, possible financial support could be caused by new forestry policy with sharp economy of federal subsidies in other regions.

South Siberia as well as Primorie and Priamurie: control of clear-cut logging with establishment of regulation and creation market situation for better forestry efficiency.

The JI Vologda reforestation project which is being considered now and, in general, new Forest Code of the Russian Federation are in good agreement with these priorities.

Acknowledgment

This work was carried out under the U.S. Country Studies Program, Cooperative Agreement DE-FCO2-93PO10118 with U.S. Dept. of Energy. The author would like to express their gratitude to Robert Dixon, Director of the U.S. Country Studies Program, John Millhone, Project Officer of the Program and Igor Nazarov, First Deputy Director of Institute of Global Climate and Ecology in Moscow, Technical Coordinator of the Russian Team of the U.S. Country Studies Program for support, great attention and valuable comments to work.

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Programs and measures to reduce GHG emissions in agriculture and waste treatment in Slovakia

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Prepared for: INTERNATIONAL WORKSHOP ON GREENHOUSE GAS MITIGATION TECHNOLOGIES AND MEASURES
Beijing, The People's Republic of China, 12-15 November, 1996

ABSTRACT

Slovakia is a UN FCCC Annex I country and is obliged to limit its anthropogenic GHG emissions in the year 2000 to 1990 level. The key greenhouse gas in Slovakia is CO_2 resulting mainly from fuel combustion processes. However the share of CH_4 and N_2O is approximately 20% of the total emissions on GWP basis. These gases are occurring mainly in non-energy sectors.

The construction of the non-CO_2 emission scenarios to reduce GHG and the uncertainty in N_2O and CH_4 emission estimation are discussed focusing on agriculture and waste treatment. The presentation will also include information on emission trends of CH_4 and N_2O since 1988 (1985).

There are already implemented measures reducing GHG emissions in Slovakia, however, not motivated by global warming. A short view of implemented measures with an assessment of their benefit concerning non-CO_2 GHG emissions reduction and some proposed mitigation options for agriculture and waste treatment are shown. Expected difficulties connected with preparing scenarios and with implementation of reducing measures are discussed.

1. INTRODUCTION

This presentation is focused more to show the potential of the country to reduce GHG emissions, than to evaluate single legislative tools and measures. Estimated emissions of methane and nitrous oxide in agriculture and waste treatment are presented (trends when available), and the share of these sectors on national total emissions. The uncertainty of non-CO_2 emission estimation is high (30-80% can be even higher), what makes the evaluation of reduction measures difficult.

Emission sources described in part 2 are as well target "groups" for mitigation options. Some legislative tools with an assessment of their potential concerning non-CO_2 GHG emissions reduction, and some proposed mitigation options for agriculture and waste treatment related to climate change are shown in part 3. Baseline (business as usual), low (some mitigation options are implemented), medium, and high (identified measures are fully implemented) emission scenarios for years 2000 and 2005 (2010) are described. It is expected, that after the year 2000 emissions should oscillate about medium scenario estimates.

1.1 National circumstances

Slovakia is one of the Central European Countries since 1989 undergoing the process of transition from a central planned to a market economy. The process of transformation together with disintegration of the Common East European market have caused a deep depression of industrial production and substantial decrease in the Gross domestic product (GDP), Table 1.

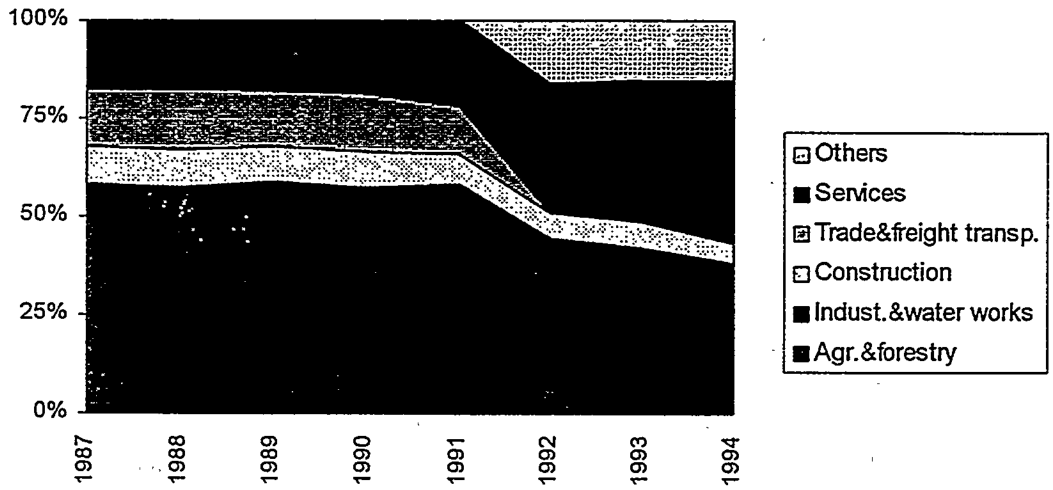
Table 1 GDP trends in Slovakia

Indicator	Year						
(Statistical yearbook 1995)	1985	1989	1990	1991	1992	1993	1994
GDP in bill.SKK, in prices of 1.1.1984	212.7	233.7	227.8	194.8	181.2	173.8	182.2
GDP in mill. USD in current prices			14 317	10 007	10 876	10 186	12 447
GDP per cap. in USD, in current prices			2 702	1 894	2 051	1 913	2 328

- Data for 1985 - 1991 are calculated from transformation method to ESA method (European System of Integrated Economic Accounts) - European standard methodology for the compilation of quarterly national accounts by the Statistical Office SR

The agricultural share of GDP (Figure 1) represents about 10%, the industrial sector accounted for 50% of GDP in 1991 but less then 30% in 1994. High demand for energy and raw materials (production of iron, steel, aluminium, cement, fertilisers, plastic materials, etc.) is the characteristic feature of the economy.

Figure 1 GDP in market current prices, the share of economical sectors



Statistical yearbook 1995

Agriculture and forestry in Slovakia employed about 250 000 people in 1992, which is equivalent to 12.1 % of labour sources or 4.7% of the population. In Slovakia there are 2 447 thous. ha of land used for agricultural purposes, including 1 486 thous. ha of arable land. Per capita acreage is 0.46 ha of farmland and 0.28 ha of arable land, what is relatively small. During the first years of economic transformation no significant changes in crop production were registered, but fertiliser use decreased. All forms of animal production dropped significant.

2. EMISSIONS OF CH_4 AND N_2O

The contribution of individual greenhouse gases to national total GHG emissions are compared on the base of Global Warming Potential (GWP) for the time horizon of 100 years. In 1990 CO_2 emissions contribute 79 per cent to total emission, CH_4 emissions contribute 12 per cent and N_2O emissions contribute 9 per cent (expressed as the CO_2 equivalent). In 1994 the share of methane slightly increased.

The main contributors to CH_4 and N_2O emissions are agricultural production, waste treatment and distribution of natural gas. Figures 2 and 3 present share of different sectors on emission production in 1990. This sector split is not changing too much in future years.

The major sources of methane are livestock (enteric fermentation and manure), fugitive emissions (from natural gas transportation and brown coal mining) and waste treatment (landfilling of municipal waste and waste water handling).

Compared to other greenhouse gases, the mechanism of nitrous oxide emissions and sinks has not been investigated completely. We are unable to quantify some of the sources so far, and some probably remain hidden. The uncertainty of estimated emissions in Figure 3 is rather high, but is rather difficult to quantify. The main source of N_2O seems to be denitrification and nitirfication of Agricultural soils.

Figure 2 The share of key activities on total CH_4 emissions

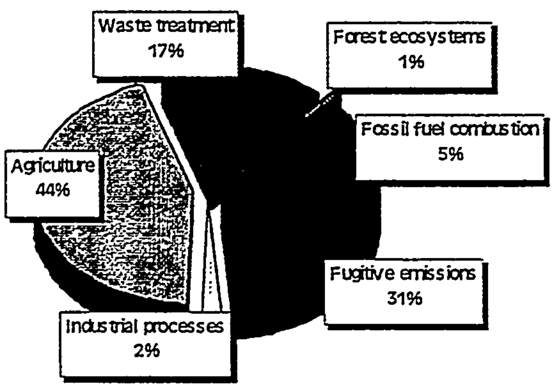
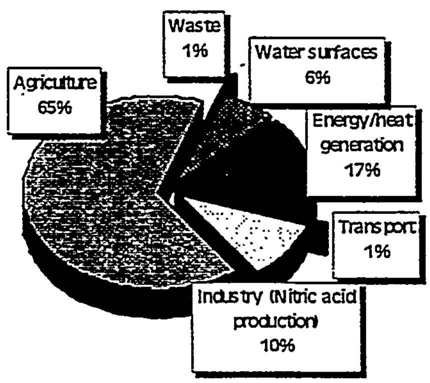


Figure 3 The share of key activities on total N_2O emissions



2.1 Agriculture Emissions

2.1.1 Livestock

Livestock operations represent a substantial source of methane emissions, both as direct product of metabolism in herbivores, and as product of organic decomposition of animal excrement (manure). Methane generation varies with animal and is driven by the type of animal, the quality and quantity of the feed and/or its energy values consumed.

The calculation of emissions for the Slovak Republic is based on statistical data in Statistical Yearbooks (1989, 1991, 1992, 1993, 1994), data presented in the Strategic Agricultural Policy Paper of 1993, and on qualified estimates of animal populations, as well as on the basis of comparing local characteristics to set the data used to derive default methane emission factors. Some feeding and grazing characteristics and purpose of genotypes were considered in applying IPCC (1994) criteria for the Western Europe region. Generally, the uncertainty in emission estimation should be within +- 20%.

Methane from animal manure occurs as a result of a decomposition of the organic matter by micro-organisms under anaerobic conditions. Methane emissions and their amount depend on several factors such as the origin of manure (types of animals, nutrition, feeding, grazing), the form of manure (solid or liquid), temperature, with liquid manure also storage type and life (e.g. open liquid manure pits or lagoons). It can be generally stated that liquid -based manure management systems represent a substantial source of methane emissions from animal manure. On the opposite, in grazing the manure dries reducing the anaerobic activities to the minimum. Analogous, the same occurs by storing solid manure.

Figure 4 The share of different type of animals (enteric fermentation) in methane emissions

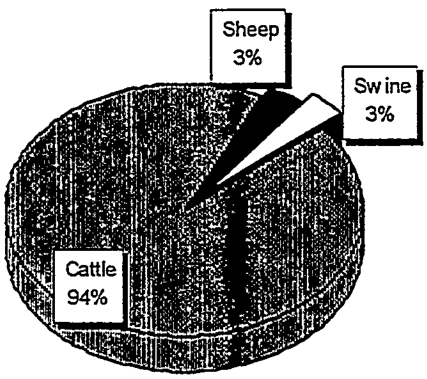


Figure 5 The share of different type of animals (enteric fermentation) in methane emissions

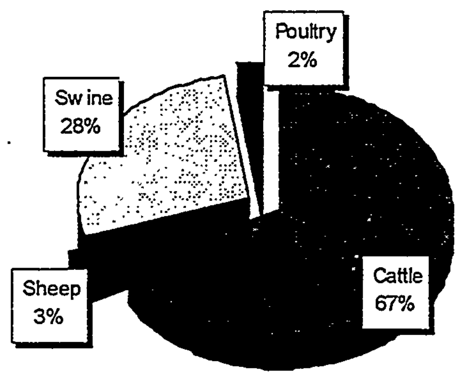


Table 2 CH_4 emissions trends from livestock [Gg]

	1988	1990	1992	1993	1994	1995
Enteric fermentation	116	106	87	68	65	85
Manure	72	65	56	43	43	54
Total	**188**	**171**	**143**	**111**	**108**	**139**

2.1.2 *Agricultural soils*

Soils are a major producer of nitrogen gases which are more or less intensively released up to the atmosphere. Emissions are a consequence of soil biological processes (denitrification, nitrification), and depend on both the content of substrates (in particular nitrates) and the sum of physic-chemical and biological parameters of the soil. Application of mineral and organic fertilisers amplify nitrogen release from the soil. The processes of nitrogen emission from soil to the atmosphere are accelerated in soils with higher contents of nitrates, in soils with sufficient supply of carbon energy sources and especially in soils with unfavourable physical (water - air) soil properties with excess of anaerobic (little aerated) conditions (denitrification is an anaerobic process). The experience shows that the strongest accelerators of denitrification are:

- high content of mineral nitrogen in the soil
- unfavourable air regime of soils

Due to intensification of agricultural practice over the period from 1960 to 1980 (in particular the use of mineral and organic fertilisers), there are real presumptions for accelerated production of N_2O in the soil and for increased release of nitrogen gases from the soil to the atmosphere

Nitrogen gases released from the soil into the air in the Slovak Republic have been assessed using methods recommended by IPCC.

Table 3 N_2O emissions trends from agricultural soils

	1980	1990	1992	1993	1994	1995
Agricultural land area [1000 ha}	2 477	2 448	2 447	2 445	2 444	2 444
Emission [Gg N_2O/year]*	16	14	10	7	8	7

** average value estimated applying IPCC method*

The increase of nitrous oxide emission can be assumed as a result of agricultural production intensification , especially when the N-fertilisers are applied with higher intensity or in areas with damaged aeration regime in soil. The increase of mineral nitrogen surpluses in soil in Slovakia prior to 1988 was followed by a rapid decline about 1995 (the acreage of agriculture land area is almost the same). This is not result of environmental behaviour of farmers, but a consequence of the economic regression in agriculture. The expected improvement of economic conditions will bring the rise of N-fertiliser consumption after 2000.

2.2 Waste management

2.2.1 Municipal solid waste

Evaluation of the amount of methane emissions was prepared according to the IPCC methodology (1995). With regard to the recent issue of waste legislation (from 1991-1993), existing data are a significant source of uncertainty in the following areas:

- total number of disposal sites (continuously clarified),
- amount and composition of municipal solid waste (MSW) generated as well as landfilled,
- land disposal operations,
- date of disposal site creation, their history, etc.

Therefore, we consider the IPCC methodology for gross estimation of greenhouse gas production from MSW disposed on land as sufficient.

All concrete data (number of inhabitants, MSW generation per capita, amount of MSW disposed on land) used for conditions of the Slovak Republic, are estimation quoted from official sources, except the number of population (exact number from Statistical Office of Slovak Republic) and the waste generation rate (expert opinion).

The vast majority of MSW was disposed on land under conditions that are not conductive to anaerobic decomposition of organic materials. Therefore, the total amount of emissions was adjusted by a factor of 0,5.

The estimated MSW production per capita between 1988-1995 vary in range 230-300 kg/cap/ year. Also the share of landfilled MSW is not the same , the estimated range is 88-92 per cent.

Table 4 Emission trends from MSW landfilling

	1988	1990	1991	1992	1993	1994	1995
MSW produced [thous t/y]	1 208	1 324	1 427	1 591	1 437	1 339	1 291
Emission of CH_4 [Gg]	50	53	57	65	58	53	51

2.2.2 Waste water treatment

Greenhouse gases emissions occur by biological treatment of waste waters and sludge under anaerobic conditions. Nitrogen is a significant share of the emissions..

Using available statistical data following processes were considered in this report:

- anaerobic waste water treatment
- anaerobic stabilisation of sludge from aerobic waste water treatment
- nitrification and denitrification (nitrogen removal from waste water)
- sludge landfillng (partly).

These processes were evaluated for following types of waste water:

- municipal (sewage)
- industrial
- septic and retention tanks

Various methodologies (IPCC, CORINAIR, ISI) were used to estimate the quantity of individual greenhouse gas (Vancová,1995):

Table 5 Greenhouse gas emissions 1992/1993 [Mg/year]

Source of emission	CH_4 [Mg/year]	N_2O [Mg/year]
WWT plants	442 - 589	0.27 - 1.15
Municipal (not served)	9 944 - 12 430	
Industrial	23 - 34	4.43 - 18.9
TOTAL	**10 409 - 13 054**	**4.70 - 20.1**
Methodology used	IPCC	ISI

there are no trends available

3. PROGRAMS AND MEASURES TO REDUCE GHG EMISSIONS IN NON ENERGY SECTORS

After 1989, as a result of economic and political changes in the former Czechoslovakia, the process of gradual harmonisation on legislation with the legislation of EU countries has been initiated, including environmental legislation. This procedure was aimed for general improvement of environment. However some of these acts and measures influence directly or indirectly emissions of greenhouse gases. Specific measures focused on climate change have not been adopted yet, and either no integral systematic program for the reduction of greenhouse gases emissions or enhancement of sinks have been developed The most important documents in non -energy sectors related to Climate Change adopted in Slovakia are:

•Principles of Agricultural Policy

This document was approved by National Council (1993). The policy concentrates on the fundamental measures to ensure ecologization of agricultural production, including rational consumption of fertilisers and the trend of further agricultural development. There are several acts regulating the agricultural sector, supporting implementation of this document.

- *Act No. 307/1992 on Agricultural Soil Stock Protection (Part 3, Paragraphs 4, 5, 6)*

  According to the above law, the user of agricultural land is obliged to use it in such a manner so as not to impair the quality of other components of the environment (water, atmosphere). A change in kind of the agricultural land may be carried out only after approval of the agricultural soil stock protection body.

- *Act No. 61/1964 on Development of Plant Production*

  Specifies the principles for fertilisation of field crops, indirectly the constant procedures for manure storage, manure termination.

- *Guideline of the Ministry of Agriculture and Nutrition of the SR No. 5000/1982 Zb., on Water Protection from Agricultural Pollution*

  Determines the principles for application of mineral nitrogen fertilisers and organic fertilisers in territories of water source protection.

- *Guideline of the Ministry of Agriculture and Nutrition of the SR No. 5001/1982 on Handling of and Fertilization with Liquid Manure and Disposal of Silage Juices*

  Determines the principles for handling of and fertilisation with liquid manure

Measures in the course of preparation or prepared for approval

- *Codex of Good Agricultural Practice in the Slovakia*

  This codex will have to be elaborated as part of the approximation of legal regulations to the EC guidelines

- *Operational Program for Reduction of the Water Pollution by Nitrates in Agriculture*

  The program will have to be elaborated in accordance with the "EC Nitrate Directive 1991". In the above document, there are strict measures for prevention of nitrogen excess in soil and thus indirectly for prevention of nitrous oxide emissions from the soil into atmosphere.

- *Methodology for Special Systems of Management in Areas of Water Sources' Protection and in Polluted Areas*

  The above methodology will strictly formulate the requirements for correct fertilisation with nitrogen which will indirectly contribute to the decrease of nitrous oxide emissions from the soil into atmosphere.

•Strategy and Policy of Forestry Development in the Slovak Republic

This document was approved by Slovak government in 1993. One of the strategic goals of forestry development in Slovakia is to preserve forests , i.e. to maintain and gradually increase the afforested area and forestry as an important contributor to ecological balance and landscape stability. (This intention will be implemented also through further afforestration of land which is not suitable for agriculture. This program assumes the afforestration of state non-forest land not suitable for agricultural utilisation with total area of 50 000 ha by the year 2000 (estimated costs are at 2.2 bill Sk).

- **Waste management program in the Slovak Republic**

The document was approved by government also in 1993. The objective of waste management program is to minimise environmental risks of waste disposal and develop a system of managed landfills and incinerators.

3.1 Measures and mitigation options in agriculture

Some measures were evaluated to estimate the potential to reduce methane a nitrous oxide emissions from agricultural sector. This is an expert estimation based on "Mitigation Assessment Guidebook". The different degree of implementation of proposed measures was then used to create emission scenarios.

Figure 6 CH_4 emission scenarios, enteric fermentation and manure

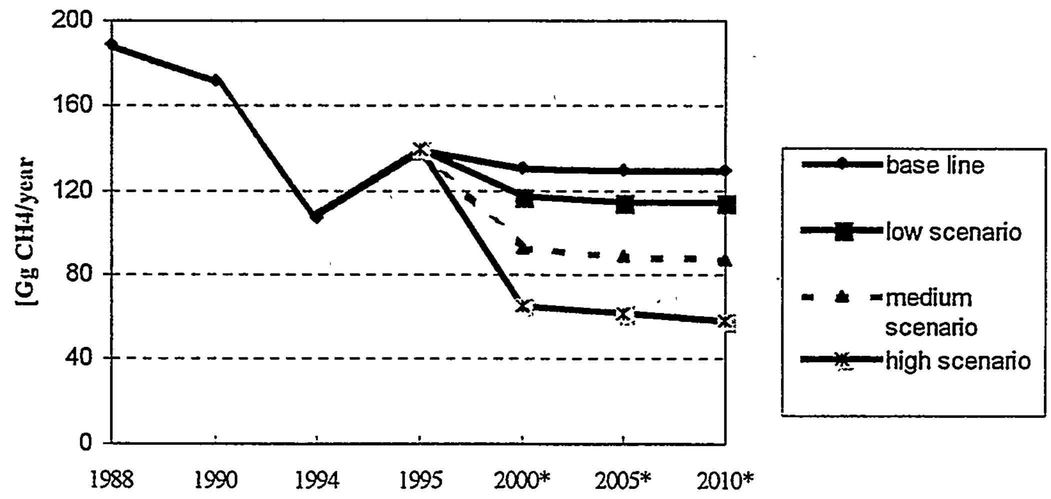


Figure 6: The baseline scenario corresponds to business as usual. The low scenario is the most easily achievable one and with high scenarios provides range of possible reduction of methane according A) - D). Technically feasible scenario is the medium one.

Enteric fermentation and manure

A) **Intensification of breeding** - above all, of the dairy cows - by selection of the best-quality species and specimens, by improved and balanced feeding of nutritionally and energetically most suitable forage, a reduction of 10 to 20 % in CH_4 emission can be achieved if measure is applied to 15 to 25 % of the farming animals.

B) **Increasing the utility of farming animals** - above all, in cattle - by gradual improvement of the herd's genotype, by controlled reproduction improvement, and by increasing the herd turnover, a reduction of 15 to 35 % in CH_4 emission can be achieved, if measure is applied to 25 to 45 % of the cattle.

C) **Intensive pasturing** - cattle and sheep - wide range of opportunities for improvement of a whole complex of pasturing intensification allows reduction of 5 to 25 %.methane emission, if measure is applied to 30 to 75 % pastured counts.

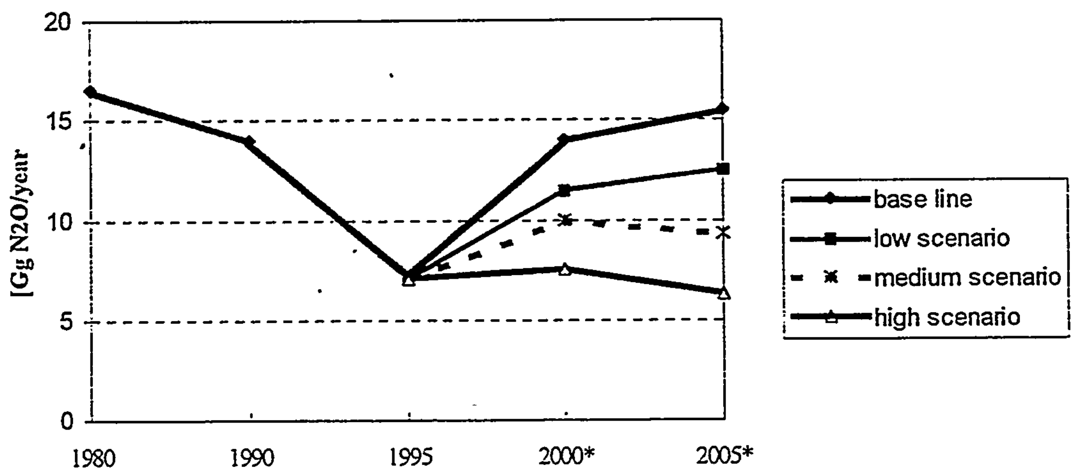
D) **The utilisation of methane** (bio-gas for power production) from excrement, after resolution of certain open technical issues and harmonising costs with performance, can after 2000 represent 1 % reduction of methane emission, after 2010 the reduction can increase at about 5 to 15 %.

Agricultural soils

To create emission scenarios for NO_2 release from soils is rather difficult due to high uncertainty of estimated emission. Just the trends not the absolute values should be the subject of evaluation. The area of arable land is expected to stay the same. Economic growth in agricultural production will in forthcoming years bring gradual growth of fertiliser consumption (N input per hectare after 2000 should reach the level of eighties). The only tool enabling to decrease N_2O emissions from agricultural soils stays the application of N-fertilisers in optimal regime, and full implementation of environmental principles of agricultural policy. This would mean to decrease unjustified growth in fertilisers consumption, to improve ways of their utilisation, to increase their availability for plants and generally, to support better utilisation of natural potentials of soil for high intensity of agricultural production

By more consistent application of measures that were issued, but not sufficiently implemented in practise, it would be possible to mitigate the presumed increase in NO_2 emissions from soil at least by 20% (low scenario). Application of N-fertilisers in optimal regime, full implementation of "Principles of agricultural policy" enables to decrease N_2O emissions from agricultural soils in the range of 40-60% (medium- high scenario) after the year 2000 comparing to 1990 Figure 7.

Figure 7 N_2O emission scenarios, agricultural soils



3.2 Measures and mitigation options in waste management

In Slovakia, there were 7 204 landfilles registered in 1992, but only 335 were licensed. Prior to 1991 there was no legal regulation for the landfilling of municipal waste. Waste had been dumped in unmanaged landfills, which did not provide the appropriate conditions for anaerobic methane production. By the year 2000 an increase in methane released from landfills of municipal waste is expected, mainly due to

- building of landfills for municipal waste with respect to legislative requirements thus ensuring suitable conditions for methane generation in comparison with the situation before the legislation
- the fact that currently produced methane is not utilised or destroyed

The waste management program prior to 2000 contains measures related to methane emissions:

A) to extend the collection and utilisation of secondary resources, by implementation of separated collection reduce the amount of municipal waste to be treated by 20% compared to 1992

B) utilisation of at least 20 % of biological waste as organic fertilisers

C) destruction of 50% of all municipal waste in landfills meeting the technical requirements

D) to start the sanation of unmanaged landfills

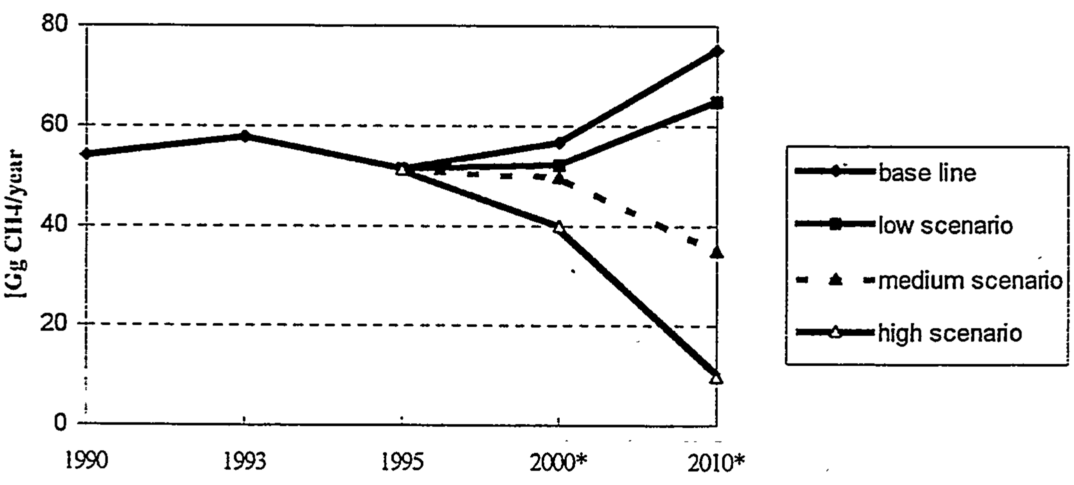
E) to build new municipal waste incineration plant

F) to build 10 composting facilities

G) to build 9 high capacity regional landfills for municipal waste

Prior to 2000 a level of methane emissions approximately equal to the present levels is assumed. In the year 2005 a decline by about 15% compared to 1995 can be expected.

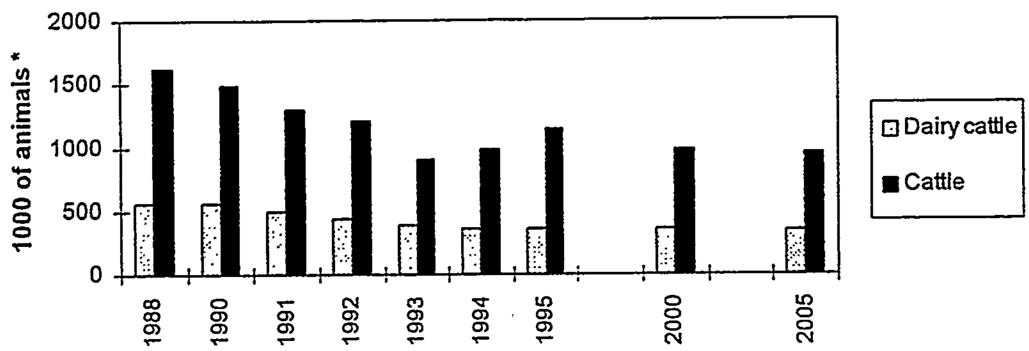
Figure 8 CH_4 emission scenarios, MSW



3.3 Medium scenarios of methane and nitrous oxide

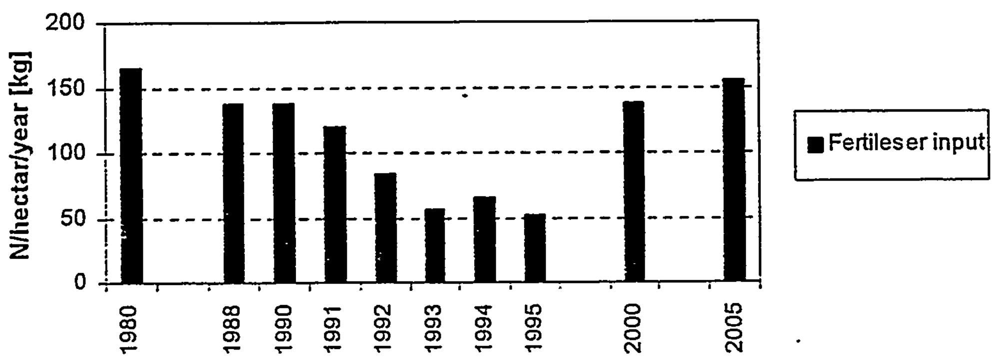
The projections in countries with economy in transition are influenced by the uncertainties accompanying the transition process. Considering the on-going transformation process, the extrapolation of historical data e.g. for energy demand, fertiliser use, waste production cannot be used Figure 9 and 10. The projections of CH_4 and N_2O emissions are mainly based on documents elaborated by the Ministry of Agriculture and Forestry. For key sectors, low, high and medium emission scenarios were elaborated for years 2000 and 2005. In this paper are presented the first estimates of medium emission projection for methane and nitrous oxide. The medium scenario (most likely scenario) is based on the future development of the economical sectors as these are presented in governmental documents.

Figure 9 Heads of cattle in Slovakia 1988 - 2005



It is very difficult to obtain average animal heads stand during the year. If comparing statistics taken in different periods of year, the difference can arise in some cases to 30 percent.

Figure 10 Average yearly fertiliser inputs in kg of N, 1980 - 2005



<u>Fugitive emissions</u>

By creating CH_4 emission scenarios we implicitly have to consider fugitive emissions, which contribute more than 30% (Figure 2) to national total. Leakage from the natural gas distribution system is the most important emission source of methane in energy sector. According the Slovak energy policy the increasing consumption of natural gas in the next decade is expected. The CH_4 emissions from this source are expected to increase till 2000. General improvement of all gas distribution facilities including local distribution network is needed.

The brown coal resources in Slovakia are rather limited, this source of methane emissions is expected to come negligible in the future.

Figure 11 CH_4 emission projection [Gg/year], medium scenario

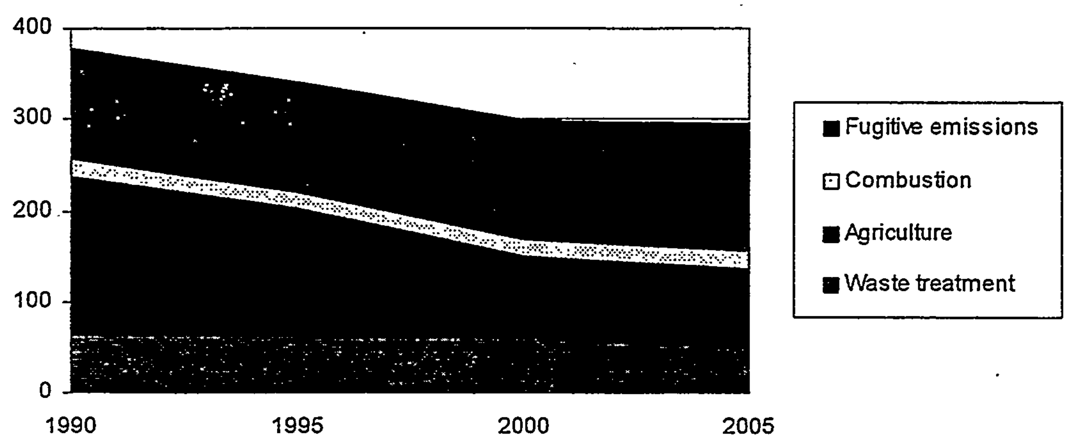
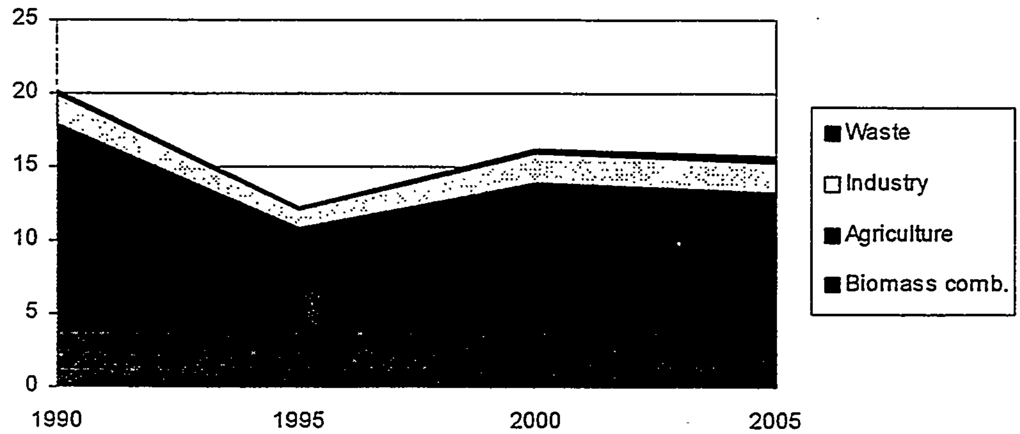


Figure 12 N_2O emision projection [Gg/year], medium scenario



3.4 Costs assessment

An independent area waiting for elaboration is the question of costs related directly or indirectly to mitigation measures. In the current stage are running only the first exercises based on the "cost per tonne of saved methane" as estimated for some western European countries run. The calculation of cost based upon foreign experience can only have an informational character with respect to Slovak conditions. However the received message is, that the reasonable reduction of GHGs especially after year 2000 will be connected with considerable costs.

3.5 Conclusions

It is vital to understand what the vulnerabilities and capabilities of economy systems are to adjust are, and how their resilience to change can be enhanced. One aspect is the development and utilisation of new technologies and another aspect is predicting human behaviour and understanding the abilities and willingness of societies to change.

The quantification of potential measures influencing occurring of non-energy methane and nitrous oxide emissions in Slovakia is mainly based on expert estimation. In "strategy" documents provided by ministries, usually just one scenario for future development of sector is presented. Additionally the estimation of future trends in GHGs emissions is complicated by the process of economy restructuring. However, it is expected, that future development of emissions will stay in estimated ranges between baseline and medium scenario. This would mean that emissions in the year 2000 would not exceed the 1990 level. To fulfil the requirement of IPCC on stabilisation of GHG emissions after 2000 is in Slovakia theoretically possible (high scenarios), but after the year 2000 with improving economy we expect the emissions start to increase slightly.

The emission scenarios presented here are not to be seen as final. The main reason is the matter of the subject. With improving knowledge we always receive different results, hoping that these do better correspond with reality.

At the current stage, no emission scenarios related to climate change are used for preparation of policy strategies on governmental level. No specific measures related to decreasing of GHGs are in preparation. The main reasons could be listed as:

- Other priorities than environment
- Limited financial resources
- Difficulties to obtain data
- The lack on relevant scientific information and models
- The high uncertainty in predictions of economical parameters. Generally the extrapolation of historical data can not be used
- The uncertainty of emission estimation,
- The changing legislation resulting from political changes and from harmonisation of legal regulation with EU (European Union).
- Estimation of human behaviour in the future and incorporation in scenarios is rather difficult
- The different view of policy makers, scientists, industries caused by complexity of the problem
- The uncertainty of climate change scenarios
- The interpretation of results achieved within the research work

Within Country Study project were evaluated measures already implemented or in preparation, which will influence also emissions of GHGs. The results achieved within this project (estimation of GHG emissions, emission projections and evaluation of different mitigation options) were used by work at First National Communication and will be further used also by preparation of 2nd National

Communication. The scenarios elaborated by the expert teams could provide base for the preparation of National Action Plan to reduce GHG emissions.

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Urban Trees and Light-Colored Surfaces as a Climate Change Strategy: Results from the U.S. and Potential in Developing Countries

International Workshop on Greenhouse Gas
Mitigation Technologies and Measures

Beijing, China, November 12-15, 1996

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Basics

- Heat Island:

$$\Delta T = T_{urban} - T_{rural}$$

- Note:

Heat Island and Global Warming are additive

Overview

- A review of heat island data in US and other countries
- Impact of heat islands on cooling energy use and smog
- Shade trees and light-color roofs to mitigate heat islands
  - Direct savings
  - Indirect savings
- Potential savings in US
- Research and implementation programs
- Potentials in developing countries

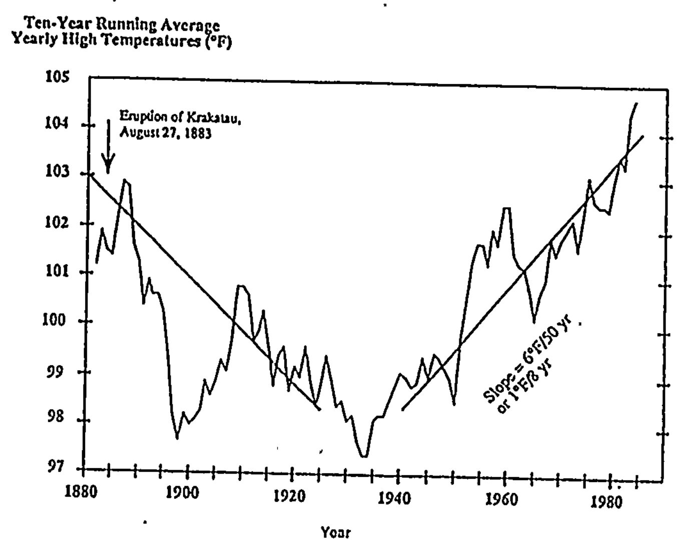


Figure 6: Ten-year running average high temperatures in Los Angeles, CA (1882 - 1984). With increasing irrigation and orchards, Los Angeles cooled 2°C/year until the 1930s. Then, as asphalt replaced trees, Los Angeles warmed 3°C (6°F). The ten-year running average is calculated as the average temperature of the previous 4 years, the current year, and the next 5 years. The pronounced temperature depression in the late 1880s-90s is due to the eruption of the Krakatau volcano.

Measured temperature trends in selected cities

City	Trend (°F/decade)	Type of Recording
Los Angeles, CA	1.3	highs
Los Angeles, CA	0.8	means
San Francisco, CA	0.2	means
Oakland, CA	0.4	means
San Jose, CA	0.3	means
San Diego, CA	0.8	means
Sacramento, CA	0.4	means
Washington, DC	0.5	means
Baltimore, MD	0.2	means
Ft. Lauderdale, FL	0.2	means
Shanghai, China	0.12	means
Shanghai, China	0.2	minima
Tokyo, Japan	0.6	means

Los Angeles, North Main 1985

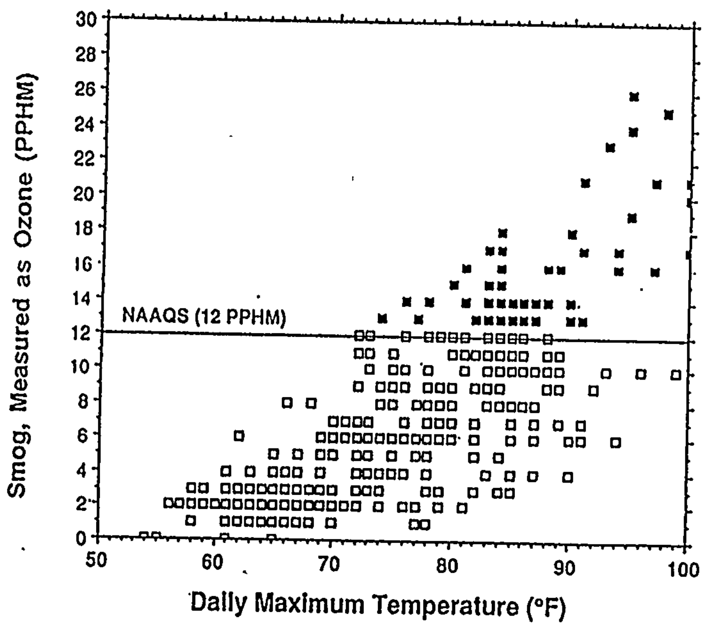
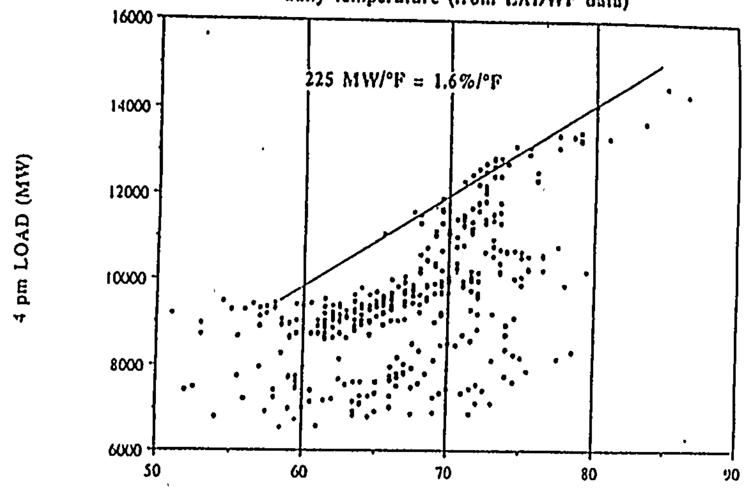


FIGURE 4. 4 pm Load at the Edison system versus average daily temperature (from LADWP data)



75 MW (LADWP) + 225 MW (SCE) = 300 MW.
300 MW * 5 °F = 1500 MW, worth ~ $150,000 per hour.

Mitigation Measures: Urban Trees and Light-Color Surfaces

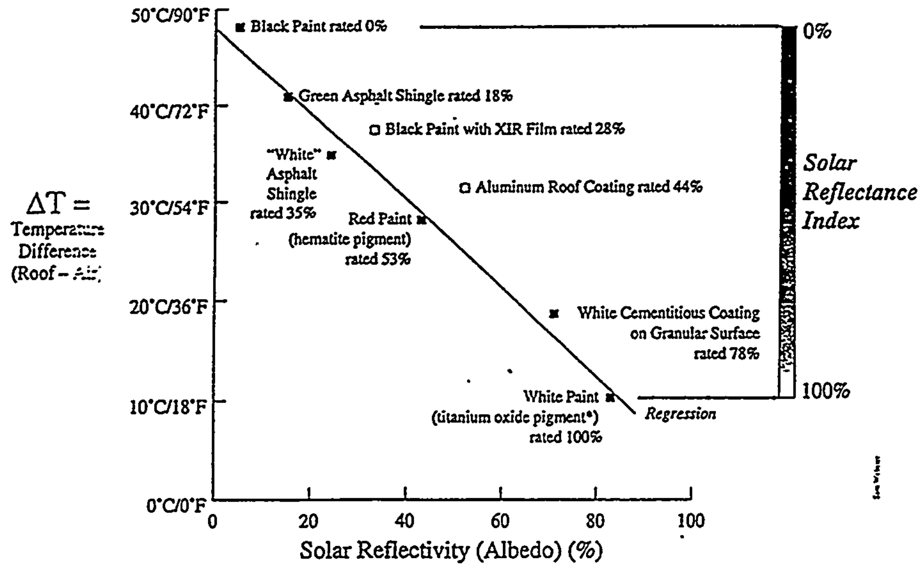
Direct Effect

- Trees that shade buildings reduce air-conditioning use and improve comfort
- Light-color roofs reflect the incident solar radiation and hence reduce air-conditioning use and improve comfort

Indirect Effect

- Trees in a neighborhood and in a city reduce the ambient temperature by evapotranspiration
- Light-color surfaces in a neighborhood and in a city alter the surface energy balance which result in a lower ambient temperature
- Lower ambient temperature reduces A/C use
- Lower ambient temperature reduces the formation of smog

Roof Temperature vs. Reflectivity and New Cooling Index



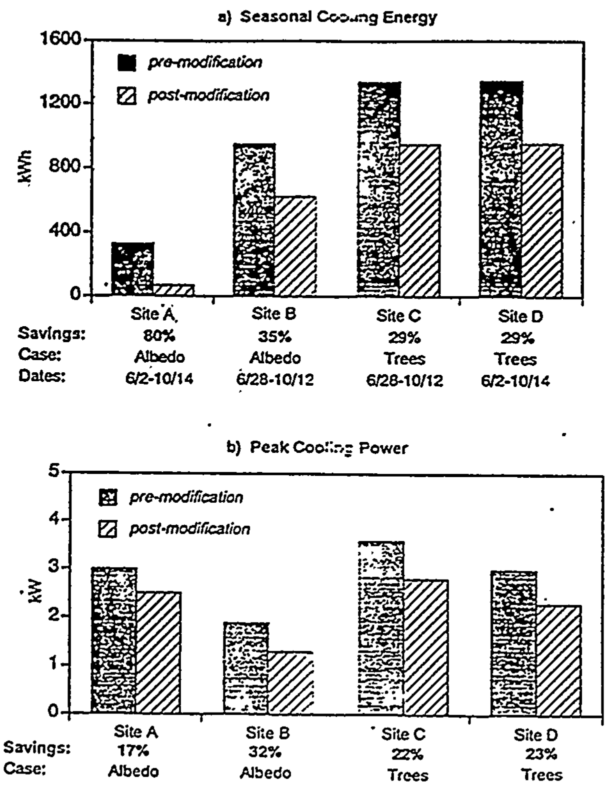


Figure EX-1 Seasonal cooling energy and [illegible] power usage for Four Buildings In Sacramento measured In the summer of [illegible] a) Seasonal cooling energy and b) peak power usage for each site before and after modification of albedo or shading. Seasonal cooling estimates are based on regressions of daily average temperature and weekday cooling energy use. Peak power usage is for the maximum [illegible] average temperature during the monitoring period. Peak power savings did not correlate with temperature

Energy, ozone benefits, and avoided peak-power of cooler roofs, pavements and trees in Los Angeles Basin. (Source: Rosenfeld et al 1996)

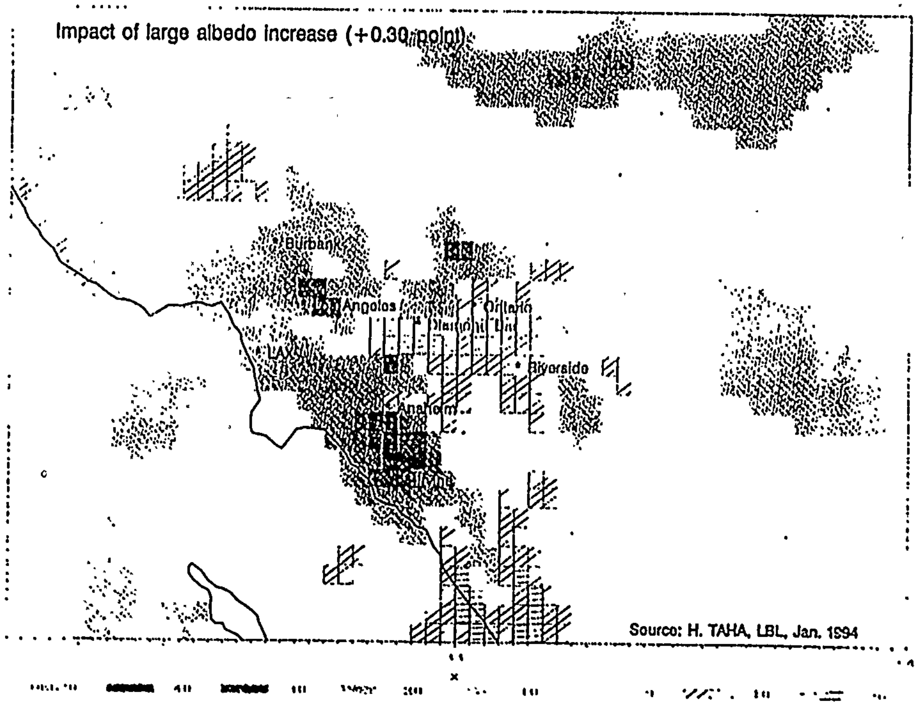
Benefits	Measures			
	Cooler roofs	Trees	Cooler pvmnts	Totals
1. Direct[a]				
a. A/C energy savings of cooler roofs or shade (M$/yr)	46	58	0	104
b. *Peak power savings (GW)*	*0.4*	*0.6*	*0*	*1.0*
c. Present value ($/100m² or $/tree)	153	64	0	
2. Indirect[b]				
a. A/C energy savings of 3°C cooler air (M$/yr)	21	35	15	71
b. *Peak power savings (GW)*	*0.2*	*0.3*	*0.1*	*0.6*
c. Present value ($/100m² or $/tree)	25	24	18	
3. Smog				
a. 12% ozone reduction (M$/yr)	104	180	76	360
b. Present value ($/100m² or $/tree)	125	123	91	
4. Total				
a. All above benefits (M$/yr)	171	273	91	535
b. Total *peak power savings (GW)*	*0.6*	*0.8*	*0.1*	*1.6*
c. Total present value ($/100m² or $/tree)	303	211	109	
5. Surcost ($/100m² or $/tree)	<25	<35	<30	

Notes:

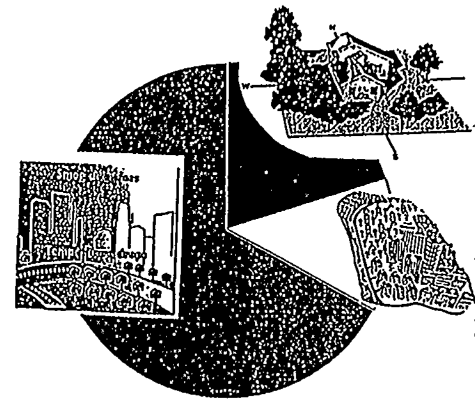
a. To estimate the LA-wide indirect and direct effects we use the data in Table 1, multiplied by the number on buildings of each type (old residences, new residences, non-residences). We assume that, of the 1.8 M residences with a/c, the relative number of old residences, new residences and non-residential buildings is like that in Sacramento, CA. These numbers are 55% pre-Title 24 (1 M "old" residences), 45% post-Title 24 (0.8 M "new" residences, energy-efficient construction), and that non-residential savings are about 25% of the residential savings (Pomerantz 1995). The calculations include 3 trees shading each of the 1.8 M residences for a total of 5.4 trees and 1M trees for non-residential buildings, for a total of 6.4 M trees.

b. The indirect savings are calculated assuming all 11 M trees are planted and all the 2,500km² of roofs and pavements in LA basin are modified, although only the air conditioned buildings benefit from cooler air.

Fig. C: OZONE CONCENTRATION DIFFERENCE FROM BASECASE (PPB) 8.27.1987, 3PM



Potential Savings in Los Angeles
$0.5 Billion per year



Assumes that in 2015 albedos of roofs will be raised by 0.35, pavements by 0.25, and 11 M trees will be fully grown.

Basecase US airconditioning use and savings potential of cool surfaces and shade tree program (Source: Rosenfeld and Akbari 1994).

Year	1995	2000	2010	2015
1. Basecase US A/C Use				
1a. Electricity (BkWh)	441	464	512	539
1b. $ Cost (utility + customer)†	$42B	$44B	46B	$49B
1c. CO_2 (MtC*)	110	116	128	135
2. Annual Savings				
2a. Fraction of basecase	0%	5%	15%	20%‡
2b. Electricity (BkWh)	0	23	77	108
2c. $ Cost (utility + customer)†	$0B	$2.2B	$7.3B	$10B
2d. CO_2 (MtC*)	0	6	19	27

† All dollar figures in 1990 dollars.

* MtC = million metric tons of carbon.

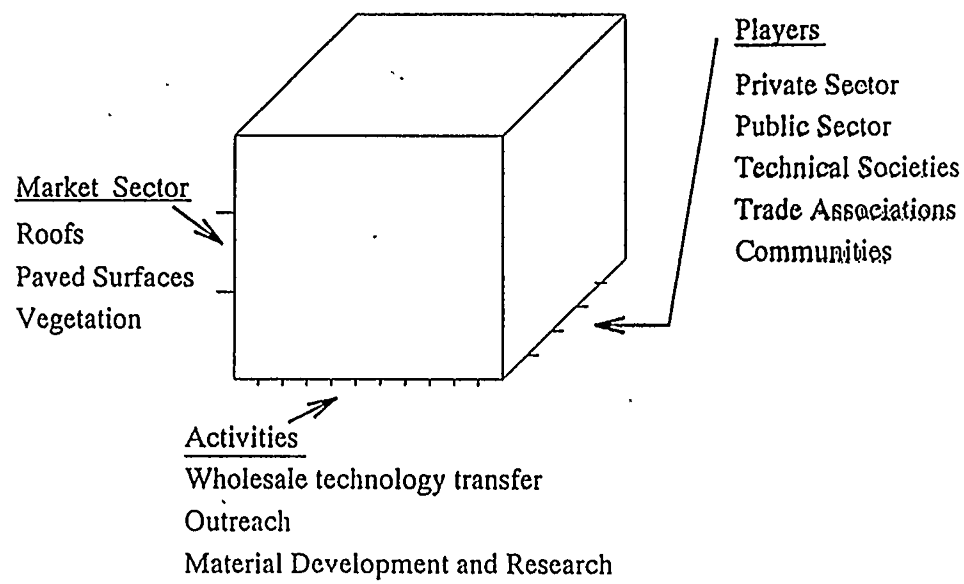
‡ Potential savings in 20 years when re-surfacing and trees have matured.

Programs

- Research
- Implementation outreach (HIP brochure)
- Utility rebate
- ASTM standards
- ASHRAE and state's building standards

HEAT ISLAND PROJECT

ELEMENTS OF COOL COMMUNTIES PROGRAM



Potentials in Developing Countries

- Example of Thailand
  - Half the MW demand increase is for buildings, and 60% of that half is for a/c
  - Building with cool roofs and shade trees, saves demand and hence with the same power plants more industry can be supplied with electricity

Potentials in Developing Countries

- Most developing countries are hot and humid.
- It is important to differentiate between potential impacts in hot/humid climates and hot/temperate or hot/dry (US)
- In developing countries
  - there are relatively few detached homes with AC
  - so shading impact may be MUCH smaller than in US
  - indirect effects may be more important

- Light-color roofs and walls can be easier to implement than shade trees. (Issue: density of Asian cities; is there space for more trees?)

Renewable Energy Project Development

International Workshop on Greenhouse Gas Mitigation Technologies and Measures

Jim Ohi
National Renewable Energy Laboratory
USA

Beijing, Peoples Republic of China
November 13, 1996

NREL

Purpose of Session

- Discuss Implementation of Renewable Energy Mitigation Options
- Identify Key Project Development Steps
- Develop Recommendations
  - key project development issues
  - key technical assistance needs

NREL

Key Project Development Steps

- Identify Target Region/Service Area
  - public/private energy service providers
  - grid-connected vs distributed generation
- Socio-economic Evaluation
  - income level, economic activity
  - energy use, energy service needs
  - willingness to pay: new energy services

NREL

Key Project Development Steps

- Resource Assessment
  - site-specific data and analysis
  - reducing uncertainty of investment
- Technology Evaluation
  - match energy service needs
  - characterize cost and performance

NREL

Key Project Development Steps

- pre-feasibility study
  - technical, economic, institutional
- feasibility study
  - sustainability requirements
  - potential for economic/social development
  - link project financing, implementation, carbon emission offsets

NREL

Key Project Development Steps

- investment decision
  - private and public sector
  - projected risks and financial return
  - determine most suitable institutional structure

NREL

DRAFT

Renewable Energy Development in China: Resource Assessment, Technology Status, and Greenhouse Gas Mitigation Potential

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International Workshop
on
Greenhouse Gas Mitigation Technologies and Measures
Beijing, China

INTRODUCTION

China, which has pursued aggressive policies to encourage economic development, could experience the world's fastest growth in energy consumption over the next two decades. China has become the third largest energy user in the world since 1990 when primary energy consumption reached 960 million tons of coal equivalent (tce). Energy use is increasing at an annual rate of 6-7% despite severe infrastructure and capital constraints on energy sector development.

Energy consumption in China is heavily dominated by coal, and fossil fuels provide up to 95% of all commercial energy use. Coal currently accounts for 77% of total primary energy use; oil, 16%; hydropower, 5%; and natural gas, 2%. Coal is expected to continue providing close to three-quarters of all energy consumed, and the amount of coal used is expected to triple by year 2020.

China's fossil fuel based energy structure implies high CO_2 emissions. China currently accounts for about 10% of global energy related CO_2 emissions. Without a change in China's energy and environmental policies, the amount of CO_2 emissions from China may surpass that of the United States within 20-30 years, making China the world's largest source of greenhouse gases by year 2020.

Currently, renewable energy resources (except for hydropower) account for only a fraction of total energy consumption. However, the estimated growth in greenhouse gas emissions, as well as serious local and regional environmental pollution problems caused by combustion of fossil fuels, provides strong arguments for the development of renewable energy resources. Renewable energy potential in China is significantly greater than that indicated by the current level of use. With a clear policy goal and consistent efforts from the Government of China, renewables can play a far larger role in its future energy supply.

RENEWABLE ENERGY RESOURCES IN CHINA

Solar

China has abundant solar energy resources. The regional solar energy resources are shown in Table 1. More than two thirds of China (Class I, II, and III regions in the table) receives an annual total insolation that exceeds 5.9 GJ/m² (1,639 kWh/m²) with more than 2,200 hours of sunshine a year.

Table 1. Distribution of Regional Solar Energy Resource by Class.

Class	Annual Sunshine Hours	Total Radiation (GJ/m²/yr)	Regions
I	2,800-3,300	6.7-8.4	north Ningxia, north Gansu, east Xinjiang, west Qinghai, west Tibet
II	3,000-3,200	5.9-6.7	north Hebei, north Shanxi, south Inner Mongolia and Ningxia, mid of Gansu, east Qinghai, southeast Tibet, south Xinjiang
III	2,200-3,000	5.0-5.9	Shandong, Henan, south east Hebei, south Shanxi, north Xinjiang, Jilin, Liaoning, Yunnan, north Shanxi, south east Shaanxi, south of Guangdong and Fujian, Beijing
IV	1,400-2,200	4.2-5.0	north Jiangsu and Anhui, Hubei, Hunan, Jiangxi, Zhejiang, north of Guangxi and Guangdong, Shaanxi, Heilongjiang
V	1,000-1,400	3.4-4.2	Sichuan, Guizhou

Wind

According to the estimated figures by the Chinese Academy of Meteorological Science, ground wind energy potential in China is about 3,200 GW of which 253 GW[1] is deemed technically exploitable. Table 2 gives wind resource distribution in China.

Table 2. Wind Resource Distribution.

Regions	Wind Power Density w/m²	Annual Hours with Speed > 3.5 m/s	Annual Hours with Speed > 8.0 m/s
1. southeast offshore & islands	200-300	6,000-7,000	3,000
2. Inner Mongolia, Xinjiang and northern Gansu	200-300	4,000	1,000
3. Heilongjiang, northern Jilin, Liaodong peninsula offshore	200	4,000	750
4. Northern Qinghai-Tibet Plateau, northern Three-North Districts	150-200	4,000	1,000
5. Yunnan, Guizhou, Sichuan, southern Shaanxi & Gansu, Henan, western Hunan, mountain areas in Fujian, Guangdong, Guangxi, Talim Basin	< 50	< 2,000	< 10
6. Other regions	50-150	2,000-3,000	500

In general, regions with favorable wind energy resources are concentrated in the north and west regions of China and along coastal areas and offshore islands. Many windy sites in coastal areas and nearby islands are found to have an annual average wind speed of over 7 m/s. In addition, many sites located in the vast flat terrains of northwest China have an annual average wind speed of over 6 m/s. For example, preliminary studies have identified Dabancheng in Xinjiang Autonomous Region and Huitengxile in Inner

[1] Shi Pengfei, "Potential Market of Wind Farm in china," New Energy Division, Hydropower Planning General Institute, June, 1996.

Mongolia Autonomous Region as excellent sites for large scale wind power development. Table 3 below gives more specific wind resource estimates of the top wind resource areas in China.

Table 3. Wind Energy Potential in Selected Provinces and Autonomous Regions.

Provinces	Wind Power Potential (MW)
Inner Mongolia	61,780
Xinjiang	34,330
Heilongjiang	17,230
Gansu	11,430
Jilin	6,380
Hebei	6,120
Liaoning	6,060
Shandong	3,940
Jiangxi	2,930
Jiangsu	2,380
Guangdong	1,950
Zhejiang	1,640
Fujian	1,370
Hainan	640

Biomass

China has a wide range of biomass resources which can be used for energy supply. These resources include crop straws and stalks, agricultural residues and wastes, fuelwood and forest residues, and organic wastes. Table 4 below lists the annual production of selected biomass materials in China.

Table 4. Annual Production of Biomass Materials in China.

Biomass Resource	Annual Production (million tons)
Straws and Stalks	600
Agricultural Residue	85
Fuelwood	35
Forest Residue	15
Industrial Organic Waste Water	30,000

Straws and Stalks Large amounts of rice, wheat, and corn straws and stalks are produced in China each year. In 1995, 600 million tons of straws and stalks were produced in China. This agricultural waste is distributed fairly evenly in rural China. 250 million tons of this resource were used as fuel in 1995 in direct combustion by rural households at low thermal efficiency. A small amount of the remaining 350 million tons was used for fodder and as raw materials for industrial production of paper, handicrafts, and organic fertilizers. About 220 million tons were discarded or burned in the field. In reality the resource potential is even larger than that described since the thermal efficiency of household stoves is relatively low compared to available biomass gasification technologies. If these agricultural waste and fuelwood were used as the feedstock for biomass gasification followed by efficient gas combustion, they can lead to a significant increase of energy supply while enhancing service.

Agricultural Residue Residues resulting from the agricultural production include rice and wheat husks, corn cobs, sugarcane bagasse, and other wastes.

Fuelwood As of 1994, China has about 4.65 million hectares of dedicated fuelwood forest[2] supplying 35 million tons of fuelwood annually. By 2000, total fuelwood plantation is expected to increase to about 6 million hectares.

Forest Residue Forest residues consist of bark, sawdust, wood shavings, and other wood wastes. Most of these biomass resources are not used currently because of difficulties in collection and distribution.

Industrial Organic Waste Water Light industry such as alcohol distillers, sugar mills, and food and leather processing plants are major contributors to China's organic waste water output. About 500 million tons of organic materials (BOD based) are contained in the 30 billion tons of organic waste water discharged annually.[3]

Geothermal

In China, the high temperature geothermal resources suitable for power generation are mainly located in Tibet and Yunnan provinces. Most of the resources in other areas, are of lower temperature (below 150°C), and are best suited for direct thermal applications, such as heat supply. Geothermal resource estimates for China are shown in Table 5.

Table 5. Geothermal Resource/Reserve Estimates for China.

Geothermal Resource Status	Area (km²)	Energy Content (EJ)
Long Term Resource Potential	257,050	3,679
Geothermal Resource Estimate	49,810	342
Proven Reserves	10,150	93

Low and medium temperature hydrothermal resources extend over 30 provinces, with the following regions having significant geothermal resources: Hebei, Tianjin, Beijing, Shandong, Fujian, Hunan, Hubei, Shaanxi, Guangdong, Liaoning, Jiangxi, Anhui, Hainan, and Qinghai. For example, Hebei province has 83.6 EJ of proven geothermal energy distributed over 9,240 km², in Tianjin City the proven resource is 3.3 EJ over 387 km², in Beijing City the proven resource is 1.5 EJ over 174 km², and in Fujian Province the proven resource is 0.19 EJ over 20.9 km².

Substantial high temperature geothermal resources suitable for power generation exist in Tibet Plateau, Yunnan and Sichuan Provinces. Although there is only 30 MW of installed geothermal generating capacity in China at present, estimates of total geothermal generating potential exceed 6,700 MW. Yangbajin geothermal field is the largest in Tibet. The geothermal field is located 90 km northwest of Lhasa, has an estimated area of 24 km² at an altitude of 4,300 m. Fluid temperature can reach 330°C at a

[2] Department of Environment Protection and Energy, Ministry of Agriculture, *Rural Energy Development in China*, December 1994.

[3] Environmental Annual Report, NEPA, 1995.

depth of 1,850 m. Fluid dryness from discharged resources have been measured at 47%. First explored in 1975, 61 wells have been drilled through December, 1988. Currently, 28 of these wells are providing energy for power generation. Total power potential from the Yangbajin geothermal field is estimated to be 62 MW.[4]

The Naqu geothermal field is located in Northern Tibet. This is a medium temperature resource with well-head temperature of 105-110°C. Well-head pressures range from 196 to 245 kPa.[5]

The Yangyi geothermal field is located approximately 45 km from Yangbajin. Systematic drilling over the past 10 years has yielded down-hole temperatures in excess of 200°C. The power potential from this field is estimated at 30 MW. Based on geologic data, the Langjiu geothermal field appears to contain high temperature resources suitable for power generation.

The Rehai geothermal field is located 18 km southwest of Tengchong, Yunnan Province. Reservoir temperatures of 230-240°C have been recorded in this field.[6] Total power potential in this field is estimated to be 330 MW. The Rudian geothermal field, also located in Yunnan Province, is expected to have reservoir temperatures of 138-310°C. The power potential is estimated to be 47 MW.[7] Panzhihua Geothermal field, located 50 km south of Tengchong, is estimated to have a 20 km^2 reservoir. A test has indicated reservoir temperatures ranging from 164-190°C. The power potential is estimated to be 49 MW.[8]

STATUS OF RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

Photovoltaics (PV)

China began her effort in PV technology research and development in 1958 for space applications. The early effort helped pave the way for the current wide spread use of PV for terrestrial applications. Although PV power stations have not being connected to the national grid in China, total installed terrestrial PV systems had reached 3 MW at the end of 1994. Over one-third of this installed capacity is used in remote and rural area applications including solar home systems and PV power stations for rural electric systems; the remainder of the 3 MW PV capacity is used for communications, transportation, cathodic protection, and meteorological applications.

Since the 1980s, China has made significant improvements in basic research, scale of production, and market development for PV. From 1983 to 1987, seven PV production lines were imported from the United States and Canada. Today annual production capacity is about 5.5 MW with all facilities producing either crystalline silicon PV cells (3.5 MW) or amorphous silicon PV cells (2.0 MW). However, actual production in recent years was much less than the production capacity because of market constraints and poor quality.

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[4] Desai, Ashok. *Energy in China*, United Nations University, tokyo, 1990.

[5] Wu and Liu, "Development and Utilization of Geothermal Resources in Tibet," *The Development of New and Renewable Sources of Energy in China*, China Technology Press, no date given.

[6] Wang, Xiong, and Chen, "Present Status of Geothermal Resources and Development in China," *SOLAR ENERGY IN CHINA: Proceedings of High-Level Expert Meeting for China*, Beijing, China, 1995.

[7] Ibid.

[8] Ibid.

Solar Thermal Applications — Solar Water Heaters

Solar water heaters are by far the largest solar thermal application in China with a total installed capacity of 3,300,000 m^2 by the end of 1994. The development of solar water heater industry in China started in late 1970's. Market demand and great efforts by the Chinese government and other stakeholders have contributed to establish a solar water heater industry supply residential market. By 1992 domestic solar water heater sales represented 53% of the global market. Three types of solar water heaters dominate the market. They are batch, flat-plate, and vacuum-tube water heaters. In 1994, 30% of the solar water heaters sold in China were batch type, 50% flat-plate type, and 20% vacuum-tube type. The key technical performance characteristics of these typesare shown in table 6. According to the government's implementation plan for the Ninth Five Year Plan and 2010 Solar Water Heater Development Strategy, the cumulative target for solar water heater installations by 2000 is 13 million m^2 and 43 million m^2 by 2010.

It is estimated that each m^2 of installed solar water heater will eliminate the use of 100-150 kg standard coal for water heating per year. The current installed capacity of 3,300,000 m^2 will save 330,000-495,000 tce a year. With the projected growth in solar water heater installation, 4,300,000-6,450,000 tce could be saved per year by 2010.

Table 6. Characteristics of the Main Types of Solar Water Heater.

Type	Volume (L/m^2)*	Daily Average Efficiency(%)	Collector Area(m^2)	Heat Loss Coefficient ($W/m^2/°C$)	Outlet Temperature(°C)
Batch (1-3 Bucket)	60	40 -60	0.3 - 1.0	8 - 10	40-60
Flat-Plate	60 - 80	45 - 60	1 - 2	3 - 6	40-70
Vacuum Tube	60 - 80	50 - 60	1 - 2	1 - 2	40-80

*Under Conditions of 5 kWh - thermal input per day.

Batch Type Water Heaters The main component of a batch water heater is the bucket absorber which can absorb and store heat energy. The absorber bucket design has to consider factors such as light absorption, pressure bearing, complexity of technology and cost of materials. Double-buckets and triple-buckets types are the most popular designs for bucket type solar water heater. Advantages of the batch type solar water heaters are low cost, high collecting efficiency, and compact structure.They are the most popular solar water heaters in rural areas. However, large heat loss from the bucket limits its effectiveness in cold weather.

Flat-Plate Solar Water Heaters Typical flat-plate solar water heater use natural convection and gravity to circulate water through flat-plate heat collector and water tank. The collector is made of a copper and aluminum alloy, and the water tank is made of galvanized or enameled steel. Some solar water heaters are equipped with a supplemental heat system. The performance, structure complexity, and cost of flat-plate solar water heaters lie in between the batch type and the vacuum-tube type. The main markets for flat-plate solar water heaters are urban residential customers and farmers in developed areas with plumbing. A small number of units have been installed in commercial and office buildings. Flat-plate solar water heaters can be used year round in the southern China where freezing is not a problem. They are effective about eight months of a year in areas north of the Changjiang. Advanced flat plate collectors with selective surfaces and antifreeze heat transfer fluid can overcome this problem.

Vacuum-Tube Solar Water Heaters Two types of vacuum-tube solar water heaters are available: all-glass vacuum-tube and vacuum-tube with heat-pipe. All-glass vacuum-tube heat collector consists mainly of inner and outer glass tubes. A selective absorptive film covers the outer surface of inner tubes, the narrow space between the inner and outer tubes is placed under a vacuum and acts as insulation. The inner tubes are connected to the tank to form a continuous loop. After water in the inner tubes is heated by solar radiation, natural circulation occurs and the temperature of water in the tank is raised. Vacuum-tube solar water heater with a heat-pipe consists mainly of a heat-pipe, absorbing plate, metal cover and de-gas agent. The major difference between the all-glass vacuum-tube type and the vacuum-tube with heat-pipe type is that the later takes advantages of the higher energy release associated with the phase change of a working medium in the heat-pipe.

The heat loss of the vacuum tube type is much less than that of the other types, and they can operate effectively even when the ambient temperature is as low as -18°C, resulting in year-round operation in northern China. However, the investment costs are higher because of the complex manufacturing process. Vacuum-tube type solar water heaters are mainly marketed for urban residential customers. Like the flat-plate type, vacuum tube types are also entering the market with an electrical heater incorporated into the water tank to provide a constant supply of hot water and to compensate for usage and for variations in solar insolation.

At present, the main application of solar water heaters is in the supply of hot water needed for bathing in individual households because the daily hot water requirement can easily be met by a modest investment in collector area. Each square meter of collector is capable of meeting the hot water demand for 2-3 persons or providing about 30 L/d per person. Total installed capacity is estimated at 3,300,000 m^2, as recent sales have surged from 400,000 m^2 in 1989, 500,000 m^2 in 1992, 600,000 m^2 in 1993, to 800,000 m^2 in 1994. Although 80% of solar water heaters are currently installed in cities and towns, the long-term market potential for solar water heaters is in rural areas where about 80% of the 1.26 billion Chinese population live. The rural economy has grown rapidly since economic reform, and farmers' living conditions have improved significantly. As a result, the demand for hot water in rural households has grown dramatically. However, the gap between supply and demand of commercial energy resources in rural areas will remain for a long time, since the use of natural gas, coal gas, or electricity for water heating in rural areas is neither technologically nor economically feasible.

Factors that hamper development of the solar water heater market in China include poor quality of many existing solar water heaters and an inadequate support network for after-sale customer service. The governmental agencies should also establish codes and regulations to integrate solar water heaters into building structures.

Solar Thermal Applications — Solar Cookers

China has developed several simple solar cookers for rural households in remote areas. Currently there are about 140,000 solar cookers in use. Each solar cooker can save about 500-700 kg fuelwood per year. In most cases the fuel savings will enable users to recover the cost of a solar cooker in 2 years.

Wind

By the end of 1995, total installed capacity of grid-connected wind power plants had reached 36 MW in China. Table 7 lists the existing wind power plants in China.[9]

Table 7. Existing Wind Power Plants in China and Installed Capacity.

[9] Shi Pengfei, "Potential Market of Wind Farm in china," New Energy Division, Hydropower Planning General Institute, June, 1996.

No.	Site	Province	Installed kW	No. of Units
(1)	Dabancheng	Xinjiang	12,750	47
(2)	Nanao	Guangdong	8,680	43
(3)	Zhurihe	Inner Mongolia	4,200	28
(4)	Shangdu	Inner Mongolia	3,875	17
(5)	Donggang	Liaoning	1,555	6
(6)	Cangnan	Zhejiang	1,255	4
(7)	Pingtan	Fujian	1,055	6
(8)	Hengshan	Liaoning	1,000	4
(9)	Xilin	Inner Mongolia	1,000	4
(10)	Shengsi	Zhejiang	426	15
(11)	Rongcheng	Shandong	165	3
(12)	Changdao	Shandong	110	2
(13)	Dongfang	Hainan	55	1
	Total		36,126	180

Development of small wind generators in China started in the 1950s. Today, over 140,000 small wind generators ranging in size form 50 W to 5 kW have been deployed in China with a total installed capacity of 17 MW. Most of these small wind generators are used in the remote areas of northern and western China, including the grasslands in Inner Mongolia, Xinjiang, Qinghai, Gansu, and Tibet, as well as in the coastal areas where grid-connected electric supply is not available. Small wind generators are used by nomadic herdsmen and by farmers and fishmen to power fluorescent lights, televisions, and other small consumer electronic appliances. Over 80% (110,000 units) of the total 140,000 installed small wind generators are in Inner Mongolia due to the aggressive policies implemented by the government of the Inner Mongolia Autonomous Region.

China is also testing the hybrid wind/PV, wind/diesel, and wind/diesel/battery systems. Experimental wind/PV systems range from a few hundred watts to 30 kW. The largest wind/PV hybrid system was installed on Xiaoguan Island, Shandong Province, in January 1995. The system consists of five 5-kW Chinese wind turbines combined with 5 kW of PV and a 110 kAh battery storage bank through a 30 kVA inverter. The system is designed as a village power system to provide stable power output and reduce the on-time of the existing diesel generator. Several wind/diesel/battery hybrid system are being tested in China in the 30 kW to 130 kW range. The largest of such system was installed on Beiji Island, Zhejiang Province. It consists of 132 kW wind, 475 kW diesel, and 100 kWh battery system.

Small wind generators of 50 W to 5 kW are in commercial production in China, but the capability of domestic manufacturing of large wind turbines, primarily in the range of 55-200 kW with alternating current output, is limited. Over 40 manufacturers of small wind generators have a production capacity of about 30,000 machines per year.[10] There are 17 manufacturers in Inner Mongolia alone. Several companies are manufacturing intermediate and large-scale wind turbines in China. The Hangzhou Electric Equipment Work started making the Bonus 120 kW turbine as a joint venture between China and Denmark in 1991. The largest machine in production in China is a 200 kW turbine manufactured by the Fuzhou Power Generating Equipment Factory. China wants to acquire foreign technologies for manufacturing larger wind

[10] "Demonstration, Development, and Utilization of the Geothermal Resources in Tibet," *New and Renewable Energy—Technologies and Products in China*, 1995.

turbines, and several Chinese companies and foreign equipment manufacturers are discussing possible joint ventures.

Geothermal (thermal)

China is a global leader in geothermal direct heating applications with current output equivalent to 2,410 MW_{th}, or 24% of the world total. The average annual growth rate for thermal related applications of geothermal energy was 11% during 1990-1995. Under the ninth 5-year plan the average growth rate for 1996-2000 is projected at 8% per year. It is estimated that geothermal energy space heating will replace 5.1 million tce in 1995. This figure will increase to 7.5 million tce in 2000, and 13.4 million tce in 2010.

Depending on the temperature and depth of the hydrothermal geothermal resource and the prospective heat load, single or multiple geothermal wells of different capacities are drilled so as to best utilize the available resources. If direct heating is chosen, hot water from the geothermal wells can be fed directly into the heating system. If the water quality is not suitable for direct heating application, a heat exchanger is used to heat the water in a secondary loop for space heating and bathing. The hydrothermal water can be reinjected into the geological formation. Water which is not returned to the underground formation has to be cooled to a temperature of 35 °C or less. Otherwise an environmental penalty will have to be paid for thermal pollution of surface waters.

As a result of consistent efforts of exploiting oil and natural gas, the technologies for exploiting geothermal resources have been well developed in China. The injection technology, system control, and acid-proof materials for wellhead equipment are areas that need further improvement.

The geothermal energy development potential depends on both the availability of an accessible local resource and a significant heating load. In northern China, the space heating season lasts 3-5 months, extending to 6 months in the northeast, and the geothermal resource is mainly used for centralized district heating. In the southern China, geothermal energy is mainly used in the manufacturing and service sectors (e.g. agricultural, industrial, medical and recreational applications).

China currently has 5 million m^2 of geothermally heated space. Tianjin has the most and it also has the fastest growth rate of new applications. In 1995, Tianjin City had 2.3 million m^2 of geothermal heated space, replacing and saving 80,000 tce of coal each heating season. In Hebei Province, the geothermal heated area is 1,830,000 m^2, of which 110,000 m^2 is in Xongxian County. In Beijing, the geothermal heated space is 300,000 m^2. Liaoning and Shaanxi Provinces also have developed geothermal space heating applications. At the end of 1991, there were over 445,000 m^2 of geothermally heated greenhouses and over 2,050,000 m^2 of geothermally heated ponds for aquaculture total in China.

Geothermal (Electric)

China has had significant experience with grid-connected geothermal power generating facilities in the 1-3 MW range. Although both flash-steam and binary-cycle technologies have been applied to power generating in China, the majority of the existing 1-3 MW installations are of the flash-steam design. The high-temperature geothermal resources required for this design are located in Tibet and Yunnan provinces.

By far the largest geothermal power generation application is the multiple flash-steam units at the Yangbajin geothermal field in Tibet. The initial 1-MW unit was installed in 1977. Currently the Yangbajin geothermal power facility provides over 25 MW of capacity. It supplies 40% of the annual energy for the

Lhasa grid, and 60% of the power during the winter months when output from hydro power plants is low.[11] The Langjiu geothermal field also has a 1-MW flash-steam unit. A 1-MW, binary-cycle geothermal power plant has been installed in Naqu geothermal field.

A 310 kW flash-steam unit has been in operation since 1970 at Fengshun, Guangdong Province. Another 300 kW flash-steam unit at Huitang, Hunan Province, has been in operation since 1975. Both locations have low-temperature geothermal resources. In addition, several small binary-cycle units ranging from 50-300 kW in size have been built over low- to medium-temperature resource areas. These small units are experimental stations, and none of them is in operation at present.

Anaerobic Digester

China is a world leader in the development and application of anaerobic technologies for the production of fuel gas and waste treatment. Starting with the introduction of individual household size biogas digester technology in the early 1950s, China has followed a consistent program of development, technical support, and assisted technology diffusion, with the result that biogas digester technology has been widely adopted to supply fuel for rural household lighting and cooking. By the end of 1994, there were 5.4 million household digesters producing about 1,270 million m^3 of biogas annually. Medium- and large-scale anaerobic technologies for the treatment of industrial organic waste water, and the animal wastes from large-scale intensive livestock operations have also been developed in the past 25 years. Today there are about 600 installations of large- and medium-sized biogas digesters, some of which are supplying biogas to 84,000 households. In addition there are 154 biogas power generating sets with a total capacity of 3 MW in operation. The majority of installed digesters are treating livestock wastes. There are currently about 150 units operating on industrial waste water.

Biogas digesters are the mainstay of anaerobic technologies. Three major types of digesters are used in China:

- **Traditional digester** The traditional digester is a simple digester, usually made of cement and steel. Small-scale, water pressure, closed systems in rural China generally use this design. There is no mixing device in this system. They are cheaper to build, but their conversion efficiency is relatively Low. Other than small-scale household biogas system, this design is also used in large-scale application for treating animal waste where the rate of convertion is not critical.

- **Anaerobic contact reactor** The difference between this design and the traditional digester is the addition of a pre-processing pool for the swage sludge storage. During anaerobic processing, clean water is discharged and sludge, which contains the bacteria, returned to the pool. As a result, the reaction speed is increased. This design has been widely used in early biogas plants in China. The largest biogas digester installation, at the Nanyang Liquor Factory, uses this design.

- **Up flow anaerobic sludge bed digester (UASB)** This more advanced design was first developed in the mid-1970s. The characteristics of this system include: simple structure, large processing capacity, high efficiency, low investment and operating cost. This technology is very popular both in China and internationally. A sludge bed is formed in the bottom of the reactor, through which the raw material is fed. The organic material will be converted into methane and carbon dioxide. Clear liquid will be discharged from the top the reactor. Because the bacteria are retained in the reactor, reaction speed will

[11] "Demonstration, Development, and Utilization of the Geothermal Resources in Tibet," *New and Renewable Energy—Technologies and Products in China*, 1995.

be increased. Compared to the traditional digester design, the yield of this system is much higher. It is widely adopted in industrial biogas plants in China.

Besides those described above, other types of processing technologies, such as two-phase anaerobic digester and plug-flow digester systems, are also used in China. The most popular digester system for large- and medium-scale anaerobic applications in China is the UASB digester.

As China's economy continues to grow at a fast rate, industrial organic wastes also increasing very rapidly. As a result, there is a ready market for biogas technologies that reduce pollution and produce energy. For example, during the 15-year period from 1980 to 1994, total liquor production in China increased from 3.68 million tons to 22.33 million tons, and beer production increased from 0.69 million tons to 14.15 million tons. China produced more than 300 million tons of alcohol along with 45 million m^3 of organic waste water in 1994.

For every ton of grain alcohol produced, about 500 kg of the organic contents remain in in the waste water. If 80% of the waste water from the nation's distillers can be used for anaerobic digestion, about 900 million m^3 of biogas, which is equivalent to 900,000 tons of coal (5,000 Kcal/kg), can be produced. Half of all industrial organic waste water generated in China would produce 25,000 million m^3 of biogas (25 million tons coal equivalent), which is almost equal the total production of natural gas in China.

Biomass Gasifier

China has by far the largest biomass gasification R&D capacity in the world with at least several widely distributed centers developing units for different market niches such as the forest and wood based industries, the rice industry, and, more recently, for the utilization of straws and stalks at the village level. There are two small factories manufacturing biomass gasification equipment with a combined annual production capacity of 300 units. The most successful gasification system on the market is the wood-fueled system, ND-600, developed by the Chinese Academy of Agricultural Mechanization Sciences. About 600 such systems have been installed in China. This system has been sold mainly to the furniture and timber drying industries. The thermal output is 175 kW (about 0.5 Mcal/hr). Its gasification chamber has a diameter of 600 mm. It requires 60 kg of fuel (sawdust or wood chips) per hour and produces 120 Nm^3 of gas per hour with a calorific value of 5.5 - 6.0 MJ/Nm^3. One ND-600 system has accumulated more than 40,000 hours of operation in a timber drying operation.

The Energy Institute of Shandong Province started a biomass gasification research project to provide clean fuels for rural household during the 7th Five-Year Plan period. Their effort has resulted in the successful development of the model XFL-600 gasifier that converts straws, corn stalks, and cotton stalks into biogas for household use. The system can supply synthesis gas to about 300 rural households.

The Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences has developed a large biomass gasifier which can handle 6 tons of sawdust per day. It is based on a cycling fluidized-bed design and has a thermal output of 800 kW and a gasification efficiency of 75%. Several smaller biomass gasification systems have also been developed. The main technical problems facing the biomass gasifier manufacturers are techniques for automatic temperature control and tar removal.

GREENHOUSE GAS REDUCTION POTENTIAL OF RENEWABLE ENERGY IN CHINA

In 1990 China produced over one billion tons of coal and today leads the world in coal production.[12] China currently accounts for about 10% of global energy-related CO_2 emissions, and, if current energy consumption patterns continue, GHG emissions could triple by 2020. China will then surpass the United States as the world's largest source of GHG emissions. Because coal consumption is almost equally divided between power generation and direct use for industrial steam generation and home cooking and heating, renewable energy can play a role in reducing GHG emissions by displacing consumption of coal in both electricity generation and direct consumption for heating and cooking.

For the electricity sector, the potential reductions of GHG emissions from deployment of renewable energy technologies must be estimated in the context of the existing energy system and how that system will evolve in the future. In general, GHG emission reductions that can be attributed to the deployment of renewable energy technologies will depend on the conventional energy systems that they displace and the fuels that these displaced systems use. For example, if wind energy technologies are deployed in a utility system, the electricity they generate will be intermittent and dispatched as generated. The generating units that the wind-generated electricity will displace will depend on the utility system's load profile and the dispatch order of the existing conventional generating units. The dispatch order, in turn, will depend on factors unique to the utility system, such as costs, system reliability criteria in place, regional inter-ties, and power purchase contracts, etc. If the wind-generated electricity is used off-grid, the reduction of GHG emissions will depend primarily on the fuel displaced and will be a more straightforward estimate.

A joint Chinese and international study team (ref. 12) prepared a baseline and three coal substitution scenarios to examine the potential of alternative energy supplies that could be developed in China by the year 2020. Given the dominance of coal (55%) and hydro (15%), however, even the"maximum alternative energy" scenario projects less than 1% of the total electricity generated in 2020 from PV, wind, solar thermal, geothermal,and biogass technologies.[13] Although the percentage of electricity generation by renewable sources is small, the size of the electricity sector (3850 Twh) means that there could be significant deployment of renewable energy technologies under this scenario. For example, the joint team projects 9 GW of installed capacity of wind turbines by 2020, whereas the current installed capacity worldwide is about 2 GW. For PV, the joint study team projects 82 GW of installed capacity by 2020, which is very large when compared to the worldwide total shipment of 55 MW of PV in 1991.

Although renewable energy is projected to play a small role in future electricity generation, it is expected to be much more significant in the total energy sector. For example, the joint study team projects total biomass usage (direct combustion and gasification) in 2020 at 270 million tce (p. 34). Biomass waste gasification can also reduce GHG emissions while providing economic benefits as well. For example, applying anaerobic technologies to intensive livestock operations and industrial waste water processing in the alcohol, sugar and pharmaceutical industries, and utilizing the biogas production provides economic benefits and reduces greenhouse gas (GHG) emissions. Anaerobic technologies can significantly reduce environmental pollution by converting about 70% - 90% of the organic materials that are in industrial waste water to biogas, a mixture of methane and carbon dioxide. Since methane is a very strong GHG with about 25 times the net effect of carbon dioxide, the effective use of biogas reduces the effect of GHG emissions dramatically. A significant fraction of the wastes will produce methane if discharged to the environment. However, the use of biogas as a fuel results in an essentially net zero contribution to the carbon dioxide GHG pool because it is derived from renewable resources such as corn, sugar, or animal

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[12]Alternative Energy Supply Options to Substitute for Carbon Intensive Fuels, Subreport no. 5, Report of a Joint Team of Chinese and International Experts, China: Issues and Options in Greenhouse Gas Emissions Control, December 1994, p. 2.

[13]Ibid, p. 31.

waste, and when it is used to displace fossil fuels, it makes a very significant contribution in reducing green house gas emissions.

To project potential GHG reductions, the joint study team prepared a "high coal substitution" scenario that includes alternative sources for direct energy use as well as electricity generation (p. 35). Under this scenario, renewable energy other than hydro provides up to 4% of the total energy supply and 88 million tons (37%) of carbon emission reduction by 2020 (p. 36). This reduction in GHG emissions by renewable energy sources other than hydro is about 3.7% of the total GHG emissions projected in 2020 under the baseline scenario.

CONSTRAINTS TO ACCELERATED DEVELOPMENT OF RENEWABLES IN CHINA

The joint study team cited the high comparative cost of renewable energy technologies as the key constraint to their large-scale deployment. Lack of capital and advanced renewable energy technologies has had significant impacts on accelerated development of renewables in China. Although China has developed an extensive technology and manufacturing base to use most of its renewable energy resources, supporting technologies such as project management, customer service, and effective marketing techniques often lag behind. Without adequate support many of the opportunities to further expand the penetration of renewable energy technologies in China may not be realized. In addition to focusing on technology research and development, effort should also be made on improving the supporting infrastructure of the renewable energy industry.

Taxation, environmental regulations, and energy price subsidy issues also affect the development of renewable energy in China.

Taxation Issues — The energy produced from biomass gasification processes, anaerobic digesters, or geothermal resources can directly substitute for coal consumption for commercial and industrial users. In the current value added tax (VAT) system, the cost of coal can offset the VAT on the commercial and industrial users, but using renewable energy produced within the plants does not have such advantages. At the same time, investment in renewable energy facilities will increase capital cost. This disadvantage of tax treatment hampers the penetration of renewable energy technologies in the commercial and industrial sectors.

Environmental Issues — Lack of strong environment protection laws is another major constraints for the development of renewable energy technologies in China. Environmental benefit is a major part of the total benefit of using renewable energy. However, environmental benefits of renewable energy are constantly undervalued or not recognized at all. The feasibility of many renewable energy projects depends partially on how strict the environmental regulations are. Environmental regulations in many parts of China, especially in rural areas, are not strict. Many polluters will simply elect to pay environmental fines instead of taking renewable energy options to mitigate adverse environmental impacts.

Energy Price Subsidy Issues — The conomic benefits of renewable energy depend on its end use and on the prices of alternative energy sources. In most areas of China, energy price does not reflect its real cost because of government subsidization. Low energy prices discourage the use of renewable energy.

CONCLUSION

China has extensive renewable energy resources that can be developed as a significant source of energy at the local and regional levels. While the enormous size of the energy sector and the abundance of coal resources make the overall contribution of renewable energy seem small, the actual deployment of renewable energy technologies for electricity generation and direct use can be many times that deployed worldwide today. Significant cost reduction as well as mitigation of other constraints will be needed for renewable energy technologies to achieve their potential in supplying energy and reducing GHG emissions in China.

Renewable Energy Development in China

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Workshop for the Assessment of GHG Mitigation

November 12-15, 1996
Beijing, China

Abstract

This paper presents the resources availability, technologies development and their costs of renewable energies in China and introduces the programs of renewable energies technologies development and their adaptation for rural economic development in China. As the conclusion of this paper, renewable energies technologies are suitable for some rural areas, especially in the remote areas for both household energy and business actives energy demand.

Background

Nearly one of fifth of the population live in the rural areas of China and in the most of these areas, energy supplies are scarce, causing over exploitation of existing forestry and farmlands. This, in turn, causes severe environmental damage. Before 1980, Chinese peasants depended almost entirely on biomass resources for their domestic fuels. Coal and other fossil fuels were mainly used in the urban areas in China. Most of the Utilization of renewable energies resources is in the low cost and non-commercial based. For example, among the 300 million tce of biomass energies, it is about 90% is non-commercial base, and less than 10% of them, mainly firewood and charcoal can be sold to the market. In other word, renewable energies development program in China, is mainly service for the local needs of rural populations. Following the economic system reform and open to outside, the living conditions of rural residential and the rural economy has been improved. As the results, commercial energies, including coal and other fossil fuels have been plaid a significant roles in rural areas of China.

Rural residential takes about 80% in the total national population in China and rural economic development becomes a very significant role in the national economic development, especially following the rural industrial development. As the results, energy demand and supply for the service of rural economic development has become very important issues in the Chinese energy supply strategy. Due to the plenty of resources availability, renewable energy resources have played a very role in the rural energy supply. By the end of 1993, biomass energy supplied about 300 million energy service to the needs of rural household and rural economic development, which took about 20% of total energy supply in China. Therefore, development of renewable energy in China is being recognized as an important component of long term sustainable energy supply.

Given the commitment by the World Environment and Development Convention, the green house gas (GHG) reduction has been concerned by the international society. As one of the major measures of GHG reduction, renewable energies technologies development has been recommended as one of the high priority areas in China. In 1993, the State Council instituted Agenda 21 of China, in which, renewable energies is one of the major components. Since 1994, the State Planning Commission (SPC), the State Science and Technology Commission (SSTC), the State Economic and Trade Commission (SETC) have jointly formulated a Development Program of New and Renewable Energies for the years of 1996-2010. The commissions are preparing an implementation plan for the Ninth Five Years Plan (FYP), based on the Program.

However, based on the conception of least cost energy supply strategy, renewable energy development is mainly for the adaptation of rural household use and the development of rural economy. Also,
currently China is with about 80 million poverty population in 1994 and most of them live in the remote areas where the fossil fuels resources are scarce and with high supply cost. Renewable

energies development program is usually associated with the poverty liberalization or in other words, solving the energy shortage issue is the one of the major tasks for poverty liberalization. The major purpose of this paper is that try to make a roughly description how the renewable energies technologies adapting the needs of rural economic development in China.

1. Government Programs for Renewable Energy Development

1.1 Integrated Rural Energies Development Program with Rural Economic Development

In the early of 1980s, a integrated rural energies development program (IREDP) was initialed by Ministry of Agriculture, Ministry of Forestry, Ministry of Water Resources, based on pilot phase. The principles of the IREDP program are as follows: 1) base energy supplies on local condition; 2) different energies resources complement each other; 3) promote the integrated Utilization of energies resources; and 4) Use energy and other resource in high efficiency. General speaking, the major conception of the Program is develop a least cost energy supply program for service the needs of rural economic development and rural residential improvement, based, or mainly based on the local resources, or in other words, base on new and renewable energies resources and technologies. In the early of 1980s, three counties located in south, central and north of China selected as the pilots for demonstration of the IREDP program in China. During the end of 1980s, following the successful pilots, another 12 counties selected among China as the representative of the various regions, nominated as large scale pilot phase demonstration of the IREDP program, which was instituted as the key project of scientific research during the Seventh FYP. During the pilot phase, the rural countries have been benefited from the least cost energy supply program, especially form the Utilization of renewable energies resource and renewable energies technologies by the fast economic growth compared with other counties without the IREDP program. Since the benefit of the Program has been recognized, in the Eighth FYP, the State Council institute a large scale demonstration program for the integrated rural energies development program among 100 countries, as so called 100 counties program. By the results evaluation, after five years implementation, the 100 counties program has been successful in the renewable energies development for the adaptation of the rural economic development. Based the calculation of MOA, totally about 10 million biomass energy resource supply ability has been increased by the firewood plantation, solar thermal or solar heater Utilization, and about 40 million tce of energy can be saved by the implementation of improved stove and other energy conservation and energy efficiency program after the demonstration in the totally about 140 counties in rural of China. Recently, the State Council has approved another 100 counties program for integrated rural energies development. By these demonstration, a lot of experiences of renewable technologies and resources Utilization adapting the rural economic development have achieved.

1.2 Small Hydroelectric Power Development Program with Rural Electrification

Although China possess more hydroelectric resources than any other country, only a fraction of this resources has been developed. More than 5000 rivers within China have a catchment area exceeding 100 squire kilo meters. The total hydroelectric power potential in China has been estimated at 676 GW. In addition, there are 70 GW of small hydropower (SHP) resources available, with approximately 21% currently being utilized. Unlike coal, which is abundant yet unevenly distributed, water resources are more equally distributed in China. for instance, more than 1000 counties in China are with small hydroelectric power resource. The southwest region of the country, where coal is scarce, accounts for about 70% of the national hydro resources.

As defined by the Chinese, small hydro power facilities are specially taken as those power station with less than 25 MW in total capacity. Thanks the small size, SHP development is adapted by the small scale rural investment. In the past ten years, small hydro power development has been increased by about 1 GW per annum. And 20% of SHP resource has been exploited, as the contrast, the large scale hydroelectric power is only exploited less than 10%.

Small scale hydropower has pointed as one of the major measures for rural electrification. Rural electrification in China, is implemented mainly through three mechanisms: 1) power network extension; 2) SHP development; and 3) small scale fossil fuels (mainly coal and diesel) power generators installation. In the current situation, small scale hydroelectric power contributed about 20% of total rural electricity supplies (see table 2.1).

Table 2.1 Power Resources for Rural Electricity Supplies

Electricity Resources	Electricity Supplies (TWh)	Percent (%)
Large Power Network	128.2	73
Small Hydro Power	31.6	18
Small Thermal Power	12.8	7.5
Small Diesel Power	2.6	1.5
Total	175.2	100

Thanks to the big contribution of small scale hydroelectric power resources, in 1983, the State Council, through Ministry Water Resources, instituted a SHP program for rural electrification in 100 pilot counties, located in the regions which are inaccessible to the national power grids. The principal goals of the program were: 1) installed capacity of 100 W per capita, and 2) annual average electricity consumption of 200 kWh per capita. By the end of 1989, 88% of the demonstration pilots had obtained the objectives. Between 1982 and 1989, the average net income per capita in the 100 pilots countries had increased from 200 to 500 Yuan, with some counties reporting average per capita incomes as high as 1,000 Yuan. According to statistics from the 100 pilot countries, the total installed capacity reached 3040 MW, largely based on the increasing of small hydro power installation..

1.3 Renewable Energies Development Program with Poverty Liberalization

Since there are about 80 poverty million population and about 100 million population without electricity. Ministries and commissions have initialed several different program for the renewable energies for power generation associated the poverty liberalization program.

As one of the example, SPC has institute a Solar Power Generation Program with Ministry of Power, try to use the solar and wind energy for power generation to supply the rural household in northwest part of China and other suitable area with electricity. This program has been supported by bilateral or multilateral international cooperation. By the implementation of this plan, several solar power supply system have been set up in Tibet, Gansu, Qinghai and other provinces, wind energy power generation for Inner Mongolia and east coastal region.

Ministry of Water Resources has launched a so called Warming Spring Program for promoting the Utilization for mini-hydro power system for directly supplying electricity to household or mini rural business. Usually, the capacity mini-hydro power system is less than 100 kW, average with about several kW and supplying electricity to several household or small communities. From the least cost point view, the mini-hydro power system is easily accepted by rural household, especially for poverty household, due to the lower cost. In the most areas, the cost of per kW mini hydro power installation is about 3000 to 4000 Yuan which is relatively cheaper than small and large scale hydro power generation, and the other advantage of the mini-hydro power system does not need the transmission network, which is usually is the highest cost for remote areas.

Another very important renewable energies development program is the solar housing system for primary school in northern part of China. since the cold weather, most of the north part of China needs heating during the winter time. However, in the poverty area, primary schools are usually without heating systems or without sufficient heating systems service to the students and teachers. By the solar housing system, about 10°C of temperature can be increased during cold winter which will contributed to alleviated the suffering of rural schools. And this program is also benefited to the rural household for them have a comfortable time during cold winter.

1.4 Improved Stoves Program with Women Liberation in Rural Areas

In China, household wife is the main person who is in charge of the responsibility of cooking and cooking fuel collection. In the some rural areas, household wife spends about 4 to 8 hours or 50% to 90% of time for cooking and cooking fuel collection. The improved stove can increase the stove efficiency about 10 to 15 percentage point and save about one third of cooking time and about 50% of cooking fuel collection time for household wife. By the end of 1994, about 150 million rural households are with improved stoves. By the improved stoves program, it is not only benefited to the energy savings, but also resulted rural women liberation and make them have more time for production and education activities. In some rural areas, women activity has become importation incomes resource, due to the improved stoves program.

2. Renewable Energies Resource and Technologies

2.1 Wind Energy

Wind energy resources estimated by the National Meteorological Bureau and the Meteorology Institute is about 1.6 TW and the existing installed capacity of wind power generator is about 30 MW. Based the criteria for qualitative determination of potential of wind energy, which are divided into: high, moderate, marginal and poor (see table 2.1.1).

Table 2.1.1 Criteria for Qualitative Determination of Potential of Wind Energy

Criteria	High	Moderate	Marginal	Poor
Hours/year wind speed over 3 m/s	>5000	4000-5000	2000-4000	<2000
Hours/year wind speed above 6 m/s	>2000	1500-2000	500-1500	<500
wind energy density W/m^2	>200	150-200	50-150	<50

Most of the high potential wind energy is located in the remote areas which is far away from the current industrialized region. However, most this area is scarce of other energy resources, which supplied a good opportunities for the remote rural population use the wind for power generation for supply the needs of themselves, such as Inner Mongolia, islands in the east coastal regions.

China has a significant history of wind turbine and wind power development, starting in the early of 1950s with small turbine development for remote applications. By the end of 1994, there are about 140 thousands household size wind turbine for supplying electricity to the remote area rural population, especially for the husbandry farmers of Inner Mongolia with competition cost compared with diesel generators.

In the recent years, China has been also developed some grid-connected wind farms, major using the imported equipment and technologies. By the end of 1994, about 14 sites of wind farmers have been set up with total capacity about 30 MW. Currently, most of the grid connected wind farmers are mainly located in the rural areas and serviced to the rural economy.

China has also developed some technologies so called as Hybrid Systems. several wind/diesel/battery systems are being tested in China in the 30 to 130 kW. The systems are mainly located in Inner Mongolia and islands of coastal region.

Most popular sized wind turbine is household sized in China and which can be accepted by remote rural areas. A typical small wind energy system consists of a 100 W generators and two 60 Ah battery. This system is sufficient to supply energy to two or three fluorescent lights, a black and white television, and a radio as a function of the wind resource and battery charging capacity. In 1993, the total cost of the system was about 1060 Yuan, and the levelized power generation cost was about 0.79 Yuan per kWh which was lower than the cost of diesel power generation in some region.

The cost of power generation in a hybrid system is cheaper than wind power system itself. Table 2.1.2 shows the cost comparison of hybrid and conventional diesel system.

Table 2.1.2 Cost Comparison for Wind/Diesel Hybrid Systems vs Conventional Diesel (Yuan/kWh)

Cost Elements	Hybrid System	Diesel System
Investment	0.33	0.14
O&M	0.06	0.15
Fuel	0.40	0.75
Total	0.79	1.05

2.2 Solar Energy

China has an abundant solar energy resources, especially in the north west of China, Tibet and Yunnan. The total solar radiation is about 0.6 MJ per squire meter average in China. Most popular utilization of solar energy in China is the solar heaters. There are about 3.3 million squire meters of solar heaters have been used in China and the annual production is about 0.8 million squire meters. Solar heater can supply hot water both to rural and urban areas for the residential use. Another utilization of solar energy is solar housing systems. By the end of 1994, about 150,000 squire meters of housing with the solar housing technologies which mainly located in northeast of China and northwest of China. Both solar heater and solar housing system mainly serviced to the needs of household energy. However, some of solar heater systems have been used for rural production, such tea, tobacco and brick drying as well as agriculture drying. Based on the calculation of MOA, solar heaters can service to rural and urban household and rural production energy about 1 million tce if which should supplied by coal.

Solar photovoltaic is the major technologies use in China for solar power generation. The annual production capacity of solar PV is about 3 to 5MWp in China and most of them sold to the communication and transportation signal systems and some of them sold to rural household for power supply. Since the high cost, solar PV technologies is hardly accepted by poverty rural household. Currently, one Wp of solar PV costs about 100 Yuan with battery system. In other words, one 50 Wp system should cost about 5000 Yuan. On other hand, the per capita incomes of most of poverty rural residential is less than 200 Yuan per year. If accounted one household with five people, it is implied that, total five years income can purchase one of solar PV system and the household should not spend any thing in other purposes. Therefore, solar PV system development in China has with several mechanisms: 1) directly sold to richer husbandry farmers who can pay the total cost for the system with different payment method, like high down payment, and low down payment; 2) sold to moderate household with government subsides; 3) send to the poor household who no enough money to buy the solar PV system. The governmental fund for the dissemination of solar PV system in China is mainly from the government poverty Liberalization fund and bilateral or multilateral assistant as well as other international assistant fund.

Solar power generation connected with gird and solar thermal power generation technologies are not developed and utilized in China. However, there is proposal for using those kind of technologies for solving the power shortage issues in Tibet, since it may be the least cost option for the power generation in Tibet.

2.3 Biomass

China possess a wide range of biomass resources which can be used for energy purpose and the resources include firewood, straws and stalks, agriculture and forestry residues, and organic wastes. The annual production of several biomass resources in China is shown in table 2.3.1. Generally speaking, annually biomass production is about 5 billion tons and among which is about 600 million tons can be use as energy purpose.

Table 2.3.1 Biomass Energy Resources in China, 1993

Biomass resource	Annual Production (million tons)
Crop straw	450
Forestry residue	15
Garbage	73
Municipal sewage	146
Rice husk	15
Sugar cane	67
Waste water	18250

Biomass is the major energy resources which service for the household fuels needs. Based the accounting, biomass takes about 70 percent of household energy in rural area, and in some area, especially in the remote area, biomass takes about 100 percent of household energy. In the recent year, following the economic development in rural area, rural people turn to use commercial energy instead of biomass. In 1993, compared with 1980, coal used in rural area it was doubled and it reached about 100 million tons. However, due to the increased environmental pressure, biomass energy utilization becomes a significant issue in China. If rural household energy relied on biomass to much, and the pressure to forestry and land use will more serious. On other hand, too much coal used in rural areas, it will cause more pollutant issue in China, since the current situation is very serious already, especially TSP and SO2 emissions.

The strategy of biomass energy utilization in China can be described as following: 1) increasing the efficiency of biomass energy, for example, promoting improved stoves program in rural areas; 2) promoting commercial utilization of biomass energy, such as, biomass gasification (biogas, for example) and etc. In the past 20 years, improved stoves program has been successful, by the end of 1994, more than 70% of rural households are with improved stoves. However, the step of biomass energy commercialization is very slow compared with improved stoves program, since the high cost and decentralization problems.

Firewood is one of the major biomass resources for energy use in rural area, which takes about 50% of total biomass energy supply in China. However, there is resource scarce problem for firewood production, since there is limited land specially for the purpose of firewood plantation. Currently, most of the firewood (more than 70%) comes from timber and other forestry plantations, which has been resulted in lower the productivity of forestry. By 1993, there was about 5.5 million hectares of firewood land which supplied about 30 million ton of firewood. In other word, increasing firewood plantation will be one of the options for supplying enough energy to the rural economic development and without minus impacts on both local and global environmental protection.

Biogas production used to be one of the measures for biomass resources commercial utilization. However, due to the complicated maintenance processing, during the later of 1980s, biogas development speed became slow compared with in 1970s. By the technologies development, biogas development program has connected with rural household economic activity. For example, usual in the northeast of China, due to the cold weather, biogas digester is not worked very well. However, recently, farmer combined the solar green house system with biogas digester. The solar green house supplying heat for both the house and biogas digester, and biogas can supply energy to the household use and the biogas residues can be the fertilizer for the vegetables in the green house. Therefore, biogas become a key roll for connect energy supply, environmental protection and rural household economic development. Based the accounting of rural household, one green house with biogas digester can increase about 6000 Yuan of income. As the results biogas program has been developed in the northeast of China, in 1994, only Liaoning one province, about 10,000 biogas digester has been built up. By end of 1995, there were about 5.6 million household use biogas digester producing biogas for cooking and lighting in Chinese rural areas.

Another development of biogas program is to develop large scale biogas digester for supply clean energy to rural and urban household, even for power generation for rural economic development. In the new and renewable energy development plan, large scale biogas development is one of the important components. The potential large scale biogas digester development is depended on rural economic growth, specially, in the recent years, large scale animal husbandry farms are developed very rapidly for meeting the meat demand both for rural and urban households. Since there are a lot of animal residues needed to deal with, biogas digester technology is selected by farmers both for environmental protection and energy production. For example, in the rural areas of Beijing, capital of China, 10 husbandry farmers are selected as the pilots of demonstration for biogas production and power generation, supplying both energy and power to the farmers production activity and household energy and power needs.

Biomass gasification & briqueting technologies are another biomass commercial utilization options. In the recent year, China has developed some biomass gasification & briquetting technologies. However, the cost is high and reliability is low. In other words, the biomass gasification & briquetting technologies are still in the R&D stage and it is far way for commercial marketing utilization.

3.4 Geothermal

In China, total resource availability of geothermal is about 3 billion tce and among which about 0.3 million tce has been utilized. Geothermal can be divided into two types: high temperature (i.e, $>150^{O}C$) and low temperature ($<150^{O}C$). High temperature geothermal resources are located in two main zones: the Yunan-Tibet geothermal zone and the east Taiwan geothermal zone and low temperature resources are loacted in north part of China. However, the rich resource is hard serviced to the rural economic development. Geothermal utilization for rural economic development is mainly the low temperature geothermal resources which mainly located in north part of China, such as Hebei and Beijing areas. The geothermal mainly used for thermal purpose, for example, house heater, greenhouse and etc. The geothermal utilization potential is depended on resources availability and drilling cost.

4. Cost-Benefit Analysis for Renewable Energies Resource

The major constrains for the development of renewable technologies are the economic competition ability of renewable energies with commercial energies. However, from the long term point view, renewable technologies are the clearest and environmental-sound energies resources. Without the continuously R&D, the future renewable energies technologies utilization potential would not come true. In other words, current renewable technologies demonstration will be technologies preparation for the future large scale use. Therefore the evaluation of the current renewable technologies should look after their future development. Or in other conception, the utilization of renewable energies technologies in rural areas is one the marketing cost for them future large scale use.

Even in the current situation, in some case, such the remote rural areas, where the commercial energies are with very high cost, renewable technologies are with high competition ability. For example, in the Inner Mongolia, most rural household power supply is depended on diesel generator. Since high cost and difficult delivering, small wind power is welcomed by the rural household in this region. Based on renewable technologies utilization in China, the avoid cost conception should be introduced to the methodologies of renewable technologies assessment. In the most case, rural energy supply, especially for the electric power supply, renewable energy supply is with a lot of benefits besides energy itself. For example, renewable energies can be directly used by household or rural small business which can save some construction investment for the power distribution system. In some case, renewable technologies can replace the high cost peak load supplier. For instance, in Tibet, solar energy availability is consistent with the power peak load in this region (see figure 4.1). Even solar power generation cost is very high, compared with base load supplier, however, compared with peak load, its cost is relatively low. For example, in Tibet, the proposed solar thermal generation cost is projected as about 1 Yuan per kWh, as the contrast, diesel power is about 1.4 Yuan per kWh.

Based on the long term cost benefit analysis, renewable energies development cost is higher than current commercial energy, especially compared with coal. However, based on avoid cost conception, some of renewable energies have the commercial based competition ability in the rural areas.

Another big benefit for renewable energies technologies development is to promote economic development in rural, especially in remote rural areas. For example, solar power with TV system can supply not only power, but also for education, information and technologies to rural people which will increase the capability of rural in their economic activities. Since renewable technologies can supply energy to rural people in a short term compared with conventional energy technologies, even their cost is higher than other type of energy, renewable energies technologies are still with competition ability in energy supply options which is one of the reason of connection solar and wind power program with poverty liberalization in China.

From the local environmental point of view, renewable energies technologies utilization can reduce the emission of TSP and SO2 which are the major pollutants in China from coal burning. And from the global environmental point of view, renewable energy utilization will contribute to the reduction of Greenhouse Gas emissions. In other words, the renewable energies used for rural areas will be resulted in the improvement of both local and global environmental pollution.

5. Central government Planning

Government planning consists of two parts, one is the implementation and dissemination planning and the other is industrial development planning, which includes solar energy, wind energy, biomass energy and others.

Solar energy The *targets* are solar energy utilisation will take about 1% in the total energy use in China by 2000, and it will be about 3% by 2010, respectively. The major *implementation & dissemination planning* is as following: 1) developing 200, 000 solar household PV system in the north west part of China; 2) setting up some solar PV stations in the 9 counties which are without electricity supply by 2000; 3) promoting passive solar housing system in the northern part of China; 4) Popularizing the solar heater Utilization in rural and urban, household, industrial and commercial users. The *industrial development planning is:* 1) improving the capability of solar PV Production by enterprises renovation and introducing new and high efficient production lines; 2) enlarging the productivity of solar heat systems.

Wind Energy The *targets* are 1) installing about 1000 MW wind farm by 2000, and 3000MW by 2010; 2) popularizing small wind turbines for about 200,000 household users by 2000 in north part of China. The *implementation and dissemination planning* is mainly focused on the coastal region and north and Northwest part of China, especially in the Inner Mongolia. The *industrial development Planning* is to develop 200 kW wind turbine for domestic production; to introduce 250 to 550 kW wind turbine production lines for domestic manufacturing.

Biomass Energy The targets are: 1) biomass energy commercial Utilization will be reached about 2.5 million tce by 2000, 17 million tce by 2010 respectively; 2) biogas users will be about 7.55 million households by 2000, and 12.35 million households by 2010, with biogas production about 2.26 billion cubic meters and 4 billion cubic meters by 2000 and 2010 respectively; 3) new biomass power generation will be about 50 and 300 MW by 2000 and 2010. The *implementation and dissemination planning* is listed as following: 1) developing bagasse co-generation in Yuannan and Guangxi; 2) Utilizing forest residuals for power generation in the forest areas which are mainly located in North East China, and southern part of China; 3) developing high efficient biomass gasification Utilization in rural areas by using agriculture residuals. The *industrial development planning*: 1) develop high efficient biomass gasification and briquette equipment; 2) develop high quality biogas power generators; 3) commercialize the improved stoves production.

Conclusion & Recommendation

Renewable energies technologies development is one of the component of sustainable energy supply strategy in China. Generally speaking, there are two types of approaches for adopting renewable energies technologies in China. One is the power generation and the other is the thermal utilization. There are a lot of special case in China for the adoption of renewable technologies for rural electrification. Due to the high cost problem, currently most of the renewable energies power generation technologies are subsided by various sources in rural areas, such as Government Poverty Liberalization Fund, Scientific & Technologies Demonstration Fund and some bilateral and multilateral cooperation programs. Only a fewer cases, such as in husbandry farming areas, household can buy the solar or wind power equipment by itself, since the husbandry farmers are usually richer than agriculture farmers in the remote areas. However, from the long term point of view, renewable energies for power technologies should go to market without any subsides. The major constrains for the utilization of renewable technologies are products cost and quality and maintenance skill. Therefore the future potential of the renewable energies power generation technologies development will be depended on the reduction of the products cost, improving quality and training. In the China new and renewable energies power generation technologies development program is focusing on overcoming the constrains mentioned above. Another constrains for the renewable energies technologies development is the limitation of household income in the rural areas. Following the income increasing, farmers will get more ability to use the renewable energies power generation technologies.

For the renewable thermal use energies, major constrains are the convenience of the energies utilization and the availability of resource. Currently, most of the renewable energies used in rural areas are non-commercial based. Since the most of renewable energies for thermal use are biomass resources, the resources availability is limited by the limitation of land availability in China. Therefore, for increasing, the utilization of renewable for thermal use, the key issue is increasing the efficiency of renewable energies utilization by the resources commercialization. The most commercialized thermal renewable energies technologies are gasification and briquetting. Even with total resources increasing, only by the commercial utilization of renewable resources, the availability of biomass for rural efficient use will be doubled, since most of the commercialized renewable energies technologies with the ability of efficiency increase. In other words, major potential of renewable energies utilization is depended on the commercial technologies development.

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Photovoltaic Rural Electrification

Neville Williams
Solar Electric Light Fund

International Workshop on Greenhouse Gas Mitigation Technologies and Measures

Beijing, China, November 12-15, 1996

Solar Electric Light Fund

SELF Financed Solar Electrification Projects

Country	Project Partner	Finance Method	PV Module Supplier	System Size
CHINA	Gansu PV Company (GPV) Gansu Solar Electric Light Fund (G-SELF)	Retail Sales Revolving Credit Fund	Qinghuangdao PV Co., Ningpo PV Co. & Solarex	20Wp
INDIA	Solar Electric Light Company, India (SELCO-India)	Retail Sales Commercial Bank Loans World Bank/IREDA Loans	Tata BP Solar BHEL Photon Energy	20 Wp, 35Wp & 50Wp
INDONESIA	Sudimara Energi Surya	Revolving Credit	Solarex	50Wp
NEPAL	Centre for Renewable Energy	Village Loan Fund	Siemens	35Wp
SOUTH AFRICA	Zulu Community Dept. of Minerals and Energy Affairs	KwaZulu Finance Corp.	Siemens	50 Wp + 200Wp village center
SRI LANKA	SoLanka Associates Sarvodaya Shramadana Movement	Rural Credit Societies Village Loan Fund	Suntec Solar Power & Light	20Wp & 35 Wp
VIETNAM	Vietnam Women's Union Solar Electric Light Company, Vietnam (SELCO-Vietnam)	Revolving Credit PV System Leasing	United Solar Systems Siemens, ASE	22Wp, 35Wp and five 225Wp village centers
UGANDA	Habitat For Humanity International Solar Energy for Africa, Inc.	Revolving Credit	United Solar Systems	32 Wp
BRAZIL	Farmers Cooperative	Revolving Credit	United Solar Systems (USSC)	35WP & 50Wp
SOLOMON ISLANDS	Guadalcanal R.E.A.	Revolving Credit	Solarex	20Wp & 35Wp
TANZANIA	Maasai NGO	Community Loan Fund	Solarex & Tata BP Solar	Lanterns, Community Lighting

Solar Electric Light Fund

Greenhouse Gas Mitigation Impacts

In the countries where it works, SELF has observed a dramatic decrease in the use of kerosene lamps by families who have purchased Solar Home Systems (SHS). Families with SHSs reduce their consumption of kerosene by an estimated 98% through purchasing a solar home system.

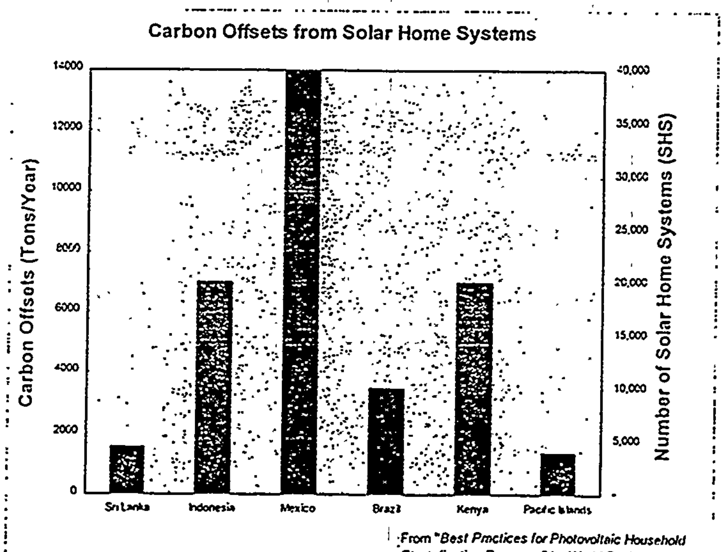
CO^2 Emissions from Average Household Kerosene Usage	Reduction in Kerosene Usage through purchase of a Solar Home System	CO^2 Offset by one SHS	CO^2 Offset Over 20 year lifespan of SHS
0.307 tons/year	98%	0.302 tons/year	6.14 tons

While providing superior lighting and electricity for television and radio-casette-players, a solar home system offsets over *six tons of carbon emissions* from kerosene lamps over it's lifetime.

Solar Electric Light Fund, 1996

Solar Electric Light Fund

Greenhouse Gas Mitigation Impacts



From "Best Practices for Photovoltaic Household Electrification Programs" by World Bank

Solar Electric Light Fund, 1996

While each watt generated by a central station coal plant produces 1.5 lbs of carbon dioxide for every kilowatt-hour generated, a PV panel does not generate any pollutants. Each watt generated by PV offsets at least one watt generated by a central station power

If 1,000,000 homes were electrified through photovoltaics rather than connected to a coal-fired central generating facility, there would be a net savings of over *62 thousand tons of carbon dioxide per year.*

SHS Size	kWh generated per year	Number of Systems	Total kWh generated per year from SHS	CO^2 Emissions per kWh(kg)	Carbon Emissions from Fossil Fuel Power Generation (metric tons/year)
50	91.25	1,000,000	91,250,000.00	0.681818182	62216

Source: John Shaeffer, Real Goods

- Data from the Chinese Ministry of Public Health indicate that chronic obstructive pulmonary disease, which has been linked to exposure to fine suspended particulates and sulfur dioxide, was the leading cause of death in 1988.
- The Government of China has reacted by making the improvement of air quality one of its major objectives in China's Agenda 21, its 1994 white paper on environment and development.
- These considerations demonstrate that the incremental contribution to ambient air pollution from thermal power plants and **kerosene lamps** is an important issue in China.

From China: Renewable Energy For Electric Power by the Asia Alternative Energy Unit (ASTAE) of the World Bank.

Rural Electric Energy Services in China: Implementing the Renewable Energy Challenge

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International Workshop on Greenhouse Gas Mitigation Technologies and Measures

Beijing - November 13, 1996

The Challenge of Village Power

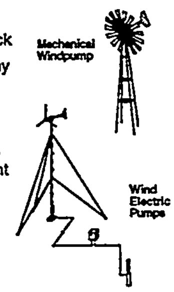
- Almost 2/5th of the worlds' population (~2 billion people) lack reliable access to modern energy services
- Grid-extension is very expensive, has poor cost recovery, and is usually heavily subsidized
- Diesel generators are cheap to install but expensive to operate, often unreliable, and have low carbon efficiency when operated on a 24-hour load-following basis.
- Small-scale renewable energy systems (solar, wind, micro-hydro, and biomass) are often cheaper than grid extension, and more reliable and cleaner than diesel gensets.

Renewables and Village Power

- Many renewable energy system configurations are commercially available to match solar and wind resources, end-use applications, and level of service requirements.
- Design tools are available to permit custom configuration of commercially available components to meet site-specific requirements.
- Decentralized single home and community power systems are starting to make an impact
  - China: 120,000 small (100 - 300 watt) wind turbines installed
  - Mexico: 30,000 PV home systems and 10 hybrid wind/PV/Diesel village systems installed
  - Nepal: 700 micro-hydro systems installed
- Decentralized systems offer the prospect of matching the cost of service to local willingness and ability to pay for energy services, vastly improving the economic viability of rural electrification

Village Power: Potable Water

- Drinking water for people and livestock
- Using underground water solves many common health problems
- Village water tap eliminates need to carry water from distant sources
- Energy requirement is proportional to population served and pumping height
- Typical size: 1 kW : 200 people
- Water storage: 3 - 7 days



Small-scale Renewable Energy Systems* in Inner Mongolia
(household applications)

- PV systems (from 22 watt to 1 kWe)
  - 22W, 35W for DC only
  - 60, 75, 85, 100, 120, 1,000 watt for AC loads
- Wind electric units
  - 100 w (DC-only)
  - 200, 300, and 2,000 w (AC service)
- PV/wind hybrids
  - 35w PV/100w wind
  - 60w PV/300w wind
  - 120w PV/300w wind
- Wind/gasoline genset (100w wind, 500w ggs)

* Lead acid and NiCad batteries, charge controllers, and inverters are Chinese-made

Household Renewable Energy Systems: Issues in Sustainability

- Long periods of non-use due to difficulty and time required to obtain spare parts and repairs
- Gasoline price is 3.65Y/liter plus ca. 3Y/liter for transport ($0.44/liter + $0.36/liter = $0.80/liter)
- Short lifetime of critical components (batteries and controllers) - made even shorter if loads exceed recommended usage
- Reliability and efficiency of small gasoline gensets need to be improved

Menu of Renewable Energy Options for Rural Energy Services in China

- Solar appliances (lanterns, flashlights, radios)
- Household systems (PV, wind, PV/wind hybrids, and wind/gasoline genset hybrids)
- PV- and wind-electric battery charging stations
- Free-standing PV, wind, and PV/wind hybrid systems
  - Water pumping, filtration, disinfection, and distribution
  - Health clinics
  - Schools
  - Community centers
- PV/wind/diesel hybrid power systems
  - "Micro-enterprise centers" for community services and productive uses
  - Village AC microgrids (household, community, productive)

PV/wind Hybrids for Households in Inner Mongolia (commercial pilot project)

- 300 - 400,000 households without electricity
- 110,000 households have small wind-electric units (some have PV)
- 1,100 unelectrified villages; 150 to be electrified by end of 1997 (47 using renewables)
- ca. 1/3 of households can afford wind/PV hybrids at $5/watt (300W wind, 100 - 150 W PV, 500 - 1,000 watt inverter) for small freezer (100 W), TV, lights, consumer electronics
- ca. $500,000 50/50 cost shared by USDOE and Ganzu Provincial Government (300 households)

Strategic Issues for Village Power

- > 2 billion people lack reliable access to electricity, and the number is growing
- Published statistics overstate the extent of useful and reliable electrification of rural communities
- Full-time reliable electricity services are essential for significant rural social and economic development
- Widespread fossil-based RE will add significantly to global CO2 emissions and climate forcing
- Low-carbon high-efficiency rural energy development paths are required for environmental sustainability

The Sea-change in Rural Electrification Policies and Practises

- Growing political pressure from rural populations for social and economic development; resulting commitments for infrastructure development; *electricity a major focus*
- Utility restructuring and privatization + new private sector roles (*eg.* private power for rural electric power)
- Recognition of rural community willingness and ability to pay for basic electricity services
- New emphasis on and resources for facilitating environmentally sustainable development (eg. GEF)
- Rapidly expanding availability of commercially proven, competitive low-carbon energy technologies

Evidence of the sea change

- Multilateral development bank lending for renewables for off-grid electrification
- Host country initiatives to promote renewable energy applications and to attract private sector investment
- Significant interest and growing commitments by industrialized country private sector, including electric utilities, in low-carbon infrastructure investments internationally

Strategic challenges for village power implementation

- Making *small is beautiful* big enough to count!
- Making "big" environmentally beautiful

Technology is ...

- The full capacity to provide a service in a specifiable, sustainable, and replicable manner
- It is *not* hardware (and technology transfer is not equipment transport)

Village Power is ..

- Reliable supply of high-quality electricity services that can support social and economic development
- At costs commensurate with community willingness and ability to pay
- In a manner that is widely replicable, transferrable, and sustainable.

The technology for sustainable off-grid village power supply

- Field-proven commercial **equipment**
- **Local infrastructure** for supply, installation, operation, and service
- In-country **policies** that support commercial markets and environmental sustainability
- **Financing mechanisms** for developers, suppliers, intermediaries, and end users

Market Aggregation as a Requirement for Sustainability

- Attracts large-scale private and public investment for decentralized electricity supply (equipment and service)
- Stimulates competition
- Justifies investments in local equipment production capability

Requirements for Sustainable Use of Village Power Systems

- Community participation
  - identification of needs and priorities
  - financial (partial/full equity, full O&M costs)
  - social organization
- Full cost recovery to owners/operators
  - Mix of community and external revenues (eg. government infrastructure investments)
  - Willingness and ability to pay

Requirements for Sustainable Use of Village Power Systems

- In-country equipment manufacture, supply, installation, maintenance, and repair
- Local operation and maintenance facilities
- Assured fuel supply
- Energy services costs match users' willingness and ability to pay
- Effective revenue collection mechanisms
- Full cost recovery to energy service suppliers

Initiatives that support large-scale implementation of renewables

- **Cost- and risk-sharing** with the private sector and government for path-finding projects for large-scale use of renewable energy-based village power
- **Financing and policy** mechanisms that support new private sector initiatives for off-grid rural energy supply and services
- Support of electrification and economic **development goals** rather than hardware

Innovative Financing Options for Private Sector Village Power

- **Create micro-utility markets to attract local and foreign investment**
- Private sector concessions for off-grid rural power delivery (eg. Argentina, 1995)
- Private power contracts (eg. to government electric utilities) for off-grid power
- Build/own/operate/transfer contracts with public sector entities
- Networks of rural electric cooperatives

International Workshop on GHG Mitigation Technologies and Measures
November 12-15, 1996

Asian Success Stories in Promoting Energy Efficiency in Industry and Buildings

International Institute for Energy Conservation (IIEC)
Bangkok 10110 Thailand

Overview

- IIEC Brief
- Examples of Success Energy Efficiency Programs

iiec International Institute for Energy Conservation

What is IIEC?

- Non-governmental organization
- Advocates sustainable energy solutions
- 4 regional offices and 5 sub-offices
  - Washington, DC (1984) 20 Staff
  - Bangkok, Thailand (1989) 10 Staff
  - Santiago, Chile (1991) 10 Staff
  - London, England (1993) 10 Staff
    - Poland, Slovakia, Hungary, Czech Republic, and South Africa, 1 staff in each sub-office

iiec International Institute for Energy Conservation

International Institute for Energy Conservation (IIEC)

- **Mission**
  - Promote the efficient use of energy as a tool for sustainable development by supporting the development of policies, technologies, and practices.
- **Focus:**
  - Energy Efficiency
  - Transport
  - Renewables

iiec International Institute for Energy Conservation

Examples of Success Stories

- Energy Efficiency Lighting
  - EGAT Fluorescent Lamp Campaign
  - Green Lights in International School of Bangkok (ISB)
- Industry
  - Transfer for Energy Management
  - South Korea: Energy Efficiency Management System
  - Energy Conservation Centers
  - Chinese Industrial Energy Efficiency Regulations
- Building Efficiency
  - ASEAN commercial building codes
  - Philippines "AirCon" Standards and Labeling
  - Green Mall (Philippines)
  - Green Building (ADB building energy auditing)

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EGAT Fluorescent Lamp Campaign

- Implement: Electricity Generating Authority of Thailand
- Background:
  - high electricity demand growth rate
  - future growth: expected to increase 1,000 MW/year
- Project Overview: Energy Efficiency Lighting
  - Cost: US $190 million for over 5 years
  - Components: private & public sector retrofits, education & public awareness, industrial and load management
- Current Status:
  - reduction in budgets & utility bills
  - capacity savings: 238 MW and 1427 GWh avoided
  - reduced CO_2 emissions

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Green Lights in International School of Bangkok (ISB)

- **ISB:**

  With 1,900 students; Planned 2 million baht in EE in 1996-1997
- **Motorola Lighting's Family of Lowest:**

  Electronic ballast: 17W, 25W, and 32 W; T-8 lamps on 1-lamp to 4-lamp model; Compared to T-12, Excellent savings;
- **Program:**

  Motorola retrofitted 50 ballast in the main library for a demonstration project in Sept. 1996. 20% of electricity saved.

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China's Industrial Efficiency Regulations

- Program began: Since 1980's
- Activities: serve the public with policy direction, procedures, regulations, technical assistance and energy conservation offices, mechanisms include energy quotas, industrial standards, equipment standards, investment funding and performance awards
- Total investment: 27 billion Yuan or US$ 5.7 billion
- Achievements: 20% reduction in Energy Intensity or 300 mil. tce saving. EE programs saved 100-140 million tce.

ADB Building Energy Auditing

International Institute for Energy Conservation

- Location: Manila, Philippines
- Size: 130,000 square meters
- Goal: Reduce electricity consumption by 56%
- IIEC Recommended ADB HQ Retrofitting Technology

  Lighting: electronic ballast; high efficiency fluorescent lamps occupancy sensors; daylight dimming systems

  Cooling: Smaller but more efficient chillers

  Office Equipment: computer, fax machines, printers
- Total Investment: US$ 3.5 million
- Results

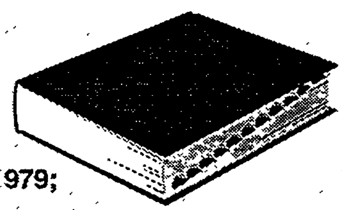
  Energy bill reduction: ~ US$ 800,000/yr.; Est. CO_2 reduction: 748 tonnes/yr. removing 588 cars from the road; planing 500 ha. of trees

ASEAN Building Energy Codes

International Institute for Energy Conservation

- **Countries:**

  Singapore, Philippines, Malaysia, Thailand, and Indonesia.



- **Mechanism:**

  First code made in Singapore in 1979;

  Program began in 1982 (USAID);

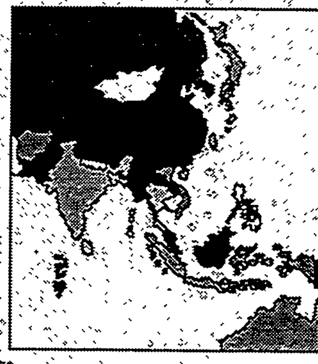
  Assisted in examining and developing cades on envelope, cooling, and lighting, developing regional consistent codes.
- **Estimated energy savings due to the code:**

  19%-24%

International Institute for Energy Conservation

A few current programs in IIEC-Asia

- Thailand
  - E* Computer Program
  - Transportation in Bangkok
- Philippines
  - Green Mall in Manila
  - Training in DSM
  - Dealmaker
- South East Asia
  - High EE motors and transformers
  - Standards
  - Voluntary Program
- China
  - Integrated Transportation in Xiamen
  - Tangshan Transportation Dispatching Center
  - Compressed Natural Gas Vehicles in Beijing



Green Lights Program in China

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Abstract

In China's 9th 5-year plan (1996-2000), the Chinese government has placed high priority on energy conservation. The China Green Lights Program (CGLP) is listed as one of the key projects of energy conservation. The basic strategy of the CGLP is to mobilise all of the potential contributors to participate in the program, and to use market signals and supplementary non-market instruments to facilitate its implementation. Governmental funds and loans will be used as seed money to attract private participation in the program.

The program contains the following elements:

1. Information dissemination to educate the public on the economic and other values of the program and to provide CGLP information to increase consumer awareness and, as a result, increase the demand for energy-efficient lighting systems.

2. Development of standards and codes for lighting systems, establishment of product specifications, and enforcement of product standards.

3. Development of quality certification and labelling system to provide assurances to consumers that the products they are purchasing will meet their performance and cost saving expectations.

4. Highlighted support and financing for production technology development and production capacity expansion.

5. Demonstration and pilot projects to boost consumer confidence in green lighting systems and to demonstrate new production technologies and processes.

6. International co-operation to expand the international exchange and absorb advanced technology and experience for implementation of the China Green Lights Program.

1. Background

The China Green Lighting Program (CGLP) was initiated by the State Economic and Trade Commission (SETC) of the P.R.C. in 1993, for the first three years , the focus has been mainly on the research studies of the current status of China's lighting system and its illuminating products industry, the major barriers of developing high efficiency lighting systems in China, and policies and measures for implementation of the CGLP. In 1995, China's total power production was 1000 TWh, lighting accounts for 10-13% of the electricity consumption in China, exceeding the projected annual electricity production of Three Gorges hydroelectric power station (84 TWh) which is under construction. The demand for electricity for lighting grew at a rate of 15% per year since 1990. It is expected to continue to grow at this rate for the foreseeable future as China improves its economy and standard of living. New commercial buildings, office buildings and public facilities notably consume more and more electricity for lighting. As a result, lighting will consume a greater percentage of China's growing electricity demand over the next 20 years.

Based upon studies conducted by Chinese governmental and research institutes, the demand for electric capacity will grow from approximately 200 GW in 1994 to 300 GW in the year 2000 and as high as 800 GW by 2020. Construction of electric power plants will require massive new capital investment. In addition, since it is expected that approximately 75% of the new electric capacity through 2020 will be coal based, dramatic increases in pollution are likely, adversely affecting China's sustainable development, Therefore, options to reduce the growth in the demand for electricity must be a very high priority in China.

Lighting systems in China are very inefficient resulting in considerable electricity waste. The average efficiency of lighting is only one third that of the advanced international level. China's traditional luminous sources are mainly low-efficiency incandescent lamps (about 80%) followed by thick tube fluorescent lamps. Efficient lighting appliances, especially efficient light sources, are rarely used and their popularisation rate remains low in China. For example, incandescent lamps are widely used in commercial, residential and industrial buildings. Lighting system efficiencies are seldom considered in new construction, and lighting conservation is not currently practised in China. This is a result of several factors including: (1) the cost of lighting represents a small share of the overall cost of business operation; (2) lack of awareness of the problem among the general population; (3) low quality of many domestically produced green lights; (4) the capital cost of good quality energy efficient light bulbs is currently too high for the large majority of users to comfortably afford; and (5) the lake of policies guide and technologies to address the problems.

Improving lighting efficiency could result in significant energy savings in China. It is estimated that the CGLP can effect a twenty percent savings in lighting electricity by the year of 2000. For example, if 300 million advanced compact florescent lamps (CFL) are used to replace incandescent lamps as intended, the end-use electricity savings could reach 22 TWh. This would result in financial savings of approximately 50 Billion Yuan in avoided power plant construction.

In addition, the use of efficient light systems would considerably reduce sulphur dioxide, nitrogen oxides, suspended particulate matter and carbon dioxide emissions. For example, by the year 2000, a total reduction in sulphur dioxide emissions of 200 thousand tonnes based on electricity saved, and carbon dioxide emissions of 7.4 million tonnes can be achieved.

At present, although there are more than 1000 enterprises which produce lighting appliances, compared with developed countries, China still lags behind in the field of high efficiency lighting appliance production. In 1995, the total annual output of luminous sources was 4.5 billion lamps, which includes 2.6 billion incandescent lamps, 350 million fluorescent lamps, among them. 80 million compact fluorescent lamps. High efficiency lamps represent only a very small percentage of the total output.

For the time being, the problems existing in China for the popularization of electricity saving illuminating appliances are mainly low technological level of production and unstable product quality with a high price. In general, the production capacity most enterprise is rather small scale, mainly with labor intensive processes and poor quality control management. China currently lacks of policies, regulations, and standards to govern the quality and performance of lighting systems. As a result, many lighting manufacturers produce low quality products in pursuit of short-term profits. This has created consumer confidence problems as efficient lighting systems have not met consumer expectations.

So in 1995, the State Economic and Trade Commission (SETC) decided to substantiate the China Green Lights Program (CGLP) with pilot projects. The program will be connected with annual technology innovation loan and demonstration funds from SETC. SETC hopes the Green lights Program will become one of the major measures to realize the electricity saving goals of the 9th 5-year plan. In April of 1996, the SETC formally listed the CGLP as the key project of energy conservation. Simultaneously an Executive Team, Project Office of the CGLP and Expert Panel were established and the decision was made to implement the CGLP under the collaboration of the SETC, China National Council of Light Industry, Ministry of Electronic Industry, Ministry of Agriculture, etc. The Executive Team coordinates all the relevant government agencies to work together in the program, provides policy guidance to the program, approves important working plans, and supervises the Project Office of the CGLP. The Project Office is responsible for developing the 5-year and annual working plans for the CGLP. The Office will organize the implementation measures for the program as well. Comprising individuals from the National Technology and Supervision Bureau, Energy Conservation Association, Chinese Society of Lighting, and the China Lighting Association, The Expert Panel provides suggestions and consultancy for the CGLP.

The basic strategy of the CGLP is to mobilise all of the potential contributors to participate in the program, and to use market signals and supplementary non-market instruments to facilitate its implementation. Government funds and loans will be used as seed money to attract private participation in the program.

2. Objectives

The objectives of the implementation of CGLP are to popularise high efficacy illuminating appliances; to save electric energy; to establish a market popularisation system for efficient illuminating appliànces; to upgrade the quality of efficient illuminating appliances, and to improve quality standards and establish a certification system, thereby protecting the environment.
Electricity savings: In accordance with the calculations made by experts, in the 9th five year plan period the popularisation of a total number of 300 million of compact fluorescent lamps and small diameter fluorescent lamps as well as other high efficacy illumination products will result in end-user electricity savings of 22 billion kilowatt-hours.
Emissions reductions: By the year 2000, a total reduction of sulphur dioxide emissions of 200 thousand tonnes based on the calculation of saved electricity, and carbon dioxide emissions of 7.4 million tonnes can be achieved.
The stepwise establishment of a market popularisation system for electric energy saving illuminating appliances will cause electric energy conservation to be introduced into the track of normal marketing practice.
Pay great efforts to upgrade product quality of electric energy saving illuminating appliances; improvement of quality standards and certification system.

3. Framework and Contents

(1) Education and Information Dissemination Plans: To increase public awareness toward electricity conservation and of the economic and environmental significance of the Green Lights Program.

The main goals of this plan include: to regularly disseminate information on the CGLP to the public through mass media to raise awareness of electricity conservation, and environmental protection, and to encourage citizens to participate in the CGLP; to spread knowledge and introduce lighting electricity conservation experiences by organising various public welfare activities such as lectures, workshops, and training courses, and to establish CGLP demonstration centres of in major cities, as long-term public show-cases.

(2) Policy Development and Macro-Regulation: To formulate relevant measures and enhance policy guidance.

On the basis of the full play of the fundamental effects of market regulation on the distribution of resources, the governmental functions of supervision, service and co-ordination should be enhanced. The tasks of this plan include: To make necessary supplements to the laws and regulations concerning electricity conservation, which also require necessary modifying and adjusting, and to research and formulate incentive policies for lighting electricity conservation. To establish a national green lighting information system, and to provide information services for policy makers, researchers, designers, manufacturers and consumers.

(3) Certification and Labelling Plan: To encourage fair competition and improve the product quality

The major activities of this plan are: to research and design certification and labelling for green lights products; to organise test and monitor institutes and manufacturers to undertake certification and labelling activities; to regularly investigate and appraise product certification to provide assurances to consumers that the products they are purchasing will meet their expectations.

(4) Pilot and Demonstration Plan: To seek efficient channels and accumulate successful experience

Demonstration and pilot projects will be developed in light of local characteristics and specific conditions to benefit both the society and individual groups. The demonstration projects include: urban public lighting system; large hotel and commercial buildings lighting system's replacement and retrofit project; efficient lighting system design for new buildings, etc.

(5) Highlighted support and financing Plans: To raise the technical level of the industry and increase the production scale of high quality products.

On the bases of product certification and enterprise investigation, SETC will provide support to some important projects of the illuminating appliance production enterprises which have good technology capacity so as to create favourable condition for quality improvement and optimisation of the allocation of resources to form step by step an economic production scale.

(6) International Co-operation Plans: To expand international exchanges and absorb advanced technology and experience.

To make use of the both international and domestic resources and markets, and to attract foreign manufacturers of lighting products to take part in the implementation of the CGLP. Simultaneously, to enhance the financial support from international financial institutes for the implementation of the CGLP by taking the advantage of the advent of the growing international concern for environmental protection and the activities of green lights programs and adopt those successful experiences which fit with China's practical situation.

5. Essential Progress of China Green Lights Program

(1) Adopt market mechanism

After more than 10-years of open-door policy, China is moving gradually toward a mature socialist market economy system. The mechanism of market competition will be incorporated into the implementation of the CGLP. The selection and popularisation of green lights appliances should obey the rules of certification and labelling in light of the principle of "survival of the fittest". The state will support and help the products with good technical characteristics and good economic characteristics so that their market share will increase.

(2) Encourage demand-side participation

The implementation procedure of the CGLP is different from previous energy saving programs which mainly emphasised supply-side (enterprise) measures. The CGLP involves electric appliance enterprises, utilities, and end-users. The active participation of the users (demand side) will play an important role in the success of the CGLP. Therefore, the CGLP will launch a large number of activities of education and science popularisation so that the public awareness of the electricity conservation and environmental protection can be enhanced. Simultaneously, the participating users will enjoy preferential policy. The method of DSM will be introduced in the implementation of the CGLP.

(3) Government guidance and macro-control by policy

Because the ongoing process of transitioning from a centrally-planned economy to a market economy in China is still in its initial stage, the government guidance and macro-control by policy should be very important over a nation-wide social systematic project like the CGLP. The government administrations should adopt proper methods of market economics to implement their functions of supervision, service and co-ordination, and formulate a series of policies, laws and standards to encourage and promote the CGLP in accordance with the related laws of energy conservation and environmental protection, so that the lighting products market and consumer behaviour will be conducted in a commendable fashion.

(4) Facilitate the development of the lighting industry in light of environmental protection and electricity conservation

China is forging ahead toward industrialisation. However, at present most of the lighting appliance enterprises are facing problems of outdated equipment and technology. Therefore, the technical process replacement and product redesign are imperative. The popularisation of the CGLP will point out the direction for the development of domestic lighting product enterprises, drive vigorously the renewal and development of this industry, and contribute to China's social and economic development.

(5) Seek international collaboration

China, a developing country, receives much attention from many international organisations in regard to its energy and environment issues. To make use of international green lights programs and to get financial support, the CGLP will actively import advanced technology from abroad and exchange experiences of high efficiency lighting systems. It will also apply to the relevant financial organisations for capital aid and low interest loans. The CGLP has already received strong technical assistance from the UNDP and the US EPA. The CGLP welcomes all the foreign manufacturers of lighting products to enter China's big market of lighting products, cooperation in which will be mutually beneficial.

A NEW MECHANISM FOR ENERGY CONSERVATION TECHNOLOGY SERVICES

by Feng Yan
The state Economy and Trude Commission

Prepared for

International Workshop on Greenhouse Gas Mitigation Technology Measurers
Beijing, China
12-15 November, 1996

In the ninth-five year plan of China, the socialist market economy model will be developed . In the stage of transferring from planing economy to market economy, the energy conservation technology services industry in china has met new challenges . Over the past ten to fifteen years ,there has developed a new mechanism for financing energy efficiency investments in market economies . The process is simple. After inspecting an enterprise or an entity for energy saving opportunities , an Energy Service Company (ESCO) which business aimed at making money will review the recommended energy conservation opportunities with the enterprise or the entity(user) and implement those measures acceptable to the user at no front end cost to the user. The ESCO then guarantees that the energy savings will cover the cost of the capital renovations using the Performance Contracting .

The Background

China is a developing country with high economic development speed. The annual growth rate of gross domestic products(GDP) in recent years kept on at a high rate of growth with two-digit number. Due to China's special historic reasons and the coal dominated energy resource conditions, the existing industry system is still backward from the general view, and the advanced industrial and civil equipment and facilities only hold a very small proportion. The average energy intensities of the major energy intensive products are 1.3 to 1.8 times as much as those in developed countries . In recent years, China adopted the policy of reform and opening to the outside world, and paid more attention as well as enhanced efforts on energy conservation . China has made notable achievement in reducing energy consumption and increasing efficiency of major energy intensive manufacturing industries, which apparently eased the long-lasting bottle-neck restriction of energy on China's economic development, causing the energy consumption per unit GDP drastically decreased . However, the energy efficiency in China is still low from the overall view. Among the newly installed industrial equipment and civil utilities , only a small proportion of them use state-of -art technologies, while most of them still adopt obsolete processes and technologies, which are of much lower energy efficiency in comparison to the advanced international levels. Production and civil utilities of low technical level, low efficiency and high consumption are still increasing rapidly due to demand stimulation induced by high-speed economic development . Therefore, China has great potentials for promoting energy conservation and reducing greenhouse gas emission as well as acid rain at present and in future, and also a lot of measures for increasing energy efficiency.

Barriers

There are two types of energy conservation projects in China now, type one projects yield major benefits for the local environment(reducing particulate or sulfur dioxide emissions) as well as energy savings. These projects are not currently financially attractive to enterprises , because they may provide major local benefits accrue to society at large, and not enterprises themselves. Government encouragement is required for such projects to be implemented, and is best pursued in directly through enactment and enforcement of pollution control regulations; Type two projects yield financially attractive life-cycle returns to enterprises under current conditions. Subsequent savings in enterprises energy costs are more than offset the costs required for investment up front.

There are a very large potential for energy savings and greenhouse emission reduction through implementation of these types of projects. However, only a small portion of these potential projects are being implemented, due in large part to barriers as follows:

--Information: enterprises know very little about the practical information of energy saving project, especially on the financial analysis results of adaptation of various newly emerging, cost-effective technologies;

--Compare to the overall cost or interest of an enterprises, the benefit of energy saving project is very small, the manager of the enterprises pay a little attention to this kind of project;

--As the enterprises are not special in energy conservation, the cost of project implementing is very high(including the project selecting, designing, measure, managerial and technical personnel). The new technology transferring is usually at a very high cost;

--There is a lack of capital for energy efficiency technical renovation projects, most of managers of enterprises pay more attention to expanding production capacity and market penetration, and less to energy efficiency. In public sectors, they have no budget for energy saving project;

--There are a lot of risks: Perceived technical and financial risks to enterprises in adopting innovative energy saving technologies, and risks of responsibility of managers and technicians, especially for those technologies that are not familiar for enterprises and may have large impact on the normal operation of the enterprises.

New mechanism

So it is necessary in China to develop a new energy conservation mechanism to overcome above mentioned barriers, enhancing effective energy conservation technology transferring and information dissemination and promoting energy conservation. To achieve this objective, we have applied a project named `China energy conservation promotion project` to World Bank and GEF. This project will support the development of new initiatives and promotion of new institutional mechanisms as well as its capacity building to overcome the principal constraints currently impending rapid adoption of more energy efficient technologies, and also develop the capability of information dissemination of the national energy conservation administrative institution, establish information dissemination system for energy conservation market, expanding the penetration of energy conservation technologies.

There are two components for this project: one part is the demonstration of new market-based mechanism to promote energy conservation, we will help to establish some demonstrate ESCO; another part is the information dissemination. The second part is also very important for the popularization of the demonstrated new mechanism.

There will be three major kinds of ESCO:

--A company developed from the original energy conservation service center;

--A new special established company which will do energy conservation service project for customer;

--A company based on a equipment manufacturer;

--A branch of utility.

The key point of the new mechanism is Performance Contracting.

Performance Contracting is a process for the sale of reduced operating costs. It consists of two parts: the first one is a contract to purchase equipment and services, payments are paid over a long time; the second one is a guarantee that the reduction in operating costs be sufficient to pay for the equipment and services.

The processes of Performance Contracting is usually as follows:

--Design phase

The ESCO should find a customer, analyses the energy usage of the customer, evaluate the potential of energy saving, design the energy conservation project;

--Installation phase

The ESCO will negotiate a deal to allocate cost and savings from energy conservation investments with the customer, select a kind of contract and sign, find investment for the project, install the equipment;

--Performance management phase

The ESCO will do on-going maintenance and operations, make performance monitoring to verify the energy savings.

There are about four kinds of contracts:

--Leased purchase, guarantee

The ESCO finances for the project and guarantee the results of energy savings(amount of the energy saving, ratio of energy saving) of the energy conservation projects implemented by ESCO; the customer will pay the contracted service fee to ESCO according to the contract;

--Shared saving(pay from saving)

The ESCO provides energy conservation service to customer and share the resulted benefit with the customer, based on the expected benefit and actual benefit.

--Equipment leasing

The ESCO will purchase and install energy conservation equipment for customer, after pay regular rental to ESCO in certain period of time, the customer will own the equipment.

--Facility operation agreement

There are advantages for ESCO which has background of equipment production to manage the equipment for the customer.

As general, Performance Contracting is an ideal vehicle to integrate measures that make money, reduce energy consumption and avoid damage to the environment. The new mechanism has a tremendous potential in China.

Prepared for
international Workshop on Greenhouse Gas Mitigation Technology Measures
Beijing, China
12-15 November, 1996

Brief Introduction of GEF Efficient Industrial Boiler Project in China

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Abstract

The present situation of installed industrial boilers, their efficiency and environmental impact are assessed. And the factors contribute to the low efficiency and serious pollution are summarized. Based on WB-assisted GEF project, "Efficient Industrial Boiler Project" aimed at CO_2 mitigation in China, a series of effective measures to bring the GHG emission under control are addressed, in technology, system performance and operation management aspects.

With the rapid development of the national economy, electricity has long been in short supply in China. As a thermal power equipment the industrial boiler (IB) has played a very important role in production and daily life of the Chinese people. At present, the total installed capacity of boilers throughout the country is 460,000 units, equivalent to 1,080,000 steam tons per hour. That is, the annual output is 30,000~40,000 boiler units, equivalent to 80,000~100,000 steam tons per hour. In China, over 95% of IBs are coal-fired and their coal consumption is as high as 350 million tons per year with the annual emission of CO_2 reaching 600 Mt and flying ashes exceeding 6 Mt, SO_2 coming up to 5 Mt, as well as a large amount of NO_x and other harmful gases. As is known, CO_2 emission will directly increase the effect of global greenhouse. And it is apparent that IB is a major atmospheric pollutant source of coal-smoke type in China. With abundant coal reserves, the energy structure of China will long remain coal-dependent in the future. It is estimated that coal consumption of IB in 2010 will account for 38% of the annual coal output of China. It is therefore becoming a both local and global concern to improve the IB efficiency of coal utilization and reduce its stack emission.

To help mitigate CO_2 emission in China, the WB assisted the MMI in initiating the *Prefeasibility Study on Efficient IB in China* in 1992 on the basis of UNDP-sponsored project *" Chinese Greenhouse Gas Emission Control and Solutions"*, by organizing a group of international and domestic experts, and in 1993 four subreports were submitted:

"Market Investigation on IB in China"
" An Investigation on the Chinese IB Production System "
" Options Assessment on Improvement of Boiler Design

and its Thermal Efficiency "
" Suggestions on Future Investment "

Then in 1994 through analyses and appraisals by experts, the WB submitted to GEF a final report entitled "Prefisibility Study on Efficient IB in China".

It can be seen that the Chinese IB industry has made marked progress, through 40 years of hard work, and has developed various IB product lines suitable for combusting various types of the Chinese raw coals. In general the Chinese boiler manufacturing level has reached such height as required by the developed countries' standards. However there is still a wide gap between China and the developed countries in the field of coal combustion technology, such as complete combustion and efficient utilization of coal. The backwardness reflects in: lower operational efficiency, higher coal consumption, serious stack emission and so on. Operational thermal efficiency of the Chinese coal-fired IB is only 60~65% on the average, i.e., 10~15 percentage points lower than average guaranteed thermal efficiency of developed countries' IB. As a result, annual CO_2 emission and coal consumption by the Chinese IB are more than those by advanced IBs in the world, respectively over 60 Mt more coal and 120 Mt more CO_2 gas.

The following factors contribute to the low efficiency and serious pollution:

1. The coal used by IBs in China is usually the raw coal with high ash content, unwashed and unscreened, containing many slacks.
2. Installation of IBs is widely scattered in China, 460,000 units are installed and used in 25,000 boiler houses over the country. Each boiler house has less than 2 boilers, each with capacity of 4.3 steam tons on the average. What is more, most users operate them on 60% load only. It is not unusual that users employ unskilled or undertrained boiler operators and that users in northern areas even employ odd hands for heating season.
3. There exist national supervisory regulations for manufacturing of boiler pressure parts in China but no national supervisory regulations for design and manufacturing of combustion equipment, which results in unreasonable combustion equipment designs here and there. Such problems are common occurrences as poor air distribution, serious air leakage, excessive coal sifting, poor workmanship of grate bars and seals.
4. Comprehensive causes in auxiliaries such as auxiliary mismatch, unsatisfactory boiler island technology due to the lack of basic auto-control and auto-adjustment means.
5. There are some problems in IB industry structure and its planning & management.

There are some 548 IB manufacturers, and numerous non-pressure boiler makers, all over the country, 80% of which are very small-sized enterprises, each with annual output of less than 200 steam tons only and most of which duplicate the production of same kind of technically backward IB products. Chinese IB manufacturers generally stint on the necessary retrofitting, some of them even make no input in the research and development. In their designing and manufacturing work, most of them just "copy" the IB products made by some other manufacturers with strong technical forces. For decades of years the management personnel at various levels have ignored the commercialization of products needed in markets and followed the beaten path under planned economy system. Till now some of them still keep their old tracks, paying no attention to needs from markets.

The mitigation of greenhouse gases emissions, like CO_2, from the Chinese IBs should begin with the improvement of IB thermal efficiency.

Under the promotion of the World Bank officials, the GEF approved the start-up of preparing " Efficient Industrial Boiler Project " in 1994. By means of this project and GEF's grant fund, China would introduce advanced coal burning technology from abroad to improve the structure design, manufacturing process and operation management of Chinese industrial boilers in order to increase the thermal efficiency and abate CO_2 from IBs, this is supposed to be one of the effective measures to bring the GHG emissions under control, with less investment but better benefit.

" Efficient Industrial Boiler " project includes the content as follows:

1. Improve the existing standard Chinese IB products:
   1). 1 - 6 t/h package water tube boiler;
   2). 1 - 6 t/h improved package water and fire tube boiler ;
   3). 6 - 20 t/h module water tube boiler;
   4). 6 - 20 t/h high sulfur coal boiler;
   5). 1 - 20 t/h package and module hot water boilers;
   6). 4 - 10 t/h package and module extended furnace water and fire tube boilers.

   The main improvements are: take the standard boiler proper as the basis, import foreign advanced technology, produce boiler and their auxiliary equipment of with good performance on a trial basis, establish model boiler-house and put them into mass-production and make dissemination after passing examination and proving successful.

2. After importing, digesting and absorbing advanced and sophisticated technologies from abroad to develop new Chinese industrial boiler products which are suitable for burning the Chinese coals. The mainly products needed to be developed include:

   1). 35 - 100 t/h CHP steam boiler;
   2). 28 - 70 MW large capacity hot water tube boiler;
   3). 35 - 100 t/h CFB boiler.

Through importing technology to trial-manufacture boilers and their auxiliary equipment; establish model boiler-houses to make thermal efficiency of new boiler units and pollution emissions of flue gas can reach the level of developed countries. These new boiler products should be put into the mass- production and disseminated after passing examination and proving successful

3. Emphasis on the improvement of systematic performance and level of boiler unit.

In addition to importing boiler proper and combustion technology, boiler auxiliary equipment also should be optimized. Therefore, the key items of secondary air system and its fan, multicyclone and bag filter, furnace de-sulfurization, ash and slag sealing treatment, automatic control system and instruments of environment protection emission inspecting and monitoring, etc. will be optimized and selected using imported technology and should be commercialized finally.

4. Improve management level of Chinese industrial boiler industry.

Through the implementation of the project, strengthen contacts between Chinese industrial boiler industry and other countries, establish completed information network and data base, improve research development and management level, revise and replenish part of current industrial boiler standards in China and make them close to or reach developed country level; train the personnel of quality management, market management and service for boiler enterprises; and train personnel of operation and management for users.

Up to now, the domestic bidder winners for nine subprojects of the project have been determined. we are preparing for that after sign on the agreement of GEF grant fund, the project will start formally and will invite bidding from foreign firms. It is planned that the demonstration units of nine subprojects should be completed, checked and accepted by 2000 around. These new boiler products should be disseminated and transferred to all boiler makers in the country through the localization. After 2010 year, all existing old and low- efficient boilers in China will be replaced by new and high-efficient industrial boiler. At that time, the social possessing quantity of new Chinese industrial boiler will be about 130,000 to 160,000 steam tons. If calculated in terms of the current annual coal consumption by industrial boiler(350 Mt), the coal saving can be 15 % of the total annually or is about 50 Mt which means that about 100 Mt of CO_2 emission can be reduced (about reduction of 1/5), and about 850,000 tons of SO_2 and 1.1 Mt of dust can be reduced.

In order to protect our earth — the environment we are living upon — we would like march forward hand in hand with our counterparts in the world and try to do our best to mitigate greenhouse gas effect and clean our atmosphere.

Overview of Mitigation Policies and Measures

In Transportation

John Ernst

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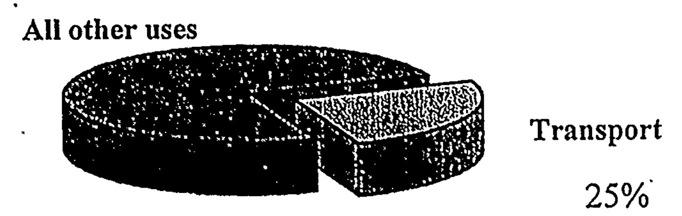
World Energy Use

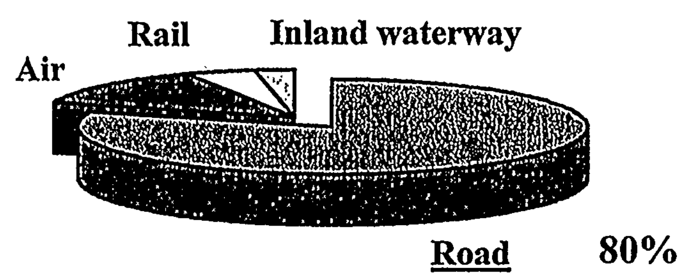


source: Michaelis, L. 1996

International Institute
For Energy Conservation

Transport Energy Use

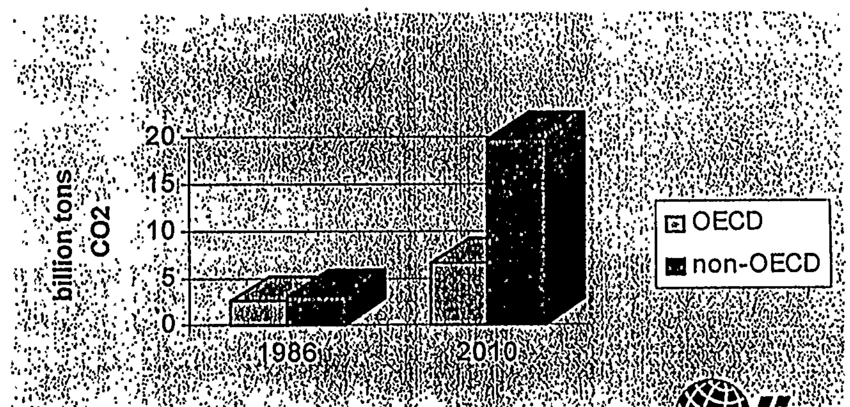
(for 20 of 23 countries with largest transport energy use)



source: Michaelis, L. 1996

International Institute
For Energy Conservation

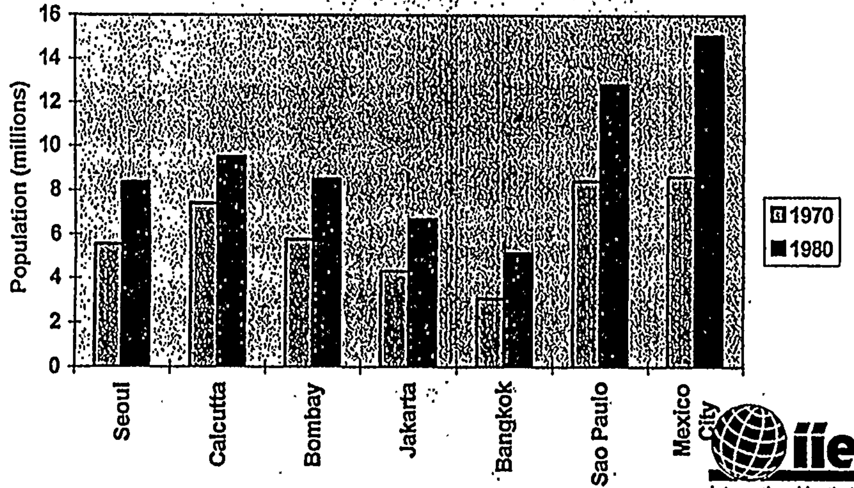
Transport Emissions



source: World Bank. 1996

International Institute
For Energy Conservation

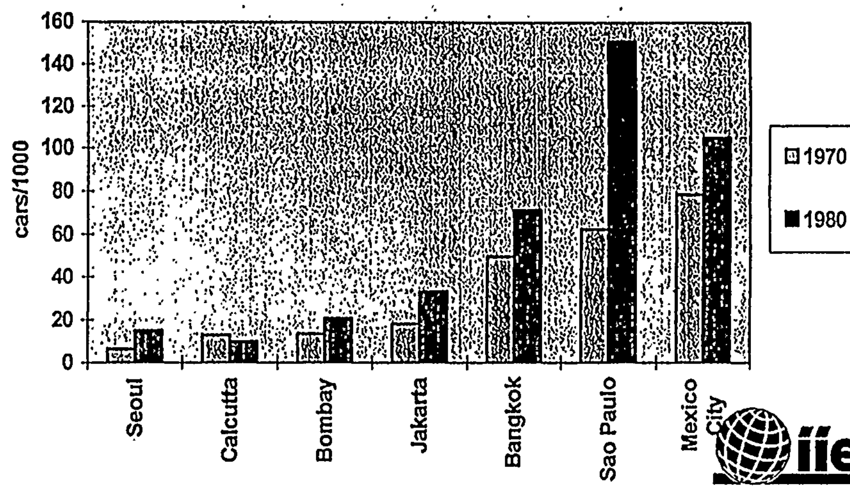
Population Growth - Selected Cities



source: Sathaye and Walsh. 1992

International Institute For Energy Conservation

Cars per 1000 in Selected Cities



source: Sathaye and Walsh. 1992

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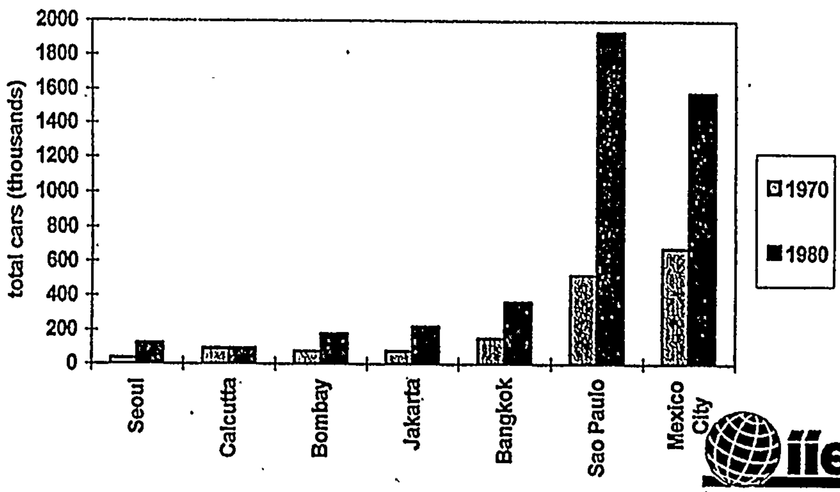
Total Cars in Selected Cities



source: Sathaye and Walsh. 1992

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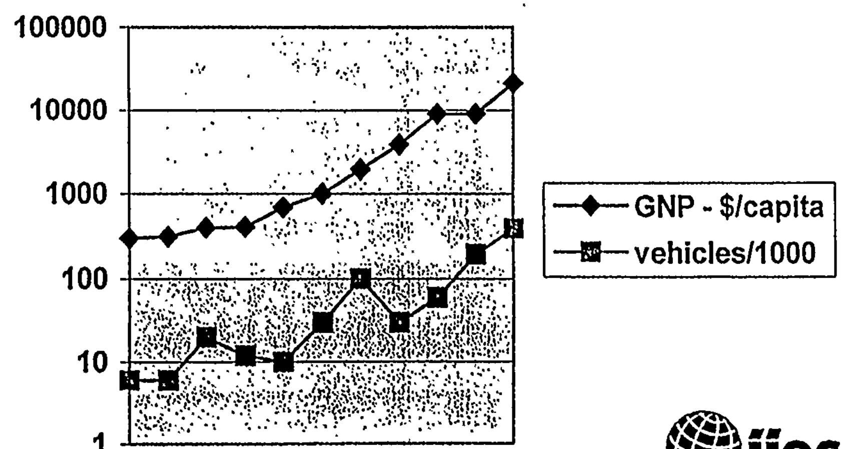
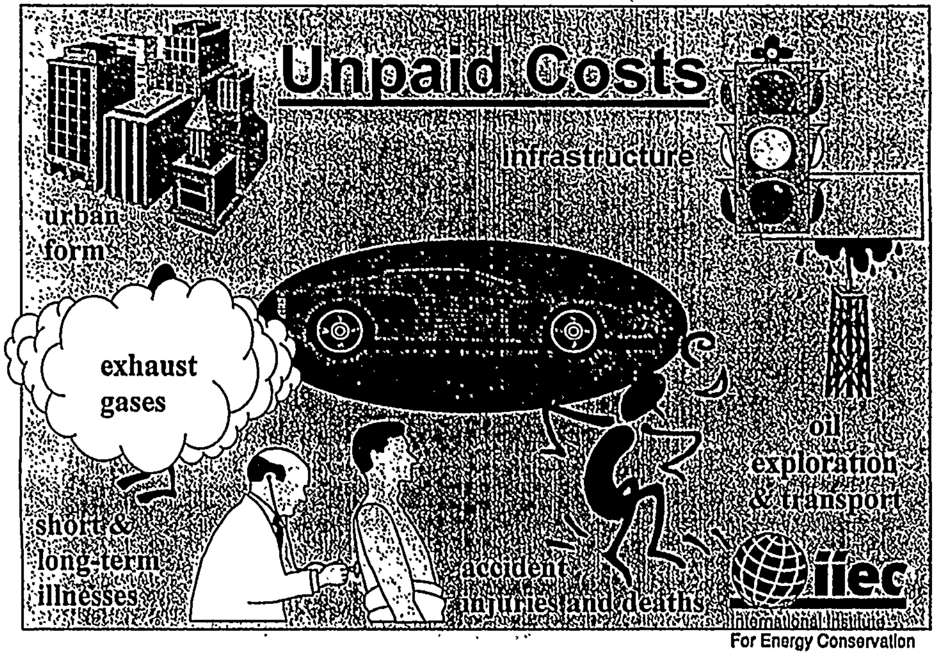
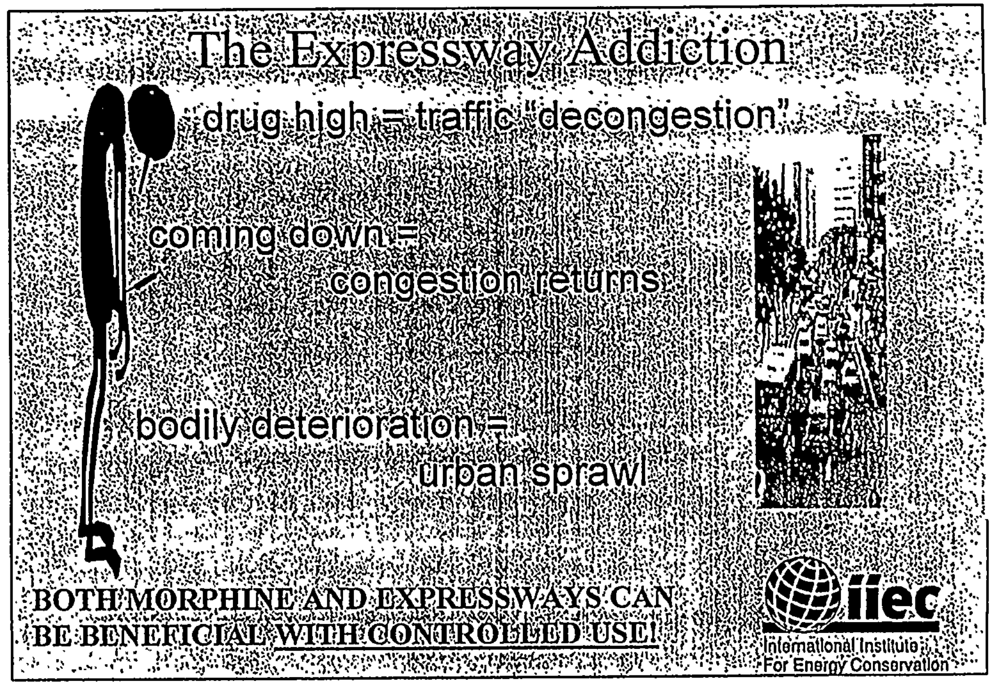
GNP and Vehicle Ownership in 11 Asian Cities



source: Sathaye and Walsh. 1992.

International Institute For Energy Conservation





Questioning Design Basics

Speed in Cities: **LESS IS MORE**

The Benefits of Speed:
- improves combustion engine efficiency
- TEMPORARILY reduces transport time

The Costs of Speed:
- induces more traffic
  (cars become faster than other transport)
- increases accident risk, noise, health problems
- weakens communities and social fabric
- reduces use of non-motorized modes

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Win-win situations

Reducing GHG emissions in transport can:

- Improve urban form for future efficiency
- Reduce dependence on imported energy
- Increase economic competitiveness by reducing energy use
- Improve the transport system, increasing labor pool and reducing business costs
- Improve health and productivity by reducing related pollutants
- Reduce costs now paid by government and citizens to subsidize car drivers

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<u>Sources cited:</u>

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Traffic Improvement and Transportation Pollution Control in Xiamen

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WU Zilin
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Abstract: In this paper, the urban traffic improvement and transportation control in Xiamen are highlighted. Xiamen is a port city and an economical special zone of China. As the economy grows, the transportation is developing dramatically and becoming the key for further economic development. The air quality is threatened by the rapid growth of the vehicles in the city. The most urgent task in improving urban traffic is to establish a sound traffic system. The municipal government takes great effort to improve the traffic condition, as well as to reduce green house gases and protect air environment. Some management and technical measures are carried out. Those management measures are mainly as follows: (1) systematic planning of the city arrangement and city functional division, and integrated planning of the urban roads system, (2) putting great emphasis on tail gas monitoring and management, and (3) establishing optimized utilization of motor vehicles. Those included in the main technical measures are (1) making the roads clear, (2) enlarging traffic capacity, and (3) developing the public transport. The most urgent task in improving urban traffic is to establish a sound traffic system. The city municipal government and Transportation Management Bureau plan to make a series of reforms to improve the urban traffic condition, such as building high quality road around the city, reducing the number of one way roads and replacing gasoline buses with electric buses. An optimized traffic system of Xiamen, taking public transport as the main means, is the key to meet the needs of both traffic improvement and urban transportation pollution control.

1. Geography, Economics, Transportation and Air Quality in Xiamen

1.1. Geographic Background

Xiamen is a port city located in south-east China Sea, and facing Taiwan Strait on the east. Xiamen urban area consists of Xiamen Island and

Gulangyu Islet, covering an area of 131 sqKm. Total area of Xiamen including suburban districts is 1,516 sqKm [1, p.20]. The city has a total population of 1,200 thousand with a city population of 655 thousand [2, p.312]. A dam was built to connect Xiamen island to mainland in 1950'. Due to its special geographic conditions, Xiamen was not well developed until 1980' when it was opened as one of 5 special economic zones in China.

1.2. Economic Background [3, p.6]

The development of Xiamen Special Economic Zone was started in October 1981. After more than 15 years' development, reform, and opening to the outside word, Xiamen has gone through historical changes. By 1995, the gross domestic product (GDP) of the city was RMB 25 billion (about US$ 3.08 billion), with an annual average growth of 21.7% since 1982. The GDP per capita was RMB 19,435 (about US$ 2,396). Industry in Xiamen is blooming. The total industrial output value of the city in 1995 was RMB 32 billion. In 1995, the total imports and exports amounted to US$ 6 billion. The total retail sales reached US$ 1.14 billion, and 250,000 overseas tourists were accommodated.

1.3. Transportation in Xiamen

Although transportation in Xiamen has grown dramatically during the past 15 years, it is obvious that the transportation problem has become the "neck of the bottle" for further economic development.

The urban traffic installation in Xiamen is middle to upper level among those cities of same scale in China. However, as the economy grows, the burden on traffic installation becomes heavier and heavier. The maximum capacity of current road net in the island is 70 ~ 75 thousand standard vehicles. At present, various motor vehicles in the island are about 40 thousand in terms of standard vehicle [1, p.26].

From 1980 to 1993, annual average growth of vehicles in Xiamen was 41%. Between 1990 and 1995, annual total goods and passenger transportation has increased 21.8% and 8.1%, respectively. Of all the increase, the contribution of each transportation modes are as follows: 59%

and 5.3% by water, 7.9% and 14.9% by railway, 8.3% and 7.4% by road and 40.3% and 34.5% by air, respectively [3, p.9].

Total transportation activities of Xiamen are summarized in Table 1 [3, p.9]. Table 2 lists the numbers of transportation and vehicle repair businesses, and various vehicles at the end of 1995 [4, p.286].

Table 1. Transportation in Xiamen City

		1991	1992	1993	1994	1995
Vehicles		35247	42798	57463	73042	108097
Boats			833	894	822	929
Passenger Transport (million -trips)	total	11.92	11.56	13.25	15.77	15.75
	railway	1.26	1.56	1.94	2.17	2.19
	road	8.04	7.19	7.69	9.80	9.64
	water	1.79	1.72	2.07	1.64	1.39
	air	0.73	1.09	1.55	2.15	2.53
Cargo Transport (million tons)	total	11.22	12.03	14.53	21.49	23.4
	railway	1.91	2.13	2.26	2.64	2.92
	road	7.28	7.46	8.77	9.60	10.62
	water	2.01	2.43	3.48	9.21	9.82
	air	0.0106	0.0155	0.0227	0.0233	0.0446

Table 2. Number of Transportation Business and Vehicle at the End of 1995

Transport Business	total	1016	
	passenger transport	87	
	cargo transport	992	
Vehicle Repair Business	total	736	
Vehicle Number	total	108000	
	passenger vehicle	17200	
	cargo vehicle	13900	
Vehicle in Business Use	total	20300	
	passenger vehicle	4365	45152 seats
	cargo vehicle	7759	41754 tons
	container vehicle	266	
	motorcycle	326	
	agriculture vehicle	2973	
	tractor	5510	

1.4. Air Quality in Xiamen [3, p.12-13]

Xiamen is an energy importing city. During the past 15 years, the municipal government adopted a policy of energy substitution. City gas is widely imported and used in the city to substitute coal. This is the main reason that the city can reduce emission although the city's economy has been keeping increasing at an average rate of 21.7% annually during 1982-1995. The main sources of emission come from industrial boilers and transportation vehicles. Due to the rapid growth of vehicles in the city, NOx has been constantly increasing in 1990s.

Because of a series of measures for improving the transportation and protecting the environment, also thanks to good geographic condition, the air quality of Xiamen has been improving. Xiamen's air quality had ranked the second level during 1982-1988, and the first level (the best) during 1989-1995. In 1995, the daily average concentration of SO_2, NOx and TSP were 0.010, 0.023 and 0.066 mg/m^3, decreasing 79.6%, 47.7%, and 82.2%, respectively, when compared with those in 1981. Table 3 [3, p.12] shows the emissions during the past 15 years.

Table 3. Concentration of Air Pollutants in Xiamen

Year	SO_2 (mg/m^3)	NOx (mg/m^3)	TSP (mg/m^3)	Dust ($tons/km^2/month$)	Rain pH
1981	0.049	0.044		12.27	
1982	0.071	0.058		14.28	
1983	0.075	0.030		13.39	4.65
1984	0.075	0.033		11.92	4.84
1985	0.064	0.025		11.17	4.85
1986	0.083	0.021	0.370	8.00	5.09
1987	0.073	0.013	0.190	11.09	4.78
1988	0.055	0.009	0.250	11.58	4.60
1989	0.013	0.010	0.080	13.01	4.56
1990	0.012	0.012	0.090	13.08	4.79
1991	0.007	0.011	0.094	8.08	4.61
1992	0.006	0.013	0.090	7.56	5.04
1993	0.009	0.018	0.100	7.96	4.43
1994	0.008	0.018	0.079	5.96	4.50
1995	0.010	0.023	0.066	5.36	5.17

2. Management and Technical measures for Improving Transportation Conditions and Reducing Air Pollution

2.1. Management Measures

2.1.1. City plan

Xiamen is planed to be built as a modern port scenic city by 2010. To catch this goal, the municipal government places policy emphasizing on making sure that the environmental quality would not be getting worse in the process of its economic development.

A sound urban traffic and communication system will do much in improving the environment as well as in bettering the traffic condition. To solve the problem on urban traffic, some important management measures have been carried out (information from Environment Protection Bureau of Xiamen):

(1) In the city arrangement, the block distribution is adopted. Each block has proper size, living and industrial areas are relatively independent to decrease the traffic communication among the blocks.

(2) In city functional division, the urban district is being arranged according to the plan of the industrial district in the north and the living district in the south. Thus, most of the freight transport vehicles will drive in industrial district lest they disturb the living district too frequently.

(3) In living district, the planning structure is "resident district -- small resident district". When urban traffic vehicles drive in the main trunk road, they do not pass through the internal "small resident district" so as to create a peaceful living environment for the resident district.

(4) In planning urban roads, the width, area and direction of the road are determined by the road quantity and shape. In order to provide necessary foundation for the urban traffic, the roads must be divided based on their function, the location of parking lot must be designed, area must be remained in advance to make it possible for grade separation to be built in crossroads where traffic is very heavy, as well as overhead bridges or underground passages must be erected in crossroads where too many people and vehicles

pass through. In case of the narrow road of old downtown, one way traffic is preferred so that the traffic can be unblocked.

(5) The development of public transport is the main policy in the plan of urban transportation. Meanwhile, the growth rate of bicycle and motorcycle should be confined. All the tricycles were forbidden in 1994. A comprehensive and multiple passenger transportation and traffic system, including railway, trolley bus, small bus, taxi, and public ferry, should be established, taking buses as the main means in public transport.

2.1.2. Tail gas monitoring and management

To protect and improve the air environment in Xiamen, as well as to benefit the public health, the following regulations are laid out [5]:

(1) The National Standards of Tail Gas Discharging must be carried out strictly by every organization and individual using motor vehicles. Maintaining and repairing of the motor vehicles must be strengthened to ensure the pollutant discharging come up to the standards. No vehicle exceeding the discharging standards is permitted to drive on the road.

(2) The vehicles should be examined, prior to annual examination, by the tail gas examination station appointed by both vehicle management branch of public security departments and environment protection departments. The certificates are granted to those up to the standards, which are necessary for vehicles going for annual examination.

(3) The vehicles must install the treatment device of tail gas if their tail gas discharged excesses the standard, before they are allowed to the annual examination.

(4) Vehicles whose tail gas is not up to the standards even after repair must be forced to install the treatment device.

2.1.3. Other management measures

The Regulations of Forced Elimination of Motor Vehicles, are in accordance with the policy of compensating discharging. The aged and high discharging vehicles will be eliminated from urban traffic system and put into suburban area step by step. Tractors are not allowed to enter the urban area and trucks are forbidden completely in inner area of downtown. On Zhongshan Road (main street in downtown), taxis and trucks are kept from passing through. In order to decrease the burden of downtown, the heavy traffic is branched. In downtown, the restriction of allowing odd-even number license plate going in odd-even date is in practice. Left turning is forbidden in some crosses and one way roads are arranged somewhere.

2.2. Technical Measures

2.2.1. Increasing traffic capacity

Xiamen municipal government has invested large sum of money in increasing traffic capacity. Some roads have been built since 1980s. The Xiamen Bridge, connecting Xiamen island to mainland in addition to the old dam, was put in use in 1992. The main downtown road, Xiahe Road, was widened three times in 1994. And a new Zhonggu tunnel, through a hill inside the city, was opened in 1995.

2.2.2. Making the roads clear

A series of projects were carried out to keep the roads clear and decrease the number of brake of the vehicles and the block of the traffic. Dozens of overhead bridges for walkers were built or are going to be built [1, p.149-153]. Recently, the temporary parking lots of mini bus and taxi are re-assigned.

2.2.3. Developing the public transport

Citizens are encouraged to utilize the public transport. To improve the public transport, buses are being remolded, new traffic lines are being added and the frequencies of the buses are being speeded. Table 4 [1, p.8] compares the various traffic means in 1988 and 1995.

Table 4. Comparison of the Traffic Means in 1988 and 1995

	percentage %			percentage %	
	1988	1995		1988	1995
walking	35.8	37.84	group bus	0.9	7.10
bicycle	49.1	26.20	private car		0.84
bus	10.3	14.80	motorcycle	0.5	9.37
mid-bus		2.10	others	4.4	
taxi		1.75			

2.2.4. Monitoring the air quality

Air quality is monitored every month by Environment Protection Bureau. The scientific data provide the bases for making the management policies.

3. Current Problems

3.1. Current Road Congestion Problems [3, p.11; 1, p.106-107]

(1) Unmatched road supply

In-use vehicles in the city increase at 18% each year, but road capacity at 15% each year. The gap between the transportation demand and supply will be even wider in the future.

(2) Limited traffic flow capacity

The transportation flow capacity in intersections limits the overall flow capacity. Intersections include how the signs and signals direct the traffic. Many intersections are overcrowded. The intersection carrying capacity is only half the capacity of the road. This increases the congestion along the roadway.

(3) Competing use of the road

In the city, there are a lot of competing uses of the road. Cars and bicycles are mixed on the road everywhere. Even some construction projects occupy part of the roads. As the crowd business area, Zhongshan Road and some other important roads loss part of their function of traffic.

3.2. Transportation Pollution [1, p.106-107; p.170-175]

(1) Increase of transportation pollution sources

The total number of vehicles is keeping increasing in the limited urban area. Unreasonable increasing of the vehicles depresses both the traffic condition and the urban environment.

The road net in the city is still unsystematic. Low quality roads, especially those in old downtown, weaken the traffic capability. In the turn, the discharge of tail gas is increased by the low speed driving and repeatedly starting of too many vehicles. What is more, there are few roads made green by planting trees and grasses.

(2) Increase of noise

Transportation noise is the main source of city environmental noise in Xiamen. The noise was as high as 76 dB in average in 1990. In 1995, the horns in the city were banned, and the noise is about 70 dB now.

3.3. Parking Problems

For many years there has been no development in the parking lots. Public parking lots take up pedestrian space and road space, so these on-street parking lots are a big problem. No permanent parking spaces designed is a severe shortage.

3.4. Possible Problems in Near Future [3, p.11; 1, p.107-109]

Most of the roads in Xiamen will reach their designed capability in a few years. The main roads entering the old part of town currently operate at 58% capacity. The small roads run from 71% to 88% of capacity right now. If the current growth of traffic were limited to 12 to 15%, it would have taken 4 to 5 years for the roads to reach their full capacity. However, the growth rate has been 19.8% for the past 2 years. Xiamen will face severe congestion if there is no powerful means to improve the situation.

4. Improvement Plans and Ideas [2, p.485-494]

4.1. Traffic Reforms [3, p.15]

The city municipal government and Transportation Management Bureau plan to make the following reforms:

(1) Widen and expand some roads to increase the traffic capacity [1, p.50].

(2) Use reasonable reorganization of traffic signals at the main intersections to increase the primary road flow capacity [1, p.166].

(3) Move existing dividers to restore some of the sidewalks on part of road.

4.2. Plans for Improving the Transportation [1, p.184-190; 2, p.89-90]

(1) Building express roads across the city and a high quality road around the city [1, p.36-37, 49-50, p.189-190]

The city municipal government plans to use a few years and millions of Chinese yuans to build up express roads across the city and a high quality road around Xiamen island. Part of the roads have to be built on the sea, hundred meters away from the shore. By 2000, the roads will be in use and the city transportation and traffic will be greatly improved.

(2) Reducing the number of one way streets and roads

In the old town, the one-way streets are not helpful because of requiring additional travel to reach a destination. In the new area the two-way roads are better in balancing the traffic on the two main corridors and improving the safety. Of cause, this plan could only be well carried out when there is enough road capacity for two-way driving.

(3) Increasing public transport [1, p.39-40, 46-47]

In laying out urban traffic policy, priority should be given to the development of public transport. Xiamen has considerable potential to develop public transport. A sound traffic system should take public transport as the main means, and combine with mid-bus, bicycle, taxi and certain amount of personal cars. In Table 5 [1, p.40], the structure of traffic means planned for 2010 is specified.

Table 5. Structure of Traffic Means Planned for 2010

means	walking	bicycle	motor-cycle	bus	group bus	private car
percentage,%	22.09	22.06	3.9	35.73	6.22	10

(4) Strengthening the management [1, p.166]

It is important to raise the public awareness of environment and transportation. The propaganda has to be utilized and more strict regulations have to be made to guarantee the performance of all the plans.

4.3. Ideas Possible in Practice

(1) Replacing gasoline buses with electric buses

It is planing to put electric vehicles in use instead of gasoline vehicles. The use of clean energy source can significantly improve urban air quality.

(2) Utilizing the existing railway crossing the city

There is a railway only for cargo trains crossing the city from the train station to the ferry. However, the railway is rarely in use since there are few cargo transferring nowadays. If the railway can be utilized to transport the passengers, then the downtown congestion problem can be improved.

5. Summary

Good geographic condition and important economic and political position promise Xiamen a prosperous future of becoming big city. As the economy grows, the transportation in Xiamen is developing dramatically and becoming the "neck of bottle" for further economic development. It is obvious that a sound traffic system is needed to improve the traffic condition, as well as to protect air environment. Fortunately, effective measures of both management and technique are taken.

The problems and challenges are still arising. It is high time for Xiamen to chose the right economic and transportation development pattern. By taking public transport as the main means from now on, the traffic system of Xiamen is leading to becoming a sound and sustainable foundation of the further economic development.

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Prepared for

International Workshop on Greenhouse Gas Mitigation Technology Measurers
Beijing, China
12-15 November, 1996

Development of Natural Gas Vehicles in China

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Abstract

Past decade and current status of development of natural gas vehicles (NGVs) in China is described. By the end of 1995, 35 CNG refueling stations and 9 LPG refueling stations had been constructed in 12 regions, and 3,100 vehicles had been converted to run on CNG or LPG. China's automobile industry, a mainstay of the national economy, is slated for accelerated development over next few years. NGVs will help to solve the problems of environment protection, GHGs mitigation, and shortage of oil supply. The Chinese government has started to promote the development of NGVs. Projects, investment demand, GHG mitigation potential, and development barriers are discussed.

China needs to import advanced foreign technologies of CNGs. China's companies expect to cooperate with foreign partners for import of CNG vehicle refueling compressors, conversions, and light cylinders, etc.

China has been developing natural gas vehicles (NGV) since the 1950s. In the mid to late 1980s, new technology and equipment was imported by the China National Petroleum Corporation (CNPC) from New Zealand, Australia and other foreign countries, and the first road test of CNG vehicles was conducted in Sichuan Province. By the end of 1995, 35 CNG refueling stations and 9 LPG refueling stations had been constructed in 12 regions including Sichuan Province and Xinjiang Uygur Autonomous Region, and 2400 vehicles had been converted to run on CNG and 700 to run on LPG.

With the rapid development of Chinese economy, urban environmental pollution has become a serious national problem. Automobile emissions are now one of the primary sources of air pollution in major cities including Beijing, Shanghai, Shenyang, and Guangzhou. Economical and clean natural gas powered vehicles will make a major contribution to reducing air and noise pollution in Chinese cities. According to test data, about 90 percent of CO emission, 70 percent of HC emission, 40 percent of NOx emission, 80% of CO2 emission, and 40% of noise pollution will be abated by substitution of natural gas for petroleum in vehicle fuel. Moreover, damage of poisonous or carcinogenic substance from petroleum fuel, such as lead, benzene, aromatic hydrocarbon, etc., will be completely removed. In addition, there is considerable economic benefit from natural gas vehicles. For example, if 30,000 compressed natural gas vehicles will be run, about 350,000 tonnes of petroleum will be substituted for. At present the price of natural gas is about 60-70% of price of petroleum, so 260-350 million yuan RMB can be saved (2,500 yuan/ton of petroleum). In addition, development of relevant industries will be drive by NGV, such as NG compressor, components for remaking vehicles to run on CNG, etc. Output value of relevant industries will exceed 62 million yuan.

While crude oil production China has increased steadily in recent years, domestic natural gas output has been on the rise as well, thanks to the discovery of several gas fields including four key gas fields: Sichuan, North Shanxi, Xinjiang, and offshore. By the end of 1995, the annual natural gas production had reached 16.5 billion cubic meters. And it is expected to continue grow quickly, exceeding 30 billion cubic meters by the year 2000. According to forecast from current material, China's NG resources will be over 38 Tm^3. Its content of exploration and exploitation is very low. The potential of reserve resources is abundant. This will provide a strong resource guarantee for the development of NGVs in China.

China's automobile industry, a mainstay of the national economy, is slated for accelerated development over the next few years. Total annual domestic production of motor vehicles is expected to reach 3 million by the end of this century, and 6 million by the year 2010. Development of NGVs will help to solve the problems of environment protection and shortage of oil supply caused by the rapid development of the industry.

The Chinese government has designated environment protection as a basic national policy and has started to promote the development of NGVs. The State Economy & Trade Commission has included NGV technology in the national key technology development program of the Ninth Five-Year Plan (1996-2000), and the State Science & Technology Commission and the State Planning Commission have organized and supported research on the application of LPG and CNG vehicles. The Ministry of Mechinery Indusry and CNPC have organized formulation of standards on NGVs. The Minisry of Labour has organized production of cylinders for NGVs. In addition, the government is sponsoring the first Beijing '96 International Symposium and Exhibition of Electrical and Alternative Fuel Vehicle Technologies, indicating its new level of support for NGV development.

CNPC, the China Automobile Industrial Corporation, Ministry of Machinery Industry, Ministry of Labour, Tsinghua University, and the Chinese Academy of Science are currently carrying out NGV research and development projects to provide technical preparation for sustained large scale NGV development. China National Petroleum Corporation has preliminary planned that during Ninth Five Year Plan CNG vehicles demonstration regions with economic scale management will be built in Sichuan and Huabei Oil-Gas Fields including several cities such as Chengdu, Chongqing, Beijing, etc., in which 33 NG refueling stations will be set up, and 4,000 vehicles will be remade to run on CNG. And it will drive development of CNG vehicles in other oil-gas fields and in cities. During the same period three bases and four centers also will be built, mainly based on domestic efforts, and ways of technology import and international cooperation. The three bases are: a production base for 50 compressors per year, a production base for 3,000 sets of component for remaking vehicles per year and a examination base for 500 vehicles per year. And four centers for improving technical level of CNG vehicles and technical service are concern with following areas: technology development, technical training, technical consultation, and information exchange. Total investment of these projects is about 15.7 million yuan, and seles income is 19.6 million yuan per year. So investment payback period is 4.3 year.

China emphasizes the introduction of advanced foreign technologies and the technical and commercial cooperation with foreign partners in the production of CNG vehicle refueling compressors, conversions and light cylinders; the development of key techniques including diesel/gas dual fuel vehicle conversions; and the construction and management of local NGV projects.

With the support of relevant government agencies and cooperation of foreign organizations, the NGV industry will grow rapidly in China. Meanwhile, Chinese experts will be pleased to collaborate with their partners around the world and made a great contribution to the development of NGVs.

Compressed Natural Gas Vehicles Motoring Towards a Green Beijing
(Draft)

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Abstract

This paper first describes the state-of-the-art of compressed natural gas (CNG) technologies and evaluates the market prospects for CNG vehicles in Beijing. An analysis of the natural gas resource supply for fleet vehicles follows. The costs and benefits of establishing natural gas filling stations and promoting the development of vehicle technology are evaluated. The quantity of GHG reduction is calculated. The objective of the paper is to provide information of transfer niche of CNG vehicle and equipment production in Beijing. This paper argues that the development of CNG vehicles is a cost-effective strategy for mitigating both air pollution and GHG.

Key Words: Fuel substitution, GHG mitigation, Cost-benefit analysis

I. Introduction

China plays an important role in the global economy with the world's largest pollution and third highest energy consumption. China has 1.25 billion people and 270 million households. The annual growth rate of Gross Domestic Production (GDP) from 1980 to 1995 was up to 10%, and GDP in 1995 reached Yuan 5,760 billion [US$ 6,930 billion (1995 price)] (Li, 1996).

China is also the third largest emitter of carbon dioxide (CO_2). China will likely become the largest CO_2 emitter within the next thirty years, if effective measures are not taken to mitigate emissions.

Beijing, the capital of China and one of the world's famous historical and cultural cities, is suffering from air pollution, mainly caused by coal burning and vehicle emissions[1]. In a bulletin issued by the United Nations, Beijing was listed as one of the ten worst air-polluted cities in the world. Pollution emissions are 10 times higher than those of the world's average (Hu, 1993).

Of all human activities, driving motor vehicles produce the most CO_2 emissions and other toxic gases. A single tank of gasoline releases 140 to 180 kilograms of CO_2 (ICLEI, 1993). However, compressed natural gas releases about one quarter to one third less CO_2 than petroleum fuels. Some of the noxious emissions are even less than this. If supplies are available, Beijing can help reduce CO_2 emissions and other harmful substances by promoting the substitution of natural gas for gasoline in vehicles.

In order to deal with the environmental problems in Beijing, various environmental conservation measures or strategies are being considered. One of these possible strategies is to convert Beijing's fleet of about 70,000 vehicles used in Beijing fleet, including taxi, buses, postal cars, and the cars used by environmental and sanitary sectors and by Beijing transportation companies[2], about 10 percent of the total vehicles in Beijing from gasoline to CNG. The China North Vehicle Research Institute (CNVRI) has carried out research and a pre-feasibility study on the project. The study shows that if Beijing wants to retrofit all the fleet as a pilot project, Beijing needs 35 natural gas filling stations, each of which distributes 500 cubic meter gas per hour and can supply natural gas to at least 200 vehicles. CNVRI also thinks that building a CNG vehicle research center is necessary to provide technical support to CNG vehicle development.

This paper describes the history of CNG development in China, and analyzes the advantages and barriers of promoting CNG vehicles in Beijing. This information provides a basis for understanding possible paths in the evolution of CNG vehicles in China. It can

[1]Relevant data indicated that the stone carved balustrades in the Imperial Palace have been corroded by acid rain in the recent 40 years more than they had been over several hundreds of years.
[2]Sanitary trucks: 1897; Trash delivery trucks: 4813; Buses: 4390; Taxies: 55993; Minibuses: 3500; and Postal vehicles: 606.

also serve foreign investors wishing to better understand the Chinese CNG vehicle market.

II. Urgency of Developing CNG Vehicles in Beijing

China will produce a large number of cars in the near future. In its Ninth Five-year plan (1996-2000) and 10-year plan, the Chinese government has listed the automobile industry as a key component of its industrial growth. Within the next thirty years, according to China's national policy, most of its 270 million households will each have one car. In Beijing alone, about 6 million cars will be added to the city, if every family buys a car.

The increase in cars on a large scale will bring serious environmental challenges. In 1995 in Beijing, 800,000 automobiles daily produced 24,000 tons of CO_2, 320 tons of hydrocarbons, 12 tons of oxides of nitrogen (NO_x), 67 tons of non-methanol carbide, 24 kilograms of benzene and lead. (Guo, 1996). If there is no improvement in vehicle technology, after thirty years automobiles in Beijing will produce as 7 times as in 1995, i.e., 168,000 tons of CO_2, 2240 tons of hydrocarbons, 84 tons of NO_x, 469 tons of non-methanol carbide, and 168 kilograms of benzene and lead, or, in total, 169,800 tons of mixed emissions a day. Under this scenario, people have come to realize the need to re-evaluate the traditional development mode and to seek a way to develop more sustainably. It is for this reason that CNG cars have been developed in recent years.

The Chinese government and the Beijing government have made great efforts on environmental protection. The Chinese government has issued policies to control emissions from vehicles. During the past decade, about nine nation wide comprehensive regulations and standards for vehicle's energy saving and emissions were made or are under development. See Table 1. In its overall planning, Beijing has emphasized the importance of early planning, early implementation and promotion of environmental conservation.

Table 1

Laws and Regulations on Saving Energy and Standards for Gases Emitted from Vehicles

Title	Status	Implementation Schedule before 88	89	90	91	92	93	94	95	96	After 97
1. Law for environmental protection of PRC	under implementation		×								
2. Law for atmospheric pollution protection of PRC (revised version)	under implementation								×		
3. Law for energy conservation of PRC	under consideration										×
4. GB-4352-84 national standard for fuel consumption for driving trucks	under implementation	×									
5. GB-4353-84 national standard for fuel consumption for driving passenger vehicles	under implementation	×									
6. GB 14761.1-7-93 1 National standard for light vehicle emission pollutants	under implementation							×			
2 National standard for gasoline powered vehicle emission pollutants	under implementation							×			
3 National standard for gasoline powered engine fuel evaporative pollutants	under implementation							×			
4 National standard for motor vehicle crankcase emission pollutants	under implementation							×			
5 National standard for motor vehicle emission pollutants at idle speed	under implementation							×			
6 National standard for diesel powered vehicle emission smoke under free accelerating mode	under implementation							×			
7 National standard for diesel powered vehicle emission smoke under full load mode	under implementation							×			
7. Management measures for protection of waste gases exhausted by vehicles in Beijing	under implementation		×								
8. Tentative management measures for protection of waste gases exhausted by vehicles in Tianjin	under implementation			×							
9. Management measures for tax of vehicles with higher oil consumption	under consideration										×

III. Main Advantages and Disadvantages of Natural Gas as a Fuel

The Chinese government has been taking various measures to develop electric vehicles, engine emission-purification technology, and use alternative fuels. Different kinds of vehicles have different advantages and disadvantages.

Developing electric cars is a good way to reduce vehicle tailpipe emissions, but at present, the cost is very high. In addition, electric vehicles consume a large amount of electricity. This makes it difficult to promote electric cars on a large scale in Beijing because it is currently suffering from power shortages. In June 1994, Beijing needed 3,200 megawatts of power but could only get 2,754 megawatts. The city was short of power supply by 6.2% (Yang and Yu, 1996).

Another possible solution is to add accessories to gasoline burning vehicles to increase efficiency and hence reduce emissions. This alternative is not expensive, but its effect is very limited.

Alternative fuels for vehicles include compressed natural gas and liquefied petroleum gas (LPG) vehicles. LPG is an important chemical material in China. Current LPG supplies are limited in Beijing and it cannot be widely used as a vehicle fuel.

Compressed Natural Gas is natural gas compressed under normal temperature in a high-pressure container. The technology is simple and mature. It has a popular choice for countries around the world to reduce car pollution.

Natural gas cars are of two main types: 1). Modified natural gas cars that are made by refitting the existing cars with a cylinder and some other parts. They use both gasoline and natural gas and are controlled by a change-over switch. The driver decides whether to use gasoline or natural gas; 2). Specially-designed CNG cars using natural gas as fuel. Natural gas cars are filled at CNG filling stations. CNG stations can be built either beside a gasoline station or on their own.

CNG cars can be a part of a green city program. The octane value in natural gas ranges from 110 to 130. Thus, a high heat efficiency (11,000 kilo calories per cubic meter) can be obtained. The percentage of methane in natural gas ranges from 83% to 99%. Compared with gasoline, CNG can be combusted more completely with little pollution. By using natural gas rather than gasoline, carbon monoxide is reduced by 97%, hydrocarbon by 72%, NO_x by 39%, and CO_2 by 25%. If Beijing could retrofit all its fleet to CNG, CO_2 emission will be reduced 42,000 tons a day in 2025.

Natural gas contains no benzene or aromatic hydrocarbons, and thus there are fewer such harmful emissions from natural gas-powered engines. The ignition temperature of CNG is 650° Celsius, much higher than gasoline's 417° Celsius. So, using CNG as fuel is safer than gasoline.

Natural gas sources are abundant in Beijing. According to Mr. Shi Bao-Hen, the director of New Technology Development Bureau of China General Oil-gas Company[3], the North China Oil-field can supply Beijing with 400,000 cubic meters of natural gas. However, Beijing can only consume 380,000 cubic meters. Beijing does not have sufficient infrastructure to send the gas to households or other consumers. Compared with coal,

[3]A speech at the Preparation Meeting of '96 Beijing International Electric and Alternative Fuel Vehicle Exhibition at the beginning of November 1996.

natural gas is expensive. Beijing utility does not have policy to use natural gas as primary energy in power plants.

There are two pipelines transmitting sufficient natural gas from the North China Oil Field to Beijing. The first pipeline has daily transmission capability 800,000 cubic meters. It now transmits 400,000 cubic meters of natural gas into Beijing a day with pressure of 14 - 18 kg/cm^2, so it has much surplus capacity. The second transmission pipeline has capability of transmitting 300,000 cubic meters a day. It now transmits 110,000 cubic meters per day with transmitting pressure 6 to 8 kg/cm.

Although natural gas is abundant in Beijing, the Beijing government still plans to transmit more natural gas to Beijing. There are two reasons for this. First, in West China, there are rich natural gas reserves which can supply cheaper natural gas to Beijing. Second, the Beijing government plans substitute natural gas for coal and oil consumption in Beijing to mitigate air pollution. Consequently, more pipelines are under construction from West China to Beijing. From 1997, each year North Shan-xi province will transmit 700 million cubic meters of natural gas to Beijing. Natural gàs supply should be sufficient for a CNG vehicle program.

The main disadvantages of CNG vehicles are the increase of the weight of the vehicles and decrease of the available space. Since CNG tanks work under high pressure, they should be made of thick steel plate. The tanks are heavier than gasoline tans. Further more, retrofitting gasoline vehicles needs the addition of the CNG tans in the vehicles. These CNG tanks needs some space which were used for cargo or passengers.

IV. CNG Vehicle Development in China

In 1988, Sichuan Petroleum Administration Bureau (SPAB) made the first introduction of advanced technology from New Zealand to experiment on CNG cars in China. SPAB carried out a feasibility study on using CNG vehicles in China, and imported a CNG filling station, equipment for retrofitting buses, and gas containers. On the basis of the imported technology, SPAB developed its own CNG vehicle technology, and CNG vehicles are widely used in city transportation in Sichuan Province.

In 1991, supported by the State Planning Commission, Xinjiang Autonomous Region worked on developing natural gas cars. The national government and Xinjiang local governments sponsored the project. Spare parts for 300 vehicles were purchased and 400 cars were refitted in 1995. To support the development of CNG cars, the Xinjiang local government issued a special policy to promote the development of CNG vehicles in 1995: all the refitted CNG cars will not be charged for using express-ways for one year.

Since 1992, the China Auto Industry Corporation and China Petroleum-Gas Corporation have held many seminars on the application of natural gas technology to cars. According to the experience of developing natural gas vehicle, the China Petroleum-Gas

Corporation made a strategy for CNG development: "Importing advanced CNG technology, producing CNG vehicles domestically". This means that the Chinese will import not only equipment, but also production technologies in CNG vehicle development.

In 1992, coordinated by the State Planning Commission and Beijing Science Commission, the Beijing Natural Gas Company, Beijing Public Transportation Institution, and funded by Daqing Petroleum Administration Bureau, Beijing government carried out a CNG demonstration project. The project included setting up a gas filling station and retrofitting 27 buses. TFS company from New Zealand provided 50 sets of spare parts. However, due to the lack of domestic R&D and technologies to support the project, the project was not sustainable.

On October 18, 1993, Ms. Wu Yi, the Minister of the Economy and Commerce, paid an official trip to New Zealand. She visited a firm producing refit parts for CNG cars and discussed the possibility of introducing the technology into China. In October, 1994, some departments of the Ministry of Economy and Commerce held a conference attended by Chinese and foreign personnel. The objectives of the conference were to introduce advanced CNG technologies and look for opportunities for the Chinese to cooperate with foreign counterparts for CNG vehicle development in China.

In 1995, at the 17th annual conference of the "New Zealand - China Joint Trade and Economical Commission", attended by the Ministry of Foreign Economy and Commerce of China and the Ministry of Foreign Affairs and Trade of New Zealand, the Chinese party put forward 4 proposals for cooperation with New Zealand to develop CNG cars. The main points include: (1) China and New Zealand would form a joint venture to promote CNG vehicles in China; (2) New Zealand would help China to build a pilot station in Beijing; (3) The joint venture would establish a maintenance service center in Beijing; (4) The joint venture would carry out the project of retrofitting diesel vehicles to CNG vehicles.

So far, there are many CNG vehicle programs in China, but the work on CNG cars has been largely concentrated on the experimental programs of technology, such as the refitting of engine-driven vehicles and the installation of filling station equipment. Such work as comprehensive study on the cost-benefit, fuel supply, best selection of technology, the raising of funds, safety standards and regulations has not begun yet.

V. Barriers to the Development of CNG Vehicles in Beijing

There are several barriers blocking the development of CNG vehicles in Beijing: lack of public awareness of CNG vehicles, capital shortages, and lack of advanced technologies. The Chinese normally think that a CNG container with high pressurized natural gas in a car is like a big bomb which is likely explode at any time. Drivers are reluctant to have their cars installed with the container, and passengers do not like to take the "risk".

Developing CNG vehicles requires establishing re-filling stations and retrofitting vehicles. This needs a large amount of capital investment. In order to raise capital on a large scale for CNG project, a special support or policy for CNG development is required.

Throughout the development history of China's CNG vehicles, China has not had the capability to produce reliable and sufficient equipment used in CNG vehicle development.

VI. Cost-Benefit Analysis for the CNG Vehicle Project in Beijing

China North Vehicle Research Institute (CNVRI) has carried out a pre-feasibility study of developing CNG vehicles in Beijing (Guo, 1996). Since the CNG vehicles are supposed to substitute for gasoline vehicles, all the economic and technical data are about the CNG and gasoline vehicles. In order to simplify our analysis, we only analyzed the cost-benefit of setting up one CNG filling station on a large scale..

6.1 Capital Investment

The capital investment of one station comprises the cost of purchasing a compressor, setting up a filling station and retrofitting 200 vehicles[4].

The investment for a compressor and other accessory equipment with the capacity of 500 cubic meters per hour, including installment and training expenses, is US$ 220,000, or about Yuan 1.83 million (1 US$ = Yuan 8.3).

The cost for retrofitting a vehicle ("Jiefang" model heavy-duty lorry) is US$ 1,450 in total, of which US$ 1,000 for two 90-liter cylinders and US$ 450 for other spare parts and labor cost. Retrofitting 200 vehicles will cost US$ 290,000. Therefore, total capital investment for establishing a CNG filling station and retrofitting 200 vehicles will amount to US $ 510,000.

We assume that total investment will be finished in two years evenly. Cash flow in capital investment is negative US $ 255,000 in both year one and year two.

6.2 Operation and Maintenance Cost

Operation and Maintenance (O&M) cost consists of three parts: cost for labor, cost for spar-parts, and cost for daily management including utility bill and water bill.

[4]In the following calculation, we do not include the investment of the land to be used by setting up the filling station. There are two reasons for that: 1). The land for one filling station is available now in Beijing; the investor does not need to spend money in it; 2). Even if capital is required in buying the land, land in Beijing is increasing its value all the time. In other words, depreciation of a piece of land is at least zero, or even negative. So, ignoring land investment is quite conservative in our analysis.

Wages and benefit for one worker is about 800 Yuan (1996 price) per month. One station needs three shifts with 4 people in each, totaling 12 people. Therefore, total labor cost for one station in one year will be Yuan 115,200 or US $ 13,000.

We suppose that the cost for spare-parts is 5% of total capital investment of the CNG filling machine and the spare-parts for retrofitting the 200 lorries, or US$ 25,500 each year.

According to Guo (1996), water and electricity bills for one station may amount to Yuan 81,000 or US$ 9,759 each year.

In sum, total operation and maintenance cost for one CNG filling station and the 200 trucks will be US $ 48,259 per year.

6.3 Savings

Basic assumptions: Heat value of one cubic meter of natural gas is equivalent to 0.86 kilogram gasoline. The sale price of one cubic meter of compressed natural gas is Yuan 1.3. The sale price of one kilogram gasoline is Yuan 2.2.

Calculation: Project savings come from fuel consumption. Daily consumption of gasoline for a Jiefang truck is about 42 kilograms. The expenses for gasoline are therefore about Yuan 92.4 a day. The retrofitted truck will consume 48.9 CNG M^3/day, so the expenses for the CNG are about Yuan 63.57/day. Daily saving from a retrofitted truck will be 36.42 Yuan. If a truck is used 300 days a year, total saving from 200 trucks in one year will be 1.73 million Yuan, or US$ 208,409.

6.4 Cash Flow and Economic Analysis

The following are supposed in our calculation:

1. The viability of the project is 20 years;

2. At the end of year 20, the savage value of the project is 10 percent of the total initial capital investment, i.e., US$ 51,000.

3. All the prices are in 1996 constant.

4. The tax rates for gasoline and natural gas per Btu are the same.

5. We made two scenarios in our calculation, with discount rate (r) equal to 5% in scenario one and 10% in scenario two.

Under the above assumptions, we calculate cash flow of the project. See Figure 1.

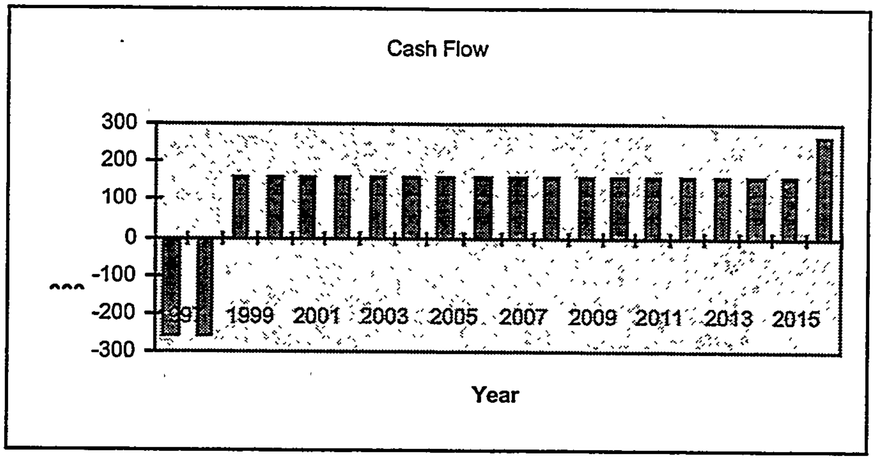

Figure 1. Cash Flow of the Project

NPV and Payback Period Calculations for Scenario One

Under scenario one, NPV of the project is US$ 1,950,530. We also calculated the payback period of the project under scenario one. It is about 4.5 years[5]. See Figure 2 (r stands for discounted rate).

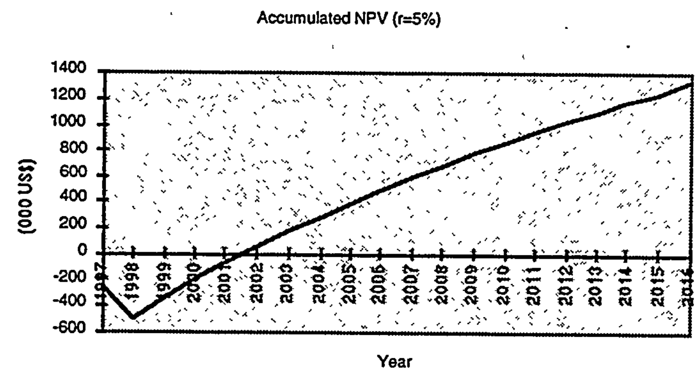

Figure 2. Accumulated NPV under Scenario No. 1

NPV and Payback Period Calculations for Scenario Two

Under scenario two, NPV of the project is US$ 1,134,330. The payback period of the project under scenario two is about 5 years. See Figure 3 (r stands for discounted rate).

[5]Due to the establishment of CNG station, the work load of current gasoline filling stations will be released. Equivalently, the investment of a gasoline filling station can be saved because of the new CNG filling station. In our analysis, we do not include the savings for stetting up and running a gasoline station for filling the 200 lorries in the projected 20 years. If we did so, the NPV would be much higher and the payback period will be much shorter.

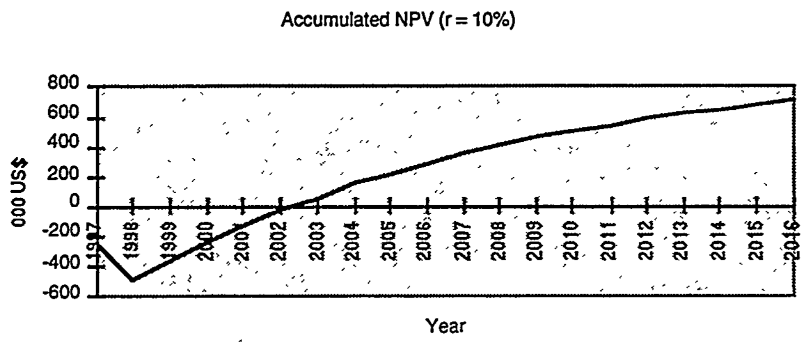

Figure 3. Accumulated NPV Scenario No. 2

6.5 GHG Mitigation from the Project

1. *Calculation of total possible emissions from the gasoline-powered lorries*

   As discussed in the previous section, a Jiefang truck in Beijing usually consumes 42 kilograms gasoline a day, and the truck is used 300 days a year. In 20 years, two hundred trucks will consume 50,400 tons of gasoline. According to IIEC and INET (1996), each ton of gasoline will emit 3.10 tons of CO_2. Total CO_2 emission from the 200 trucks in the 20 years would be 156,240 tons.

2. *Calculation of mitigation of CO_2 emissions by retrofitting the trucks*

   According to USDOE (1996), natural gas produces about 75 percent of the CO_2 emissions of gasoline per Btu. We assume total Btu consumption for the trucks are the same before and after being retrofitted, then total CO_2 mitigation due to the project will be 39,000 tons.

As well known, the natural gas contributes greenhouse gas effect as about fifteen times as CO_2 does. Because of data shortage, in our calculation, we do not consider the leakage of natural gas due to the use of CNG vehicles. However, we ensure that there will be not much natural gas leakage in natural gas transmission and distribution related to the project, because all natural gas pipelines are well designed and constructed in deep underground, and Beijing will use advanced CNG technologies such as those from New Zealand and Italy in CNG filling stations.

VII. Conclusions

Due to its large population and fast economic development, Beijing may have more than 7 million cars in the next thirty years. If all these cars are powered by gasoline, 210,000 tons of CO_2 will be emitted daily.

The Chinese and Beijing governments pay much attention to mitigating vehicle emissions. Various laws and standards were issued to minimize emissions. In order to facilitate a CNG project to be conducted by the China North Vehicle Research Institute in Beijing, we have carried out a cost-benefit analysis for the project. Our main conclusions are as follows:

- Investing US$ 510,000 in the first two years will gain profit of US$ 725,220 with discounted rate of 10% or US$ 1,339,650 with discounted rate of 5% in the following 20 years. The payback period of the project is between 4.5 and 5 years depending on different discount rates between 5% and 10%.

- By investing US$ 510,000 and setting up a CNG filling station, 3,906 tons of CO_2 will be reduced, or in other words, investing one dollar will reduce 7.85 kg of CO_2 from the project.

- All the above analysis and conclusion are on the basis of setting up one CNG filling station and retrofitting 200 lorries. As mentioned earlier in this paper, Beijing has a huge market for CNG vehicle business. To feed 10% of the 700,000 vehicles in Beijing needs 350 CNG filling stations, total investment for all the stations and retrofitting vehicles will amount to US$ 178.5 million, and total CO_2 mitigation potential will be 1.3671 million tons.

Developing CNG vehicles is a win-win-win proposition. A company can make profit of it. Beijing can make use of its abundant natural gas and save gasoline. CNG vehicles will mitigate pollutants not only globally but also locally. Improved environmental quality from CNG vehicles substituting for gasoline vehicles benefits everyone. CNG vehicles can motor Beijing towards a green city.

Acknowledgment

Acknowledgment is due to the US DOE (Department of Energy) and the US EPA (Environmental Protection Agency) for providing financial support for this research. The authors wish to thank Mr. Steve Meyers of Lawrence Berkeley Laboratory in California and Ms. Kristina Egan of IIEC for their comments on this paper.

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STRATEGIES FOR DEVELOPMENT AND CO2 ABATEMENT IN CHINA'S POWER INDUSTRY

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Prepared for

International Workshop on Greenhouse Gas Mitigation Technology Measurers
Beijing, China
12-15 November, 1996

Abstraction: Chinese Government has set a series sustainable energy development policies and strategies to alleviate atmospheric pollution and to mitigate the CO2 emission. Some major policies and measures that will be emphasized in China's power industrial development will be addressed in this paper.

After UNCED of 1992, Chinese Government has raised "10 environment and development strategies of China" and "China's Agenda 21", and has set on a series sustainable energy development policies to support the implementation of FCCC, to mitigate the CO2 emission, and to alleviate atmospheric pollution.

Along with the increase of the population and the boost of economy, energy demand has been increasing continually in China. But on the other hand, with a large population, China is a country the energy resources per capita correspondingly deficient. Therefore, it is necessary for power industry, known as the core of China's energy industry, to change its way of development, from the traditional extensive production to a intensive and resources efficient production, a way consistent with prevention of pollution reduction and CO2 mitigation.

1. Current Situation of China's Power Industry

Since China's economic reform, power industry has launched into a fast development period, high growth rate of installed capacity and power generation is kept. By the end of 1995, national installed capacity reached to 217 GW and annual generation 1006.9 TWh, ranking third and second respectively in the world. In the meantime, the policy to lay equal emphasis on both energy production and energy conservation has been pursued, the principals of environmental protection and CO2 abatement have been stipulated in power industrial planning, some have been put into implementation.

a) Make efforts on improving resources composition of power generation, give priority to develop hydropower, nuclear power and renewable power generation. By the end of 1995, installed hydropower capacity 52.18 GW, shares 24% of national installed capacity. Three Gorge Hydropower Station with total capacity 18.20 GW has been under construction since 1994. Qinshan Nuclear Power Station with 300 MW and Daya Bay Nuclear Power Plant with 1800 MW have been put into commercial operation successively, declared an end to the history of no nuclear power generation in mainland

China. And currently, about total 40 MW wind turbines have been in operation in remote areas.

b) From the "8th Five-Year Planning" (beginning in 1991), in new built coal-fired power plant, most units are the units with capacity 300 MW and over and high steam parameters, the construction of small-size and high fuel rate condensing units is under strict restriction.

c) Strengthen the renovation of old thermal units, raise the energy efficiency of existing thermal units. Recent years, over 150 units with mid or low steam parameters have been replaced by large-sized and high-parameters units; near 50 units with unit size 200 MW have been renovated, increasing availability about 6% and raising generation capacity about 850 MW. During last five year, gross fuel rate of thermal power plant decreases by about 15g/kWh, corresponding to reduce coal consumption over 14 Mt and CO_2 emission 20 Mt, results significant economical and environmental benefits.

However, China's power industry now still can not fully satisfy the requirement of social-economical development as well as peoples' livelihood improvement. In 1995, installed capacity and electricity generation in per capita was 0.18 kW and 815 kWh respectively, only about 6% and 6.5% of that in US in 1993. In addition, there are still 16 counties with 90 million population with no electricity supply. Speeding up the development of China's power industry will be a task in a long period.

2. Strategies For Development And CO2 Abatement in Power Industry

In 1995, coal consumption for power generation was over 430 Mt, taking first position. In is estimated that by the year 2000, coal consumption will reach to 620 Mt as installed thermal capacity will reach 220 GW, CO_2 emission will increase unavoidably. Therefore the tasks to curb pollutant emission and promote the power industry into a environmental sound development mode are more arduous now than ever before, the major policies and measures will be emphasized include:

a) Persist in "laying equal efforts on both energy production and energy conservation", and "equally stressing the development of both hydropower and thermal power", and appropriately develop nuclear power, optimize the generating source mix and utilize energy resources rationally. It is planned that by 2000, installed capacity of hydropower will amount to 70 GW, new built nuclear capacity 6~8 GW, and total capacity of wind turbines 100 GW.

b) Change power industrial development and management from extensive to intensive mode, improve generating efficiency and reduce the fuel consumption. The mainly option of new built thermal turbo-generator should be the units with high steam parameter, high efficiency, and unit size 300 MW and over. The renovation of existing units will be speeded up, by 2000, about 8 GW mid-and small-sized units which are old, low efficient, high polluting will be forced to retire or renovated, this will reduce, in average, 34g/kWh of fuel rate nationwide. And to curb the loss in power transmission and distribution, the construction and retrofit of power grids will be strengthened

c) Make efforts on developing clear-coal technologies, build IGCC and PFBC demonstrating projects to cumulate experiences for greater strides in development of advanced thermal generation in next century. And to develop natural gas (including LNG) based, high efficient combined combustion units appropriately.

d) Introduce DSM by training and pilot projects, and disseminate this method and make it more active in China's energy conservation and energy management.

e) Speed up the implementation of "green-lighting" programme, make endeavors to realize the goal of decreasing 20% electricity consumption for lighting, that is annual saving 30 TWh, about yearly electricity generation of 6000 MW thermal capacities and 15 Mt coal consumption.

f) Increase the international coloration on environmental protection of power industry, encourage technical exchanges and personal training, and import some pollution controlling technologies which are suitable specific situation of China. We are going to seek, from foreign governments and international funding, more mid- and long- term loans for a group of comprehensive projects, which will benefit to energy efficiency and CO2 mitigation.

China as a developing country, insufficiency of power supply will be a bottle neck of social and economical development in a rather long period. In the coming decades, China's power industry will keep rapid growth, in the same time, China power industry will modify his way towards sustainable development, the policies and measures mentioned above will be insisted on industriously. On the other side, we hope that the developed countries will fully implement commitments and responsibilities stipulated by the UNCED and FCCC, to provide financial and technical supports to developing countries (including China), to enable them to adopt environmental sound technologies, especially energy efficient technologies, and enhance their capabilities to address climate change. We will join international efforts and make contributions in protection of the earth, our common home.

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CO_2-Mitigation Measures Through Reduction of Fossil Fuel Burning In Power Utilities.

Which Road To Go?

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PART I

Introduction

All fairy tales begin "Once upon a time ..." and end "... happily ever after". CO_2-mitigation projects, to the contrary, start out gloomily (They do not exist as such) but also end on a happy note; despite their non-existence, most of them are highly economical.

Within the context of this paper, and elsewhere, the term "CO_2-mitigation project" is used for convenience, but this is really a misnomer. Very few people in the private sector would actually be patriotic enough, or responsible enough "world citizens" to invest in activities for the sole purpose of reducing CO_2 and other emissions causing the "greenhouse-gas effect". The truth is, there are financially attractive private and public sector investments which, as a welcome side effect, reduce CO_2-emissions. These we refer to as CO_2-mitigation projects, as if by design.

If "CO_2-mitigation projects" are defined as common investments with this specific side effect, it is obvious they have existed since humans started burning fuels.

For the investor, whether private or public, financial viability is a necessary, but not totally sufficient, requirement for any CO_2-mitigation project. Since the primary motivation for investment is profit, and the environmental benefit a bonus it is not enough for a national emission reduction plan to merely encourage private sector investment at random.

Options must be compared thoroughly. Financial attractiveness is only one indicator (and a poor one at that) for a successful national CO_2-mitigation program. Furthermore, it says nothing about the overall impact and social/logistical problems of implementing the project.

Five conditions, at minimum, should be examined in the comparative analysis of CO_2-mitigation options for the power sector.

Under the continuing constraint of scarce financial resources for any private or public investment in the power sector, the following combination of requirements characterise a successful CO_2-mitigation project:

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1. Financial attractiveness for private or public investors.
2. Low, or even negative, long range marginal costs (LRMC) per ton of "CO_2 saved".
3. High impact on CO_2-mitigation, which indicates a large market potential for the measure.
4. The number of individual investments required to achieve the impact is relatively small. In other words, logistical difficulties in project implementation are minimised.
5. The projects are "socially fair" and have minimal negative impact on any segment of the society.

This paper deals with options to reduce carbonaceous fuel burning in the power sector. Part I explains how projects should be selected and classified. Part II describes the technical options. Since reduction of carbonaceous fuel burning may be achieved through Demand Side Management (DSM) and Supply Side Management (SSM) both are treated. Within the context of this paper SSM does not mean to expand power supply as demand grows. It means to economically generate and distribute power as efficiently as possible. By DSM we also refer to the mostly forgotten original meaning of DSM:

> "The planning and implementation of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape."(Gellings)

In too many instances DSM has degenerated into efficient lighting programs and utility managed incentives and rebate programs. To what extend this is a desirable situation for utilities in Developing Countries that face totally different problems as their counterparts in highly industrialised countries remains to be seen. Which road to go is the topic of this paper.

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1. Diversification and CO_2 mitigation projects

The term *diversification* is typically used in the context of reducing a firms risk to changing market conditions. The term also makes sense when talking about our environment and preserving the genetic pool of "mother nature". In both cases it is a necessity of survival to diversify or keep diversifying.

Just talking about the need for diversity of CO_2-mitigation projects in the supply side and demand side sectors of power generation is a luxury we certainly cannot afford, given the finite amount of financing and human resources to accomplish the objective.

The argument for diversification, as manifested in a long list of possible *Supply Side Management* (SSM) and *Demand Side Management* (DSM) measures, suggests that *Joint Implementation* (JI) projects may at best be compared based on their financial/economic as well as commercial viability, with no regard whatsoever for how to avoid *High Cost / Low Impact* measures (HCLI). One may conclude that it is essential to compare financially attractive CO_2-mitigation options based on an expanded set of parameters to avoid an ever increasing greenhouse gas problem caused by highly successful HCLI measures.

In the JI business it is less important what has been done in this field than what has not been done and why.

2. How do we compare?

In the next paragraphs an expanded set of criteria how to judge the merit of these projects will be presented.

2.1 Future economic costs of "tons of CO_2 saved"

One effective and understandable parameter is the future average economic costs of "one ton of CO_2 saved". Calculating this parameter is the same as calculating future average economic costs of one kWh of electricity. The method is standard and given only as reference.

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Future average economic costs are equal to the *long range marginal costs* (LRMC) in our case.

$$LRMC = \frac{\sum_{i=0}^{n} \frac{C_i}{(1+d/100)^i}}{\sum_{i=0}^{n} \frac{T_i}{(1+d/100)^i}}$$

Where d = discount rate
C_i = costs in the year i, either total resource costs or utility costs
T_i = tons of CO_2 saved in the year i
n = observation period (15 - 30 years)

"Tons of CO_2 saved" is not yet a good or bond bought or sold widely, or listed on Wall Street. Some may therefore object to discounting a fictious good. However, discounting "tons of CO_2 saved" has a very educational effect: Bad projects become even more evident, while the attractive ones look even better on paper. Try it out. A proposal with a negative LRMC becomes even more negative when divided by a smaller number, while a large positive LRMC becomes even larger if divided by a smaller number. In the literature other definitions such as "levelized costs" and "cost annuities" as well as LRMC (type 1) and LRMC (type 2) are found. These definitions are derived special cases of the above most general equation.

2.2 Rate your own understanding about project selection

Recall the project objective: "Reduction of carbonaceous fuel consumption in power generation". Consequently all SSM and DSM projects are included. For the sake of comparison assume that you have four proposals and all four are financially attractive for the implementor (the utility, or the end user, or both). Figure 1 shows the LRMC and impact. Remember we have already dealt with the issue of financial attractiveness, all four options are assumed to be highly attractive for the implementor! The projects have equal areas which means total resource costs are the same, except for the sign, and shape. Selection depends on your personal understanding about the right strategies for promoting CO_2-mitigation projects in the SSM and DSM sector.

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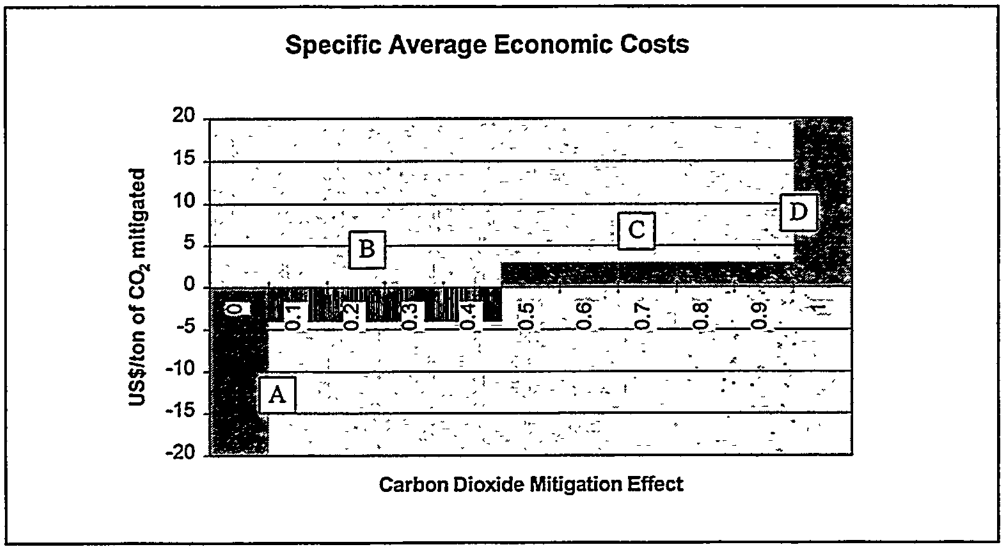

Figure 1: Comparison of LRMC for major type of options

Your options are:

a) *Do nothing, reject all proposed projects because they are financially attractive and the power sector and end user should invest anyway.*

You believe in free market forces and argue that whatever is financially attractive is automatically pursued by the utilities or the end-user of power.

However, there is more than circumstantial evidence to suggest that when it comes to investments in this area, the end user, as well as the utility try to minimise investment costs and don't look into life cycle costs. This decision also implies that your preference is to support uneconomic CO_2-mitigation measures that require subsidies (incremental cost reimbursement).

b) *Project A*

This project has very attractive LRMC costs because the "costs" are negative. This means society as a whole benefits. You hope that most people will not even notice that you have selected a project that looks good on paper but has a very marginal impact. Furthermore, by favouring A you may even harm CO_2-mitigation efforts because high impact options may be denied resources.

c) *Project B*

In terms of "high impact / least cost" measures this project has the best overall benefit.

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d) *Project C*

This option favours high impact measures, even if it may not be the lowest cost option.

e) *Project D*

This option is the least desirable and a typical "low impact / high cost" project. One justification is that you may strongly believe in diversification of CO_2-mitigation projects and testing of various options. Such projects are usually labelled "Pilot projects" because it is already clear at the project planning stage that the costs are high and the impact is marginal. The potential damage done by such projects is to report their "successes" and invite others to commit the same mistakes.

Some may object to this way of previewing projects because other factors such as project logistics, political will to implement, as well as finding the "right" implementation partners are certainly equally if not more important. However, in any rational decision making process we first pick the "winner" and than ask ourselves what other reasons there may be against implementation, and not vice versa. There is always time to reject the best solution and move on to the second best. However if you pick the losers from the very beginning you have missed an opportunity to do better.

2.3 Sustainable investment errors

Assume we see a certain urgency for CO_2 mitigation. Consequently one criterion is to select projects where we prevent sustainable investment errors.

One such sustainable investment error is the purchase of inefficient refrigerators. This investment decision cannot be reversed for the next 10-15 years because it is uneconomical to replace a refrigerator with a η-refrigerator.

A power plant with a low thermal efficiency (by design) is also a sustainable investment error for at least 20 years.

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One reversible investment error is incandescent light bulbs (ILB). About every 1-6 months a whole nation of ILB users must replace their ILB's. A project has ample opportunity to change consumer behaviour, at several points during the year.

Purchase of inefficient electric motors is another reversible investment decision. In most cases we could scrap a one day old motor and replace it with a η-motor that costs 20-50% more and still save.

Therefore, if you see a certain urgency for CO_2-mitigation, select projects that prevent sustainable investment errors, and put the others on the back burner because they will take 10 - 20 years to achieve a 50 - 100% market penetration.

2.4 "Instant" or "incremental success", and "business as usual"

JI projects may also be classified by to what extent they achieve an instant or incremental CO_2-mitigation effect, and what the impact is if they are not implemented.

Assume the objective is to save 10% of CO_2 emissions in a power generation system of 1000 MW(1- 50 power plants), that has annual sales of 5,256,000 MWh.

To achieve the effect one may either

- generate and distribute electricity at a higher efficiency, saving 10% of the fuel or
- lower demand by 10% at the end-user side without lowering quality of life or productivity.

Depending on the nature of the project, the 10% saving target can be achieved

- within 1 to 3 years of an observation period of 20 years ("Instant success").

  Example: The next investment in power plant and distribution system reduces fuel consumption by 10 percentage points.

- within a 20 year period ("Incremental success").

  Example 1: Improvement of thermal efficiency of generation and distribution system of existing power plant(s) over a 20 year period.

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Example 2: Initiate a CFL lighting program that will gradually reduce annual consumption for lighting from 0 to 525,000 MWh (= 10%) within 20 years.

You may as well do nothing. In this case it is interesting to calculate the impact of a "business as usual" scenario (= impact of missed project opportunity). In fact doing nothing is by far the most common decision in SSM.

The result of this exercise is given in Figures 2 and 3.

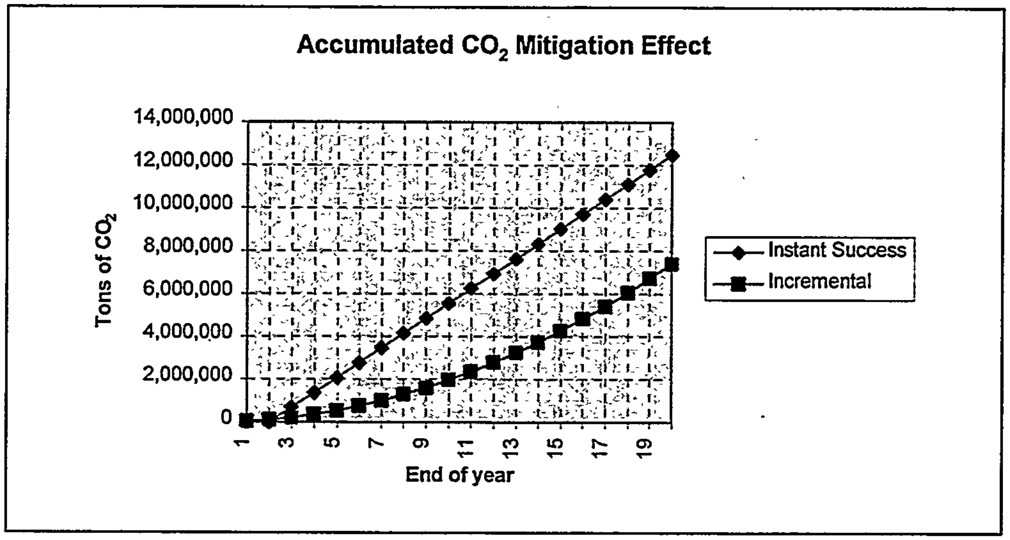

Figure 2: *Accumulated CO_2 mitigation effect based on "instant success" and incremental success scenarios.*

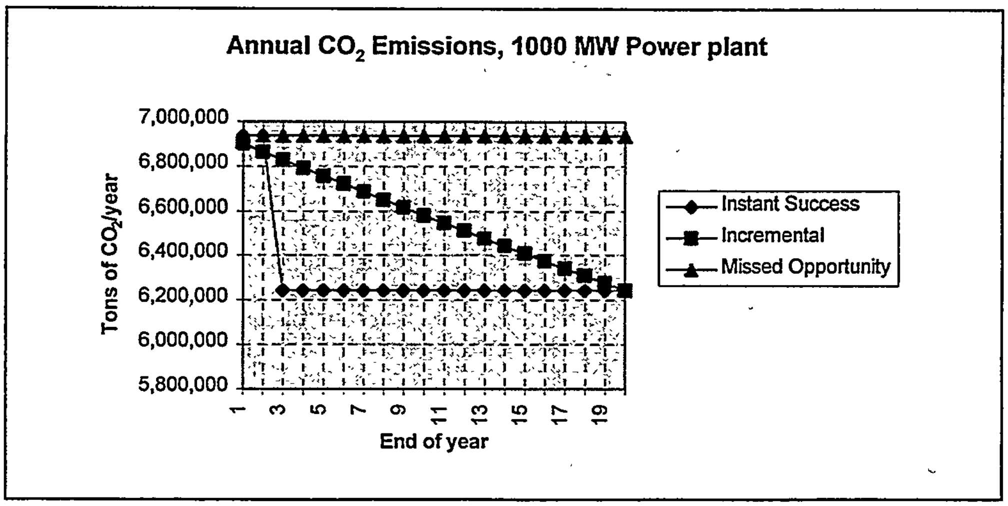

Figure 3: *Annual CO_2 emissions based on three scenarios.*

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Note:
- Power generation and distribution efficiency of 25%
- Fuel is coal with 60% carbon and a 'Higher Heating Value' of 24 MJ/kg as fired
- One kWh sold generates 1.32 kg CO_2
- Annual sales of 5,256,000 MWh
- Fuel burning reduced by 10 percentage points.

As shown the "incremental approach" attains only 60% of the CO_2-mitigation effect of the "instant success" approach.

3. Losers and winners

It would be naive to assume that all CO_2-mitigation projects in the power sector have only winners. Quite a few have also negative effects and there are also losers. To understand the issue we distinguish between projects that result in "lost revenues" and projects that result in "reduced costs".

For instance all economic efficiency-improvements under a SSM plan directly reduce costs, while all economic DSM measures result in "lost revenues". Although the trade mark of any DSM measures is always "lost revenues" that does not mean it is necessarily bad for the utility. It really depends on the financial situation and operation of the utility. However there is one scenario where SSM must prevail over DSM and all DSM measures would be extremely counter productive.

> **"A utility with very high generation and distribution losses, that cannot recover their costs, should never be involved in DSM activities."**

In such a case DSM measures are totally out of place and harmful.

4. A classification scheme

As pointed out, besides financial attractiveness a successful CO_2-mitigation project should also answer the questions

- Is the effect sustainable over 15 - 20 years?

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- Does it prevent non-reversible investment errors for the utility or end-user?
- Is the CO_2- mitigation effect as "instant" as possible?

A project that can answer all these questions with "yes" has certainly a higher priority than a project where all the answers are "no".

PART II

5. A real life example

It is not very helpful to calculate and compare CO_2-mitigation potentials of various SSM and DSM options by looking at the power and end-user sector of an entire nation. A more realistic and practical approach is to isolate a manageable say 50 MW segment of power plant capacity and their end-users. This approach will result in a comparison of project activities that would require investments of between US$ 200,000 and US $ 4 Million. This order of magnitude of financing is manageable and gives a more realistic view of what JI projects could do. By investments we mean total resource costs (TRC) for the project.

As an example a 50 MW "segment" of a coal fired power plant and the neighbourhood of consumers it provides with electricity was chosen. Coal was selected as a fuel, because despite all commendable efforts in the field of alternative and renewable fuels, we are again entering the "coal age" when it comes to future power generation in South-East Asia.

There are sound political, economic and rational reasons behind this emphasis on coal. Since it cannot be the purpose of this paper to look into the future beyond 2030, it is assumed that coal will significantly dominate the power sector, while oil and gas will stagnate or play a less important role, for the next 35 years to come, based on already planned power plant capacity extensions. What happens beyond 2030 is open for speculation and a matter of personal belief and opinion.

A typical example of a fairly good annual generation efficiency of 32 % (coal to HT power after the generator) followed by a significant distribution loss of 15 % (technical) is presented. The end-user profile is based on a typical mix of residential areas , commercial business and small industries in a tropical country.

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One may object to the high distribution loss of 15%, however this number reflects a very common situation in most developing countries where the increase in transmission capacity lags behind and is worsened by overloaded LV grids .

5.1 Interpretation of results

It is emphasised that the given example does not refer to extremely ambitious efficiency improvement schemes involving the latest or even experimental technology. All options are down to earth standard procedures and technologies one would recommend in such a case. We are therefore not talking about highly efficient fluidised bed gasifier power plants at 50% thermal efficiency or amorphous steel transformers that reduce standard D-transformer losses by 50%.

As shown in Figure 4 half of the CO_2 saving potential is at the generation and distribution side, while the rest is shared by various DSM activities.

- A very modest improvement of 3 percentage points at the generation side would already account for 35% of the saving potential. This is mostly achieved by better housekeeping measures
- Another 18% is accounted for by simple projects such as load balancing, power factor improvement and rewiring at the end-user side.
- Another 36% is accounted for by typical DSM measures such as efficient refrigerators, air-conditioners and replacement of ILB with FL lamps. Naturally mandatory minimum energy performance standards (MMEPS) have a big advantage over minimum energy performance standards (MEPS) or simple energy labelling programs.
- The rest such as replacement of ILB with CF lamps, highly efficient distribution transformers and E-motors are considered critical projects with little impact that should be considered last. A very special case are electric motors where it is very difficult to convince buyers to look into life cycle costs instead of first investment costs. Once the wrong investment decision was made there is little chance to revert it. In fact the situation in terms of efficiency worsens because low efficiency motors have a higher heat generation and less torque. Rewinding of the motor up to three times is one practical solution to the wrong investment decision.

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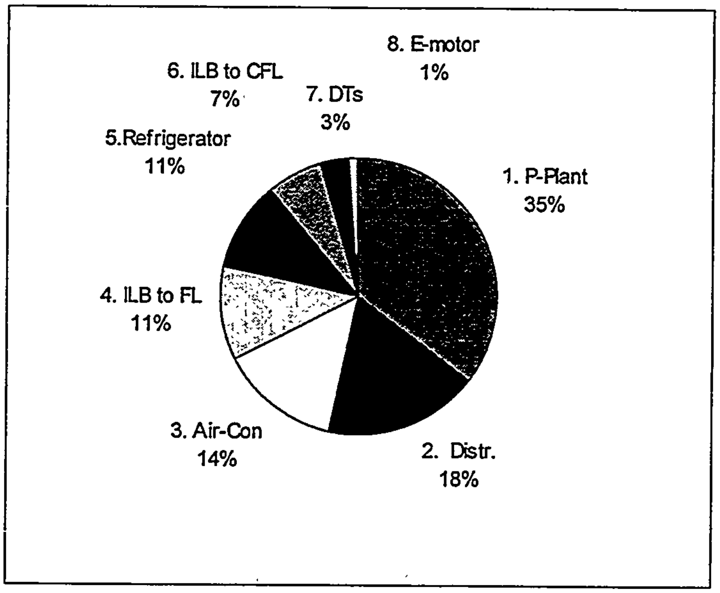

Figure 4: Contribution of various options to the total saving potential

Project	Initial MWh	%saved	Market(%)	MWh saved	%of total
1. ILB to CFL all sectors	18,764	70	30	3,940	1.76
2. ILB to FL all sectors	18,764	50	70	6,567	2.94
3. Eff.-refrigerators	45,793	20	70	6,411	2.87
4. Eff.- air conditioners	60,313	20	70	8,443	3.78
5. Eff.- electric motors	33,507	4	50	670	0.30
6. Eff.-generation side	223,380	3	100	20,942	9.38
7. Eff.- transformers	8,048	30	80	1,932	0.86
8. Distribution system	31,372	40	100	12,549	4.78
Sum				**61,455**	**26.67**

Again, SSM measures will reduce *operational costs* while DSM measures will reduce *revenues.* In addition DSM measures will reduce electricity consumption and costs for a selected group of customers while SSM measures will reduce specific fuel consumption for all. From a utility point of view it is of course better to first reduce operational costs before measures are initiated to reduce revenues, even if there is the possible positive benefit of deferring future investment costs. In situations where DSM does reduce only base load demand and not peak load demand we would reject the notion of *deferred investment cost.* An example are residential lighting and peak load in the afternoon.

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Figure 5 shows the actual percentage savings of coal for each option.

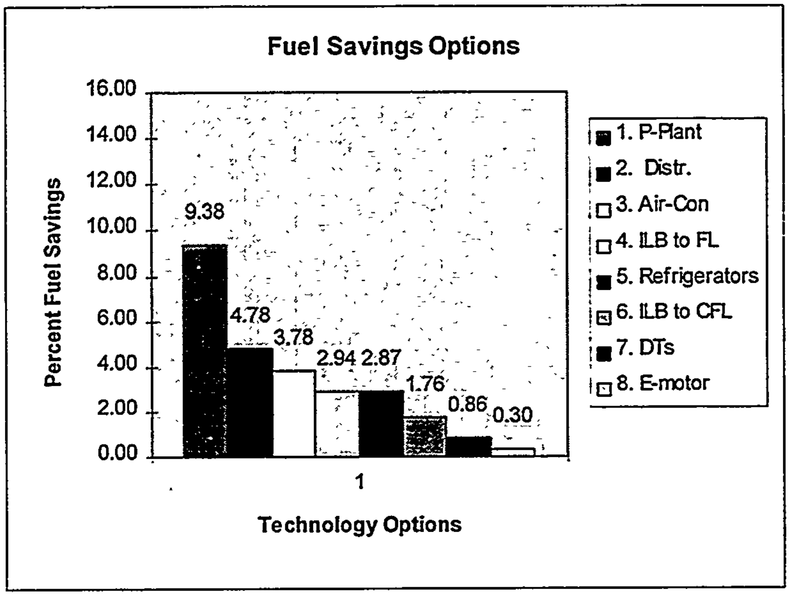

Figure 5: Absolute fuel saving potential of various SSM and DSM options

5.2 Conclusions

DSM measures are fine with healthy, highly optimised and efficient utilities having low system losses. Most DSM measures make perfectly sense, in a situation where SSM is already an integral part of an efficient utility. Within the context of this paper SSM does not mean to expand power supply as demand grows: **It means to generate and distribute power as efficiently as possible.**

Most modern utilities that have completed their rural electrification and provide power to almost anybody have few economic opportunities to become more efficient at the generation and transmission side. Exceptions are ongoing fuel switching activities and pilot plants for highly efficient combustion systems.

A totally different picture exists with utilities in developing countries that have to cope with an ever increasing demand combined with a chronic lack of power supply. In addition they face the need, or pressure for rural electrification. Under such conditions large specific fuel consumption reduction potential at the SSM side outweigh DSM measures.

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5.3 A SSM program that applies to almost any utility.

Step 1: ***Loss identification and better housekeeping measures with small investments.***

a) *Voltage and frequency mapping*

Loss statements in annual reports of utilities are not always helpful, because they rarely distinguish between technical losses and non paid electricity bills. Loss numbers also refer to the entire grid. Published losses average good and bad sections of the grid and don't allow to identify problem areas. A frequency and voltage mapping of grid sections would give a first indication about problem areas where SSM is cost effective.

Voltage and frequency mapping by small "ELV-power monitors" at the end user side(wall socket outlet) is by far the most inexpensive method to get a reliable and very dense data net. These plug-in monitors store minimum and maximum values of frequency and voltage. Monitors are connected by meter readers whom as well collect the data. Cost of one monitor is US$ 60.

Voltage and frequency mapping (at the end user side) would quickly identify insufficient external or internal wiring. Results automatically lead to recommendations how to reduce distribution losses.

b) *Load balancing*

Identification and correction of load imbalances is another important task, that is inexpensive and will quickly lead to projects with substantial fuel savings "per kWh of electricity distributed".

Measuring load imbalances at DT's does require one set of automatic monitoring equipment worth US $ 7,000. Correcting load imbalances is a "better housekeeping" measure with no further investment.

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c) Power factor compensation

This is supposed to be a common task of utilities to convince commercial and industrial clients to compensate at the source(the clients electrical machines). No matter who is compensating (utility, industry or appliance manufacturer), the utilities' benefits are improved utilisation of the grid capacity and decreased specific fuel consumption "per kWh distributed". In most European countries a commercial or industrial customer must compensate up to a power factor 0.92 to avoid penalties. A more realistic figure in developing countries is 0.75.

Some badly designed "ILB to CFL" or "ILB to FL" programs achieve the opposite effect. They increase the specific fuel consumption per "kWh distributed" by lowering the power factor.

The above three measures undertaken in a grid with 12-15 % technical losses will in most cases result in 3-4 % fuel savings and benefit all consumer groups. Measures are either better housekeeping activities, or require small investments. A rarely mentioned very positive side effect of the above measures is electrical equipment and appliances protection in developing countries. Technical life of visible and invisible electric motors as well as lights is very much reduced by voltage fluctuations, prolonged and frequent brownouts as well as frequent blackouts.

Utilities having trouble with power quality and power reliability can seldom match the power quality requirements for efficient lighting and have been running in problems by promoting efficient lighting for which they cannot guarantee adequate power quality. On the other hand the efficient lighting industry will not be too excited to manufacture lights that could cope with large voltage fluctuations and surges in the net.

Step 2: ***Improve thermal efficiency at the power generation side.***

Modern utilities have pushed the thermal efficiency of power generation very high for any given power plant design and technology. Thermal efficiency gains may only be achieved by switching to new State-of-the-Art technologies. A few years ago a good *annual average thermal efficiency* from the fuel to HT power after the

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generator was 38%-40 %. Today we talk about 50% for modern fluidised bed gasifier turbine systems, that may emerge as a future technology for low grade coal. Utilities in developing countries face more often the problem of improving first operational efficiency (not design efficiency).

Improvements of the *annual average thermal efficiency* of an existing power plant by 3-4 percentage points through better monitoring and control of fuel quality and the combustion process itself is a standard measure that requires more patience than capital investments.

Most inefficient thermal power plants suffer from high excess air combustion (poor control of air and fuel ratio) as well as high stackgas temperature caused by poor heat exchanger performance (scale and soot problems at water tubes, economisers and air preheaters). Lack of control starts with lack of monitoring important parameters. Non-functioning in situ Zirconia oxygen analysers and/or oxygen trims as well as fouled in situ conductivity and pH meters are typical indications how difficult it is to monitor thermal efficiency of power stations.

An interesting point that would require more in depth analysis are bidding procedures and technical appraisal studies for new power stations. There is a premium paid for power plant expansion taking into account efficiency considerations.

To our best knowledge only one large international financing institution specifically instructs their evaluators to refrain from recommending new power plant expansions if availability ratio of the system is below 75% and system losses are over 20 % (technical and non-technical).

Least cost analysis is mostly based on comparing different modes of power generation but not different system efficiencies. In other words bidding and appraisal procedures allow inefficient and uneconomic designs from the very beginning. Combine design inefficiencies with operational ones and you end up with a compounded effect that is not any longer statistical noise in an overall loss balance.

Step 3: ***Other SSM opportunities***

There are a few other opportunities that are more difficult to implement, because they concern *sustainable investment errors* and would require substantial investments in redesigning transmission and distribution grids.This is not always

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economic for an utility, in particular an utility that cannot recover their costs. The most prominent fuel saving solutions are:

- Switch to higher voltage lines
- Reduce length of single phase systems in favour of three phase systems
- Exchange low efficiency DTs for high efficiency DTs

Any one of the above recommendations would require substantial investments that may be economical but are seldom done because expansion of power capacity is given priority.

6. A final point

Most utilities in South East Asia cannot match an ever increasing demand for kW and kWh with adequate capacity expansion. On the other hand the present DSM programs, even if they can achieve their full potential, remain "statistical noise" in an environment where we face annual electricity demand and consumption increases of 7-13 %.

This situation leaves those concerned with the greenhouse gas effect the choice to either attempt to reduce specific fuel consumption per kWh distributed through the above SSM measures or drastically change their approach to DSM by significantly expanding high impact low cost DSM measures.

Project description	Sustainability (10-20 years	Project prevents non-reversible investment	Instant success (1- 2years)	Typical activities
A. Supply side management (SSM)				
1. Thermal efficiency improvement of existing power plants.	Yes	No	Yes	Improving in line monitoring of performance parameters relevant for efficiency improvements. Controlling fuel moisture. Waste heat recovery. Automatic oxygen trim. Improved performance analysis. Management contract.
2. Built future new power plants more efficient.	Yes	Yes	Yes	Improve financial assessment of power plant. Reject lowest bidder principle. Change tender documents to include comparison of premium paid for efficiency.
3. Replacement of installed transformers with more efficient ones.	Yes	No	Yes	Temperature scan and load testing. Switching of transformers. Eliminating hot spots.
4. Future purchase of more efficient transformers	Yes	Yes	Yes	Improved assessment of life cycle costs with respect to loading (80 % versus minimizing losses at 50 %).
5. Upgrading existing distribution lines	Yes	No	Yes	Changing bank policies for financing power plant expansion without adequate distribution line capacities. (KFW model)
6. Switching from single phase to 3 phase distribution.	Yes	Yes	Yes	Assessment of cost effectiveness relative to linear power density in kW/km
7. Balancing grid loads	Yes	No	Yes	Program to measure imbalances and rewiring
8. Power factor improvement	Yes	No	Yes	Switching from 100 % energy tariff to mixed energy/power tariff. Metering kVAr. Improving compensation at the source. Setting stricter standards for invisible appliance compensation. Increasing the "good customer" limit from 0.8 to 0.92.
9. Fuel switching within same fuel category	Yes	No	Yes	Looking into fuel benefication.(moisture, size, tramp ash)
B. Demand side management (DSM)				
10. Replace incandescent light bulbs (ILB) by Compact fluorescent lamps(CFL)	No	No	No	Either "utility driven and administered" or "private sector driven" campaign based on various standard implementation procedures. Parallel activities to ensure that power factor is not lowered by CFL program and base load is not affected. Solving legal issues if utility acts as supplier and promoter,

				but cannot guarantee adequate power quality to ensure technical life of at least 4000 hours.
11. Replace incandescent light bulbs (ILB) by Fluorescent lamps(FL)	Yes	No	No	Either "utility driven and administered" or "private sector driven" campaign based on various standard implementation procedures. Parallel activities to ensure that power factor is not lowered by program.
12. Long term switch to efficient refrigerators	Yes	Yes	No	Setting standards (mandatory or recommendations). Labeling of refrigerators. Marketing campaigns. Controlling imports or locally manufactured refrigerators
13. Long term switch to efficient air conditioners	Yes	Yes	No	Setting standards (mandatory or recommendations). Labeling of air conditioners. Marketing campaigns. Controlling imports or locally manufactured conditioners
14. Replacing inefficient "visible" electric motors	Yes	No	No	Demonstration of electricity savings. Phasing out of rewinding of electric motors. Incentives program. Supporting local ESCOs
15. Switching to efficient "visible" fans, blowers and compressors	Yes	Yes	No	Demonstration of electricity savings. Strong support for local ESCOs.

Notes:

- The assumption is that all individual measures are economic and financially attractive under certain conditions.
- Economic fuel costs to generate one MWh may vary from US$ 4 (efficient coal power plant located at mine mouth) to US$ 190 (1 MW automotive Diesel genset , island location).
- End user costs for one kWh vary from US cents 3 to US cents 30.
- The order of preference is: (Y,Y,Y) → (Y,N,Y) → (Y,Y,N) →(N,Y,Y) →(N,N,Y) → (N,N,N)
- Project 7 has the lowest investment costs and the least logistic difficulties.
- Project 10 tends to have the highest specific **overhead** costs and a low sustainability with respect to "tons of CO_2 saved".(Exceptions exist)

International Workshop on Greenhouse Gas Mitigation Technologies and Measures

Beijing, China 12 - 15 November 1996

Efficiency Improvement of Thermal Coal Power Plants

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Introduction

The discussion concerning an increase of the natural greenhouse effect by anthropogenic changes in the composition of the atmosphere has increased over the past years. The greenhouse effect has become an issue of worldwide debate. Carbon dioxide is the most serious emission of the greenhouse gases. Fossil-fired power plants have in the recent past been responsible for almost 30 % of the total CO_2 emissions in Germany. Against this background the paper will describe the present development of CO_2 emissions from power stations and present actual and future opportunities for CO_2 reduction.

The significance attached to hard coal as one of today´s prime sources of energy with the largest reserves worldwide, and, consequently, its importance for use in power generation, is certain to increase in the years to come. The further development of conventional power plant technology, therefore, is vital, and must be carried out on the basis of proven operational experience. The main incentive behind the development work completed so far has been, and continues to be, the achievement of cost reductions and environmental benefits in the generation of electricity by increasing plant efficiency, and this means that, in both the short and the long term, power plants with improved conventional technology will be used for environmentally acceptable coal-fired power generation.

The geographical location of VKR power stations is in the industrial Ruhr area in Germany. VKR has about 5,900 MW installed capacity based mainly on coal. The largest power station and one of the largest hard coal fired conventional stations in mainland Europe is Scholven having some 3,600 MW installed capacity (fig. 1). On average between 6 and 7 million tonnes of high ballast hard coal direct from the Ruhr area and between 4 and 6 million tonnes lignite are fired in VKR power stations each year. The annual electricity production is between 17 and 18 billion kWh.

The consumption of fossil fuels for power generation is paired with CO_2 emissions. The most effective method to reduce CO_2 emissions is to raise the net efficiency of the plant, described as the ratio of the net electrical output to the fuel thermal capacity input based on the lower heating value (fig. 2). This applies to all valid environmental regulations in Germany.

Power generating companies do have great interest in producing electricity with the least possible effect on the environment and with the best possible preservation of available resources. The introduction of legislation in Germany governing flue-gas cleaning led to the single largest investment program by operators in recent years.

Previous development

To assess the possibilities of generating power from coal with lower CO_2 emissions in future, it is necessary to look back at the development so far. It will be seen that the term efficiency has taken on major significance. Improvements in efficiency which have taken place over the last few decades, and the specific CO_2 reductions which have been achieved, were always a result of initiatives from industry for the purpose of achieving greater design and operational efficiency.

In hard coal-fired power plants alone, efficiency has doubled over the last 50 years. The reason for the stagnating development which was evident in the 80's was caused by the retrofitting of power plants with flue gas cleaning systems. Hard coal-fired power plants are currently operating with a mean efficiency of 36%. This takes into account reductions in efficiency levels which result from the use of flue gas cleaning systems, which has nevertheless been compensated for in part by exploiting other areas in this aging power plant components offering improvement potential (fig. 3).

The result of this constant striving for improvement, i.e. steps taken which must be looked on as safeguards for the environment and not end-of-pipe technology, can be seen from the following observation. In the period from 1950 until the present day, power generation in the fossil-fired public utilities operating in western Germany has increased more than tenfold, whereas CO_2 emissions as a result of the developments described in the area of power plant efficiency have increased only fivefold . This is quite an impressive achievement on the part of Germany's power industry (fig. 4).

Efficiency increases in existing power plants

With the retrofit of flue gas cleaning systems (desulphurization, NO_X removal), power plant efficiency levels have gone down by 1.5 to 2%, due to the increase in the plant's own power requirement. For every tonne of SO_2 removed, an additional 2 tonnes or so of CO_2 are emitted. Compensation for lower efficiency has been achieved by upgrading components and subsystems in existing power plants. The modification was not allowed to put constraints on power plant availability, i.e. this had to be performed within already scheduled component refurbishment work, and was also required to satisfy economic criteria, while taking into account the remaining life expectancy of the components. The key options available for improving efficiency levels in existing plants include:

- improvement of the steam generator efficiency by reducing exhaust losses
- improvement of the turbine efficiency (replacement of turbine blading)
- refurbishment of pumps and blowers, and
- optimization of the cold end (condenser).

Improvements of this kind have been implemented in Germany over the last few years and will continue in the near future. Since January 1993 German utilities have commissioned 228 measures for improving the efficiency until March 1996. Almost 50 % of these are apportioned to improvements in the sector of steam generators and 25 % to improvements in the turbine sector. The remaining approx. 25 % refer to activities concerning other power station components. After their realisation the introduced measures will result in a CO_2 reduction of 8.5 Mio t/a (fig. 5).

Improvements of steam generators

The improvements of steam generators refer to the fuel, air and flue gas. The improvements of pulverized coal distribution, mill fineness, air balancing and distribution at the burner have led to a significant higher boiler efficiency. The reduction of excess air and preheater leakage is the most effective meassure at the steam generator (fig. 6). At several power plants in China combustion adjustments were carried out by VKR. The improvements of boiler efficiency are between 0.8 and 3.8 %-points.

Significant improvements have already been achieved in VKR power plants by carrying out conversions on turbines and cooling towers, and replacing feed water pumps. In the following examples will be presented to demonstrate measures which, considering said components of total heat consumption, have led to partly notable fuel savings.

Improvement of steam turbines

The turbines of the power station in Scholven (Units B to E), commissioned about 1970, which comprises one high-pressure, one intermediate-pressure, and two low-pressure section turbines, have a capacity of 400 MW each. After about 90,000 operating hours the following modifications were carried out.

The guide blade of the last stage of the low pressure section was originally made of grey cast iron with thick rear edges attributable to the casting technique. They were replaced by a welded steel plate which is considerably better as regards flow conditions. In addition, the new blade is provided with slots to suck off final moisture so that removal and entrainment losses caused by the unavoidable formation of droplets are reduced. The outlet diffusor has also been changed; it has been extended and provided with a more favourable extension ratio. The specific heat consumption of the machine declined by about 100 kJ/kWh which is equivalent to 1.2 % efficiency points (fig. 7).

The high-pressure turbine, has also been improved. The blades were replaced by blades with new profiles and shapes. The contour is continuously curved. Together with an improved quality of fabrication and better surface finish the blade exchange led to a decrease in specific heat consumption of about 1 %.

Basically this measure can also be taken at the inlet section of the intermediate-pressure turbine. Under the given conditions this was, however, economically inefficient.

Improvements of the "cold end"

The cooling tower is a wet natural-draught type cooling tower with a total height of 115 m and a diameter of 80 m at the air inlet. Cooling water throughput is about 50,000 m3/h; the cold water design temperature is 23 °C at a moist air temperature of 8 °C. Installation of new splash packings with reduced pressure loss and a longer residence time of water resulted in lowering the cold water temperature by 2 K (fig. 8). As a result of the temperature decrease, the condenser pressure sinks and enthalpy drop in the machine rises. At the same time, the steam outlet velocity from the last stage of the low-pressure turbine rises and with it the exhaust loss. Fuel savings are here about 20 kJ/kWh, that corresponds to around 0.25 %. The value of 21 °C as cold water design temperature was the result of an optimization calculation conducted with due regard to investment cost.

Refurbishment of Pumps

The feed pump system of the considered 400 MW unit comprises 2 half-load and 2 quarter-load pumps, thus the overall pumping capacity installed is 150 % relative to the maximum feed water flow. The original half-load pumps with a capacity of 600 t/h, 280 bar final pressure, and 75 % efficiency, had a power requirement of about 5.5 MW They have been in operation for around 100,000 hours without any inspection. In the meantime the manufacturing companies have developed pumps with higher speeds, more stages and above all an improved flow design for the same performance data. Instead of proceeding to the scheduled inspection of the existing pumps we resolved to install new pumps. With an efficiency of 84.5 % they reached power savings of around 500 kW per pump, that means an improvement of total efficiency by arount 0.25 percentage points (fig. 9).

Existing power plants have large potentials for improvements. The areas of greatest potential improvement are the steam turbine followed by the boiler at the cold end. This rage of potentials is valid for existing power plants with an efficiency level between 33 and 37 %. Lower efficiencies will led to higher improvement potenials (fig. 10).

Further development

Just recently, the new, state-of-the-art hard coal-fired power plants went into operation with efficiency levels of around 43%. Compared with the average efficiency level previously mentioned, this means fuel savings and, consequently, reductions in CO_2 emissions of more than 16%.

Lignite-fired power plants are being built today that, when commissioned, will feature efficiency levels of 40 to 43%. The first to go on-line was the Schkopau power plant at the end of 1995, with an efficiency of about 40%; it is the starting point of further new construction activities in Germany employing improved power plant technologies. The new power plants will then follow, resulting in fuel savings and CO_2 reductions of up to 30% compared with the current situation in lignite-fired power plants.

An other option available for increasing efficiency levels is to improve the water/steam cycle by increasing the process parameters and the efficiency levels of individual components. The restrictions on temperature and pressure increases are determined by the high-temperature materials currently available, scheduled load changing requirements and the required availability.

The ferritic-martensitic material P91 developed over the last few years permits a further increase in steam conditions, with the result that this material has been chosen for the header and connecting pipe work of the turboset for steam conditions that will be in the order of 580°C/270 bar (HP) and 600°C (reheat) in hard coal and lignite-fired power plants currently being designed or under construction (fig. 11).

With the introduction of this high-temperature design, and with the improvement in efficiency of the previously mentioned individual components, efficiencies of around 45% and 46% are now being achieved in coal-fired power generation facilities (fig. 12).

Final consideration

The described measures show that it is possible to achieve notable savings in specific heat consumption - also at existing power plants - with economic success. Further there are quite a number of additional measures which lead to the same end. Of course it is necessary to study each individual measure for its economic efficiency. In each case the decrease in specific heat consumption (that is the gain in efficiency), the investment cost and the anticipated operation of the plant, which is an important variable, are to be taken into account.

The exploitation of fuel energy can be notably increased by combined heat and power generation. The sales of district heat are, however, limited to certain locations and seasons. Thanks to combined heat and power generation district heat supply has become - also in the Federal Republic of Germany - one of the most important primary energy-saving and environmentally acceptable heating systems which should be given priority in future.

Location Plan

VKR Power Plants

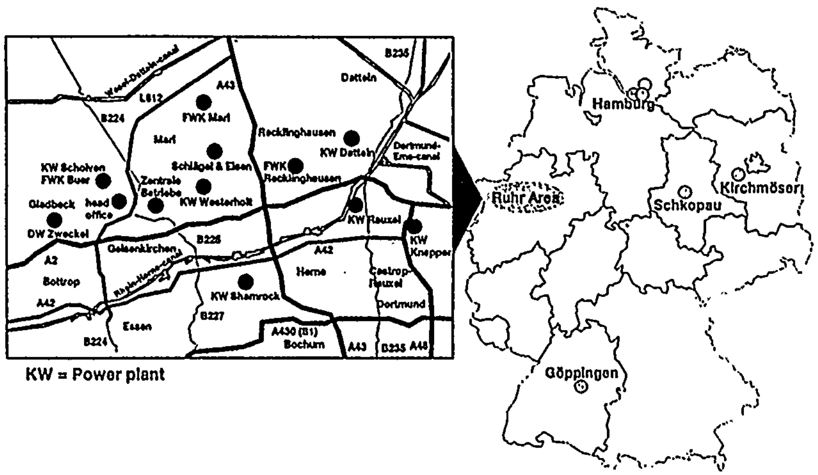


Figure 1

VKR TM-D, 18.11.1998 - DSF32

Specific CO_2 emissions

different fuels

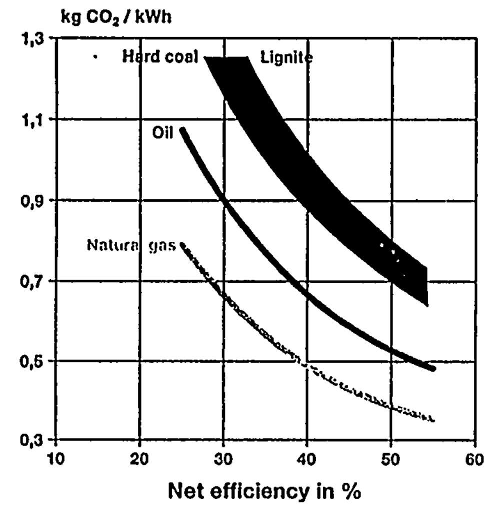


Figure 2

Development in Germany

Hard coal-fired power plants

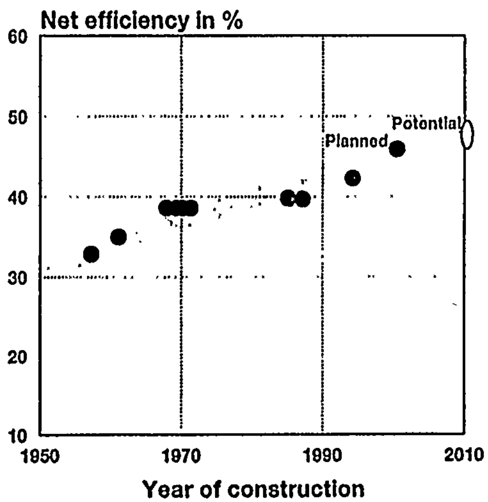
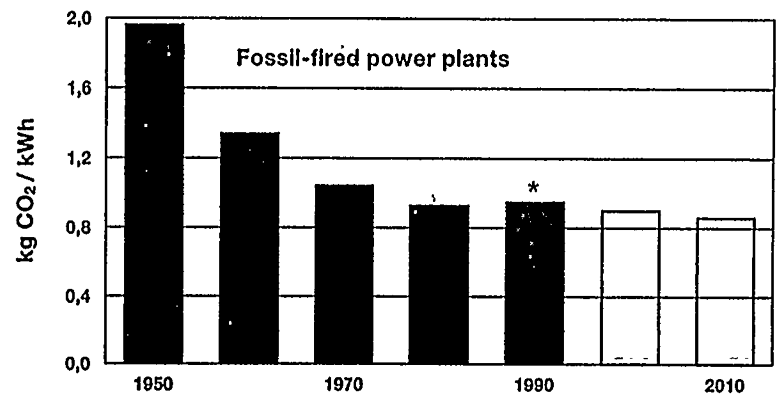


Figure 3

CO_2 emissions and power generation

in Germany

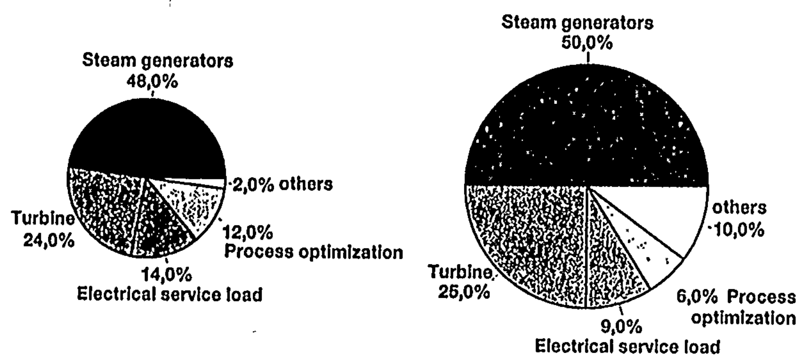


* effect of flue gas cleaning

Figure 4

Commissioned measures

existing power plants



CO2 reduction: 1.8 mill. t/a

CO2 reduction: 6.7 mill. t/a

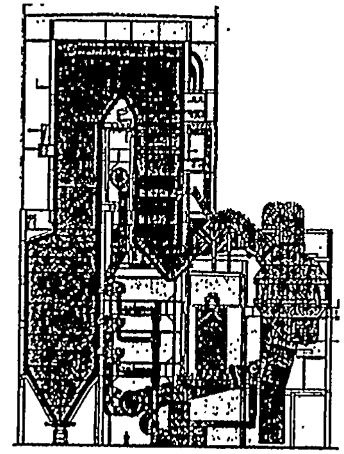
Source: VDEW

Figure 5

VKR TM-B, 18.11.1996 - PR23

Combustion optimization

Measurements for combustion adjustment



Fuel:
- Pulverized coal distribution
- Pulverized coal mill fineness

Air:
- Air balancing
- Air distribution at burner
- Swirl of the burn

Flue gas:
- Excess air in the furnace
- Air preheater leakage
- Flue gas analysis at the furnace walls

Figure 6

VKR TM-B, 21.11.1996 - DSF39

Steam turbine

Power plants Scholven B to E

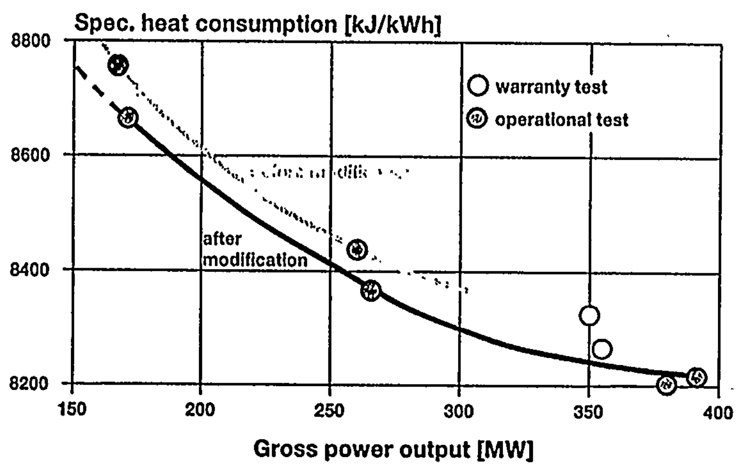


Figure 7

VKR TM-B, 18.11.1996 - PR24

Cooling tower design

Power plants Scholven B to E

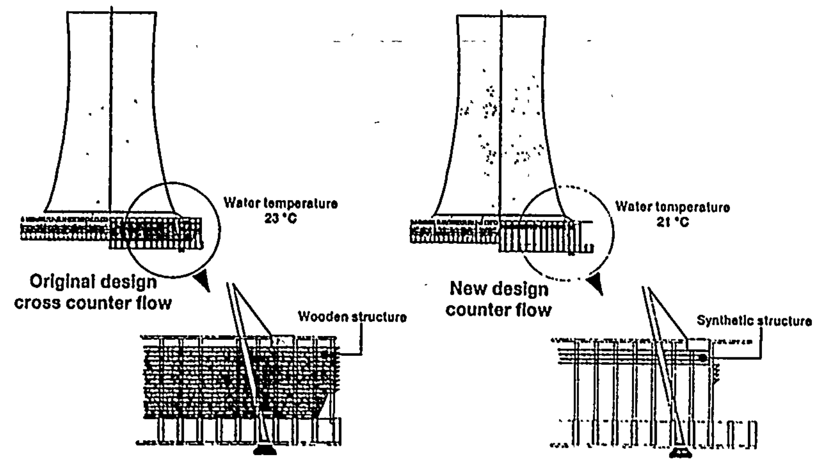


Figure 8

VKR TM-B, 18.11.1996 - DSF33

Efficiency improvements

Power plants Scholven B to E

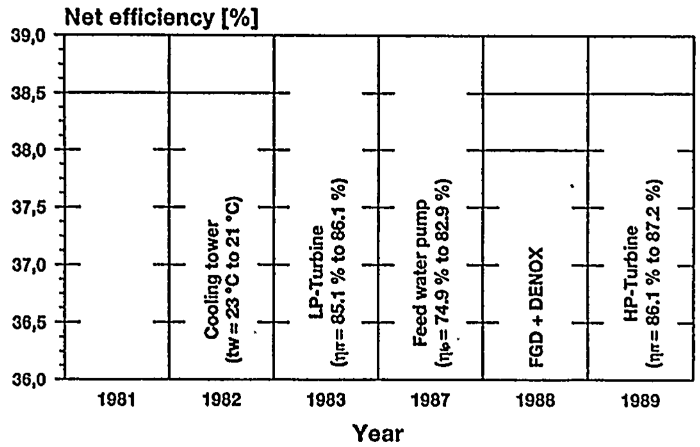


Figure 9

Potential ranges

Existing power plants

	$\Delta\eta$ in %-point
Improvement of turbine efficiency	1.0 - 2.5
Reduction of exhaust losses	0.2 - 0.5
Use of low-loss controll actuators	0.1 - 0.2
Refurbishment of pumps and blowers	0.2 - 0.3
Optimization of cold end	0.2 - 0.4

Figure 10

New materials

Main steam formed piece

Design pressure 300 bar
Design temperature 580°C
weight economy ca. 60 %

Material: P91

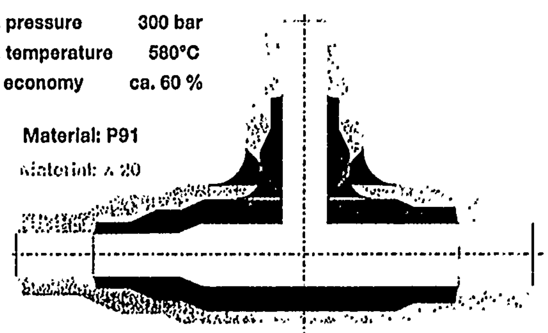


Figure 11

Further development

Hard coal-fired power plants

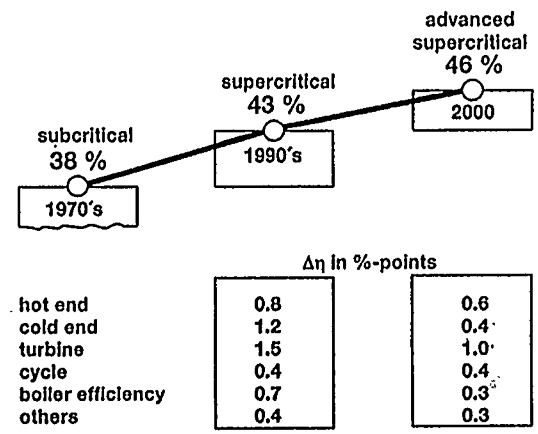


Figure 12

ENERGY CONSERVATION TECHNOLOGIES BASED ON THERMODYNAMIC PRINCIPLES

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Professor Emeritus, The University of Tokyo

ABSTRACT

In order to reduce CO_2 emission to prevent global warming, the most promising way for electric generation in the Northeast Asia is to introduce cogeneration and "repowering" technologies based on high temperature gas turbines fueled by natural gas. Especially the old type coal burning boiler-steam turbine plants should be retrofit by introducing gas turbines to become highly efficient combined cycle. Same technologies should be applied to the old garbage incineration plants and/or even to the nuclear power plants. The exhaust heat or steam should become much increased and it should be utilized as the process heat for industries or heat supply as the district heating or cooling for residential area. This paper introduces a brief survey of these new technologies.

INTRODUCTION

It has been long said that the 21st century will be the Asian century. The Asia-Pacific region contains a diverse range of countries which stand at different developmental stages. In recent years, economic interdependence among these countries has advanced at an accelerated speed and it is expected that this region will undergo a dynamic transformation in the future.

Economic growth in the Asia-Pacific region is expected to bring about a conspicuous growth in energy demand. Fig. 1 shows a forecast of the energy supply and demand in Asia prepared in June 1995 by the Advisory Committee for Energy, Ministry of International Trade and Industry of Japan. This committee expected that the total primary energy demand in Asia should become almost double in 2010 compared to the amount of 1992. If the predicted rapid growth of energy consumption is met chiefly by coal, as shown in this figure, environmental pollution would be unavoidable. Oxide pollutants, especially sulphur oxides and nitrogen oxides, emitted in China have already begun to expose South Korea and Japan to acid rain and snow. Also a huge amount of carbon dioxide is emitted in the region, causing serious results to global warming. It should be essential to realize as soon

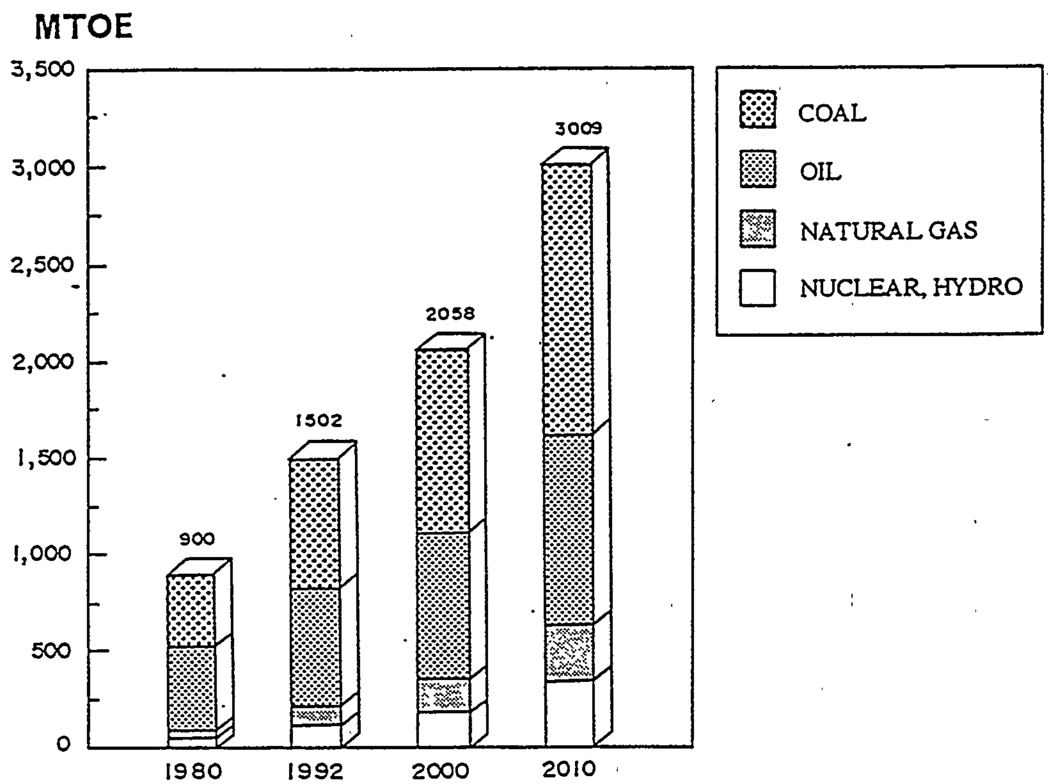


Fig.1. Forecast of Energy Supply and Demand in Asia (MITI, June 1995).

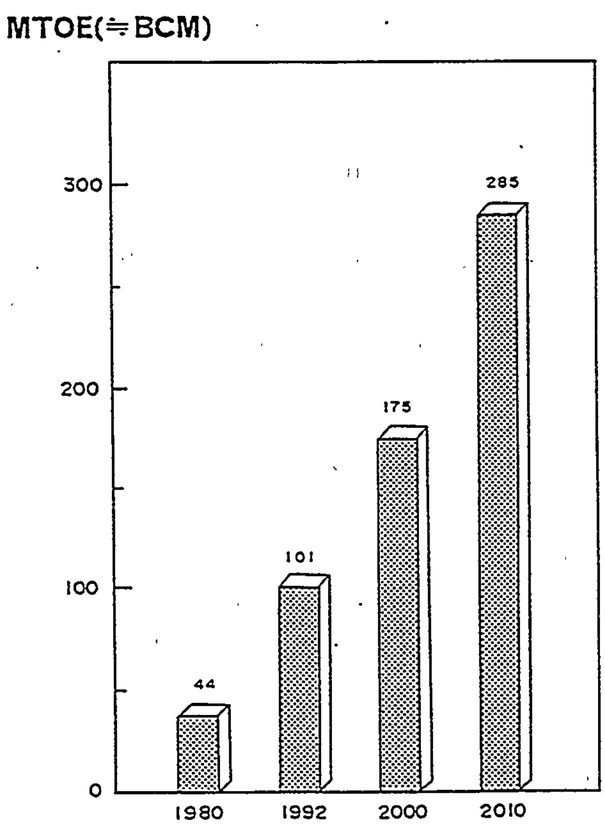


Fig.2. Forecast of Natural Gas Demand in Asia (MITI, June 1995).

as possible that natural gas be supplied to the countries in Asia-Pacific region, and that the energy saving technologies described later be spread there. Fig.2 shows the forecast of natural gas demand extracted from the same data as shown in Fig.1.

It is reported that the Asia-Pacific region has vast reserves of untapped natural gas. The development and utilization of these resources at sustainable levels constitutes a crucial issue in the future. In order to increase the intra-regional use of these vast reserves of natural gas, the National Pipeline Research Society of Japan proposes the construction of international trunk pipelines, called the "Trans-Asian Natural Gas Pipeline Network" , linking the gas fields with major consuming markets.

This Trans-Asian Pipeline will play a vital role in the international infrastructure of the 21st century and assist in finding a solution to problems involving the global environmental problems and a long-lasting security in Asia.

EFFICIENT ENERGY SYSTEMS BASED ON NATURAL GAS FUELED HIGH TEMPERATURE GAS TURBINES

Everyone may envisage a plan to build series of dams and hydroelectric power stations along a river in different reaches from the top of a mountain to the bottom of sea water level so that the water head is used up completely, as shown in Fig.3. Water, after reaching the sea level, is no longer useful for power generation. As the proverb says, spilt water cannot be gathered again. In the case of heat utilization, temperature differences correspond to the water head differences and the ambient temperature corresponds to the sea water level. Effective utilization of heat energy requires arrangements to use up what corresponds to water head in a full range of heat potential from a high temperature of more than 1,500℃ generated by burning fuel to the ambient temperature of 15℃. Heat energy, after falling down to the ambient temperature, is no longer useful, but strangely, efforts have seldom been made to use up heat in decreasing order of temperature like the way water is used in hydroelectric power generation.

Once fuel is ignited, it should be first considered to operate a heat engine to produce motive power. It has been the past practice to install boilers when heat or steam is needed. From now on, we first have to install engines or gas turbines whenever we want to get heat. The first step in rational use of heat energy is to convert higher temperature heat into power by using a heat engine and then supply lower temperature heat discharged from the engine to baths or space heaters.

A "series-flow" heat utilization system, that uses higher temperature heat for electric power generation by using heat engines and supplies lowered temperature

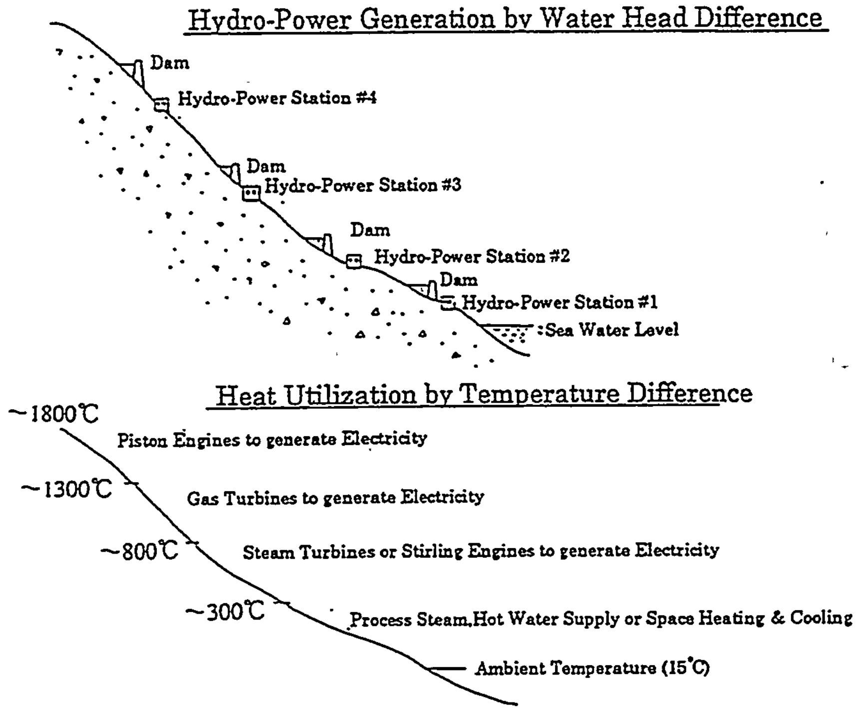


Fig.3. Similarity Between Water Head Potential and Temperature Difference.

heat discharged from the engines for heat applications, is called "cogeneration." The technology according to the thermodynamic principle is the only way to materialize energy conservation technologically. With this in mind, the following paragraphs will propose some specific measures for the creation of system energy with priority on high-temperature gas turbines fueled by natural gas, which is the most effective key technology to turn high-temperature heat into power. Natural gas-fired gas turbines use clean or low-pollution fuel and, therefore, their TIT - turbine inlet temperature - continues to rise steadily, reaching 1,350℃ now in commercial installations. A forecast says that their TIT will reach 1,500℃ by the end of the 20th century and, with the adoption of steam cooled turbine blade, may further rise to 1,700℃ early in the 21st century. All technologies proposed below are varieties of repowering or combined cycle system that sets such a high-temperature gas turbine at the topping of a thermodynamic cycle and uses turbine exhaust heat at the bottoming.

(1) Cogeneration

Cogeneration systems in Japan reached 2,190 units with an installed capacity of 3.7 GW at the end of September 1996. This accounts for some 1.7% of the total power generation capacity in Japan. In average, cogeneration systems have been approved that the energy conservation effectiveness is approximately 30%. The Japanese government decided to promote to introduce a cogeneration capacity of 5.4 GW by the year 2000 and 10 GW by 2010 through a mix of deregulation measures. The Environment Agency of Japan recently proposed that additional 1.3 GW must be introduced by 2000 in order to reduce more CO_2 emission. This additional cogeneration will contribute 170 kT of carbon equivalent reduction of CO_2.

(2) Repowering

A method of improving thermal efficiency of existing power plants equipped with a boiler-steam turbine system or, in some extreme instances, only with boilers by adding high temperature gas turbines to them is called "repowering." The underlying principle of this method is to use up all available heat from the top to bottom of its temperature range exactly in accordance with the fundamental theory of thermodynamics. Again Environment Agency of Japan proposed to introduce 19.5 GW repowering and 23 GW new combined cycle systems into Japanese industries by 2000 to reduce 148 kT-C of CO_2 emission.

(3) Gas Turbine Combined Garbage Incineration Plant

There are now some 1,900 garbage incineration facilities in Japan, but combustion heat from incinerators is seldom utilized, lest boiler tubes be corroded by hydrochloric acid contained in combustion gas. Currently combustion heat is used for power generation at only 120 incineration facilities, and at all other facilities the heat is only discharged into the air. Even if the steam temperature is held down to the level which does not cause the corrosion of boiler tubes, i.e., about 290℃, a natural gas fueled gas turbine should be installed additionally, and the exhaust gas of which is used to superheat the steam from the incinerator, resulted to become a combined cycle. Then the incineration facility would be changed into a highly efficient power plant. This proposal by the author has been promoted since fiscal 1993 as a Ministry of Home Affairs project under the name of "Super Waste-to-Energy Power Generation." The first super waste-to-energy power generation plant is the Takahama Clean Center in Gunma Prefecture, which is scheduled to start commercial operation in November 1, 1996. A power generating capacity of more than 10 GW could be provided if this technology is applied for continuous running incinerators of 435 facilities in Japan.

Fig.4 shows the process diagram of the 1st plant in the world which was put into operation in February 1995 at Linkoping in Sweden. In this plant, 18-bar, 207℃ steam from the garbage incinerator of a capacity of 740 tons a day is superheated to 430℃ by gas turbine exhaust and then sent into a steam turbine. The output of the gas turbine is 25MW and of the steam turbine is 25MW. The use of a gas turbine increases total initial investment but minimizes the investment per unit output of

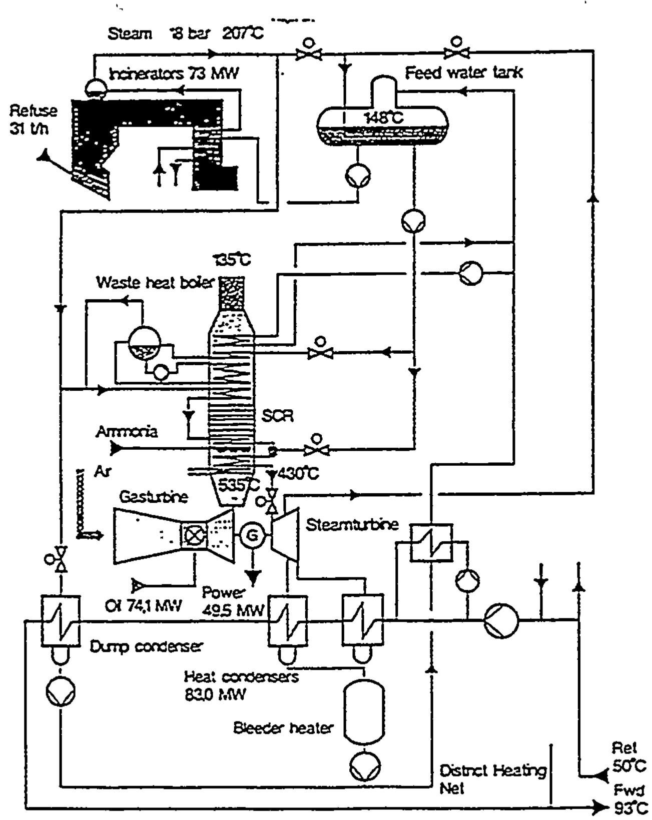


Fig.4. Natural Gas Fired Gas Turbine Combined Garbage Incineration Plant(Linkoping, Sweden).

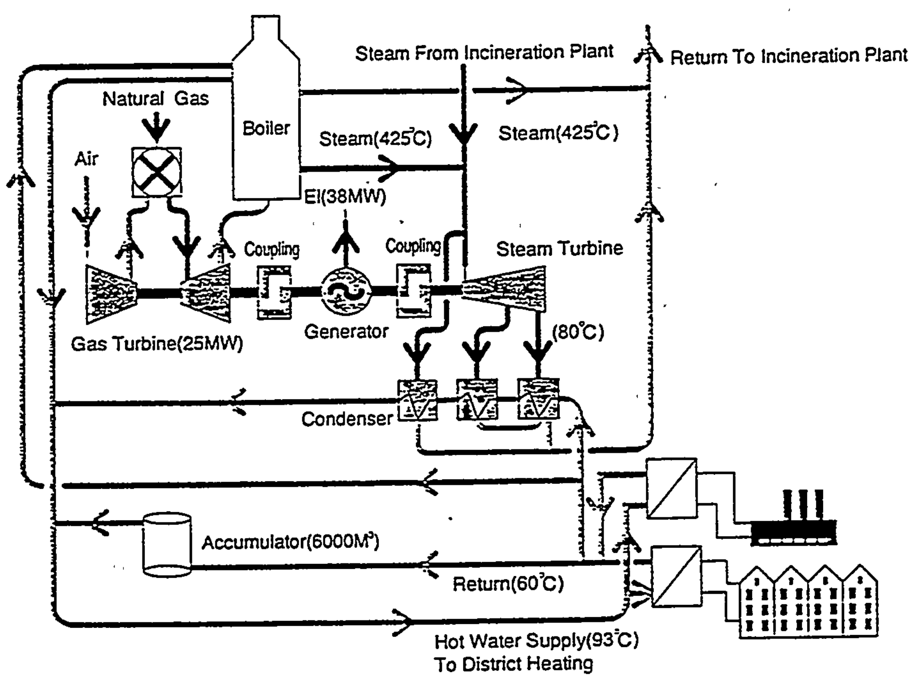


Fig.5. Example of Gas Turbine Combined With Existing Incineration Plant(Naestved, Denmark)

electricity.

As another example of incineration combined cycle, Fig.5 shows a process diagram of a gas turbine combined with an existed incineration plant. The 425 ℃ steam produced by the exhaust gas of a 25MW gas turbine is connected with the steam from the incinerator, which was built in 1983, to drive a 13MW steam turbine.

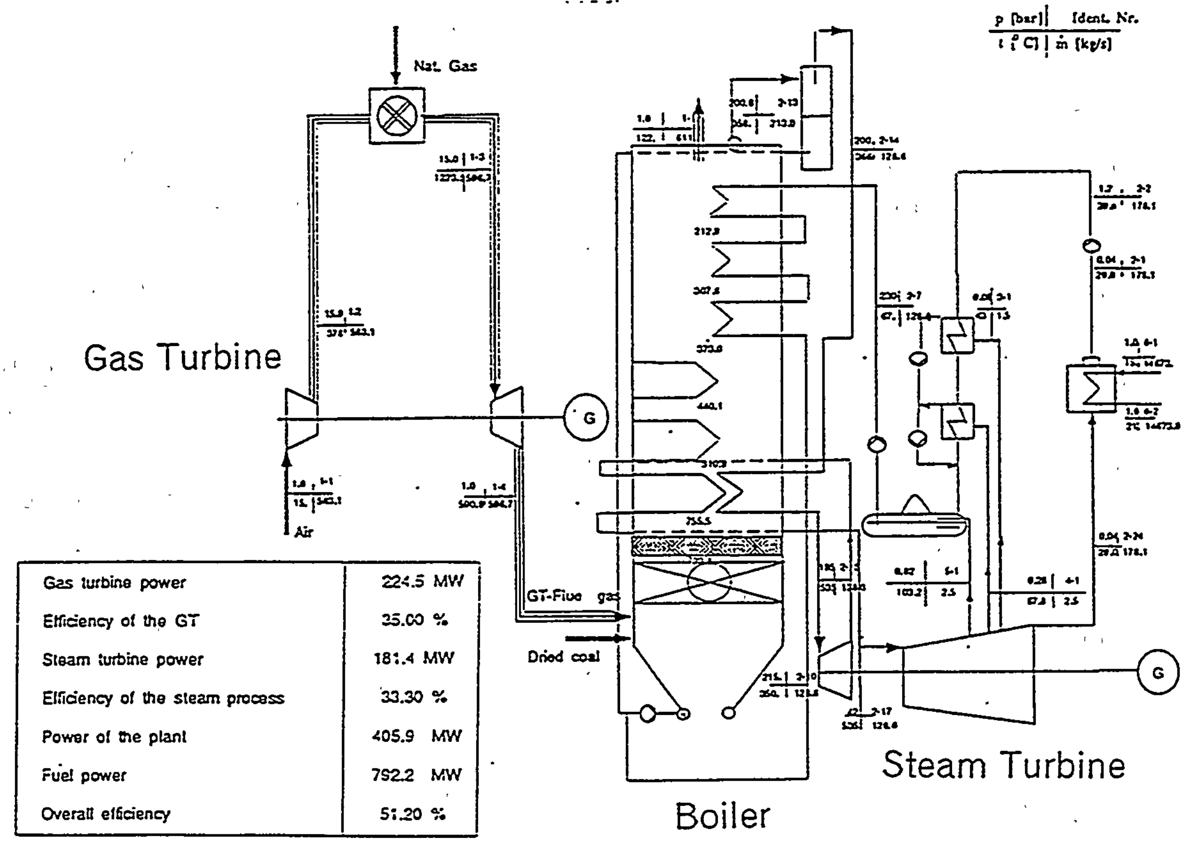
Among conceivable technologies for relatively small incinerators, an idea of highly efficient, simple power generation is a system that the steam from the incinerator is superheated by gas turbine exhaust and is injected into the gas turbine itself. In this case, the repowering efficiency which is defined as the electric power output divided by the additional heat input by burning fuel is estimated as around 49%(LHV) at the maximum for plants in an 1,100℃ TIT range and at some 55% for plants in a 1,300℃ TIT range, which are better than that of a combined cycle system using a steam turbine. This implies that use of gas turbines as prime mover eliminates the need for steam turbines or condensers and provides a simplified, compact version of highly efficient super waste-to-energy power generation system that can effectively utilize combustion heat from garbage incineration.

The Environment Agency proposed to introduce at least 70 super waste-to-energy power generation plants up to 2000 resulting 1.2 GW electric generation capacity and 570 kT-C of CO_2 reduction.

(4) Natural Gas Fired High Temperature Gas Turbine Combined With Coal Fired Steam Power Generation

The maximum permissible temperature for coal fired power plants as a heat engine cycle has been around 650℃ for the ultra supercritical pressure steam power generation technology and 850℃ for the integrated coal gasification combined cycle (IGCC) power generation technology.

As a breakthrough in this area, it is proposed that the principle of repowering be applied to coal fired power generation. The targeted thermal efficiency for coal-fired ultra supercritical pressure steam power generation (352 ata and 649℃) is now set at 44.4% (1 GW class, HHV, gross output). A hybrid combined cycle system formed by adding natural gas fired high temperature gas turbines to the coal fired boiler-steam turbine system could achieve a thermal efficiency of somewhere between 46% and 47% (HHV) for plants in a capacity range of 300～400 MW. An example of German estimates [1] given in Fig.6 indicates that a thermal efficiency of 51.2% (LHV) could be attained by an "additional firing" that uses gas turbine exhausts like air pre-heating of the boiler.



Gas turbine power	224.5 MW
Efficiency of the GT	25.00 %
Steam turbine power	181.4 MW
Efficiency of the steam process	33.30 %
Power of the plant	405.9 MW
Fuel power	792.2 MW
Overall efficiency	51.20 %

Fig.6. Natural Gas Fired Gas Turbine Combined With Coal Fired Steam Turbine System (Air Pre-heating System).

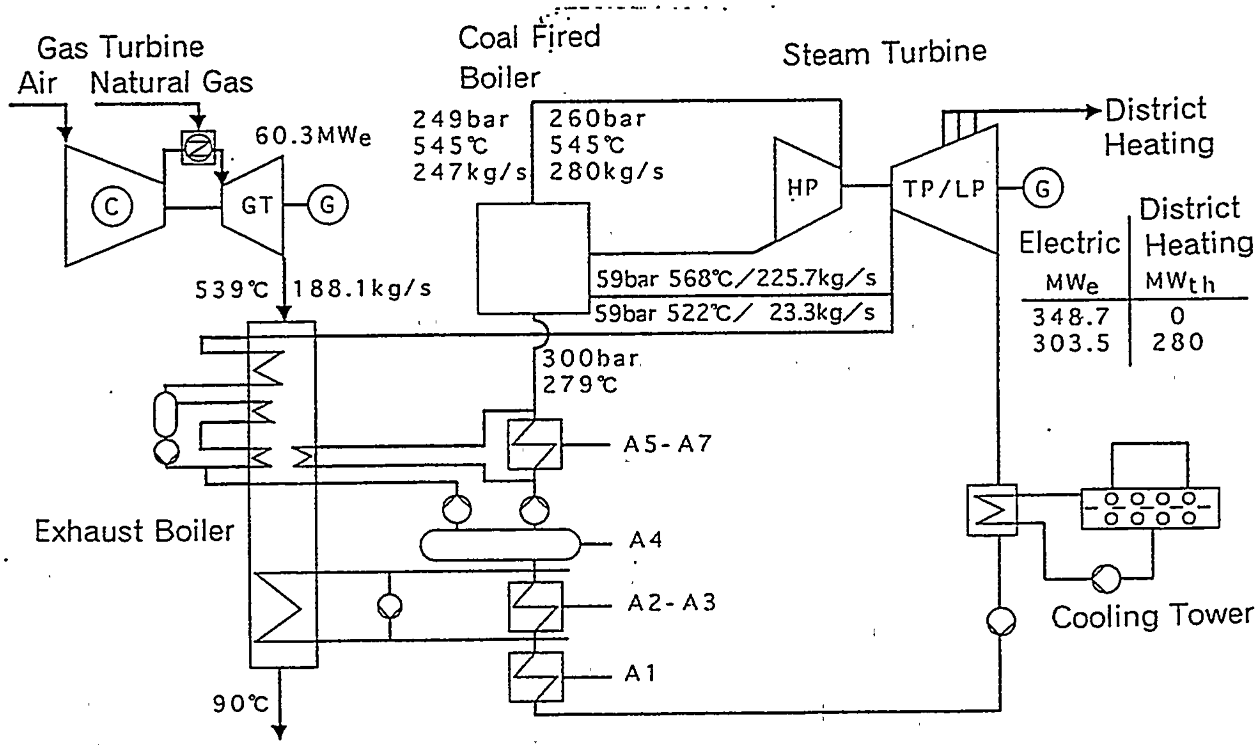


Fig.7. Natural Gas Fired Gas Turbine Combined With Coal Fired Steam Turbine System (Steam Combined System).

Another hybrid system of combined cycle of gas-fired gas turbine and coal-fired boiler-steam turbine is shown in Fig.7. In this case, the steam produced by exhaust from gas turbine is combined with the steam from coal fired boiler and sent to the steam turbine.

(5) Natural Gas Fired Gas Turbine Combined With Nuclear Power Plant

A similar concept should be applied to nuclear power generation. At present Japan has 49 nuclear power reactors with a total installed capacity of 47 GW. The allowable limit of steam cycle temperature for nuclear power plant is around 320℃ because the maximum pressure of the plant is limited by the strength of the reactor pressure vessel and the maximum temperature is limited by the saturation temperature corresponding to the system pressure.

It is desirable, therefore, that nuclear power plants be repowered by installing high-temperature gas turbines in their sites. Rough estimation has shown that a 1GW nuclear reactor should be repowered by gas turbines of 1.2GW and the steam turbine becomes 1.5GW, and the total output should become 2.7GW. Thermal efficiency is increased up to 44～45% compared with 30% of conventional nuclear reactors. Similar idea has been proposed by the Battelle Memorial Institute in USA as shown in Fig.8.

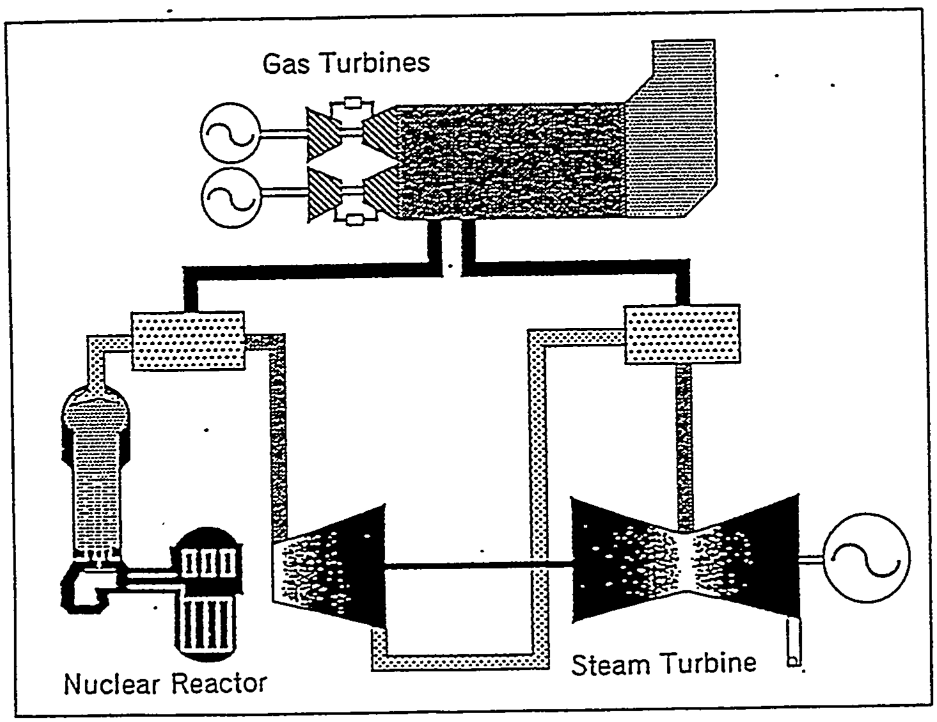


Fig.8. Repowering of Nuclear Reactor by Natural Gas Fired High Temperature Gas Turbines (Battelle Memorial Institute).

In order to distribute the above mentioned highly efficient energy systems within the Northeast Asia, natural gas should be supplied as fuel to all over the area. Major sources to meet the huge amount of future demands in Northeast Asia are considered to be Central Asia (Turkmenistan, Uzbekstan and Kazakhstan) and East Siberia (West Irkutsk, Yakutsk and Sakhalin) . The Northeast Asian Gas Pipelines should be constructed and these gas resources will be interconnected with the consuming countries as shown conceptually in Fig.9.

To promote the construction of this network, the 2nd International Conference on Northeast Asian Natural Gas Pipeline was held in Beijing on September 22 to 24, 1996, and enthusiastic discussions were obtained between 160 participants from 13 countries including China, Mongolia, South and North Korea, Russia and Japan. The 3rd Conference will be organized in Seoul, Korea, in 1997.

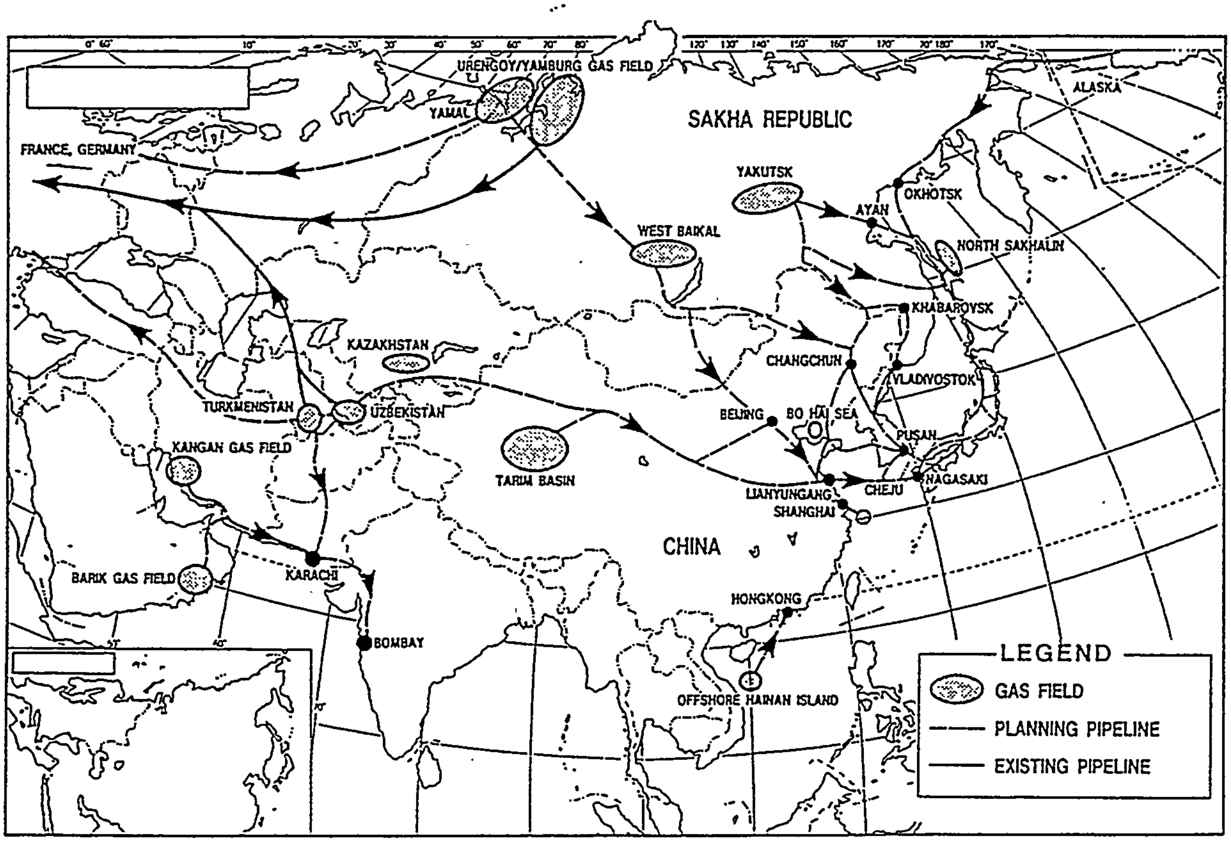


Fig.9. Northeast Asian Natural Gas Pipeline Network.

CONCLUSIONS

Natural gas does not contain sulfur, thus no SO_x discharged from combustion. Natural gas and air pre-mixed combustion technique is generally adopted, so it is easy to control combustion temperature and to reduce NO_x emission. The amount of CO_2 discharge is almost half compared with coal, and 2/3 of oil combustion for the same amount of heat release. Natural gas does not only contain sulphur, but also heavy metals as vanadium, and it is easy to develop high temperature gas turbine integrated cycles for the highly efficient power generation systems.

In 1994, the Worldwatch Institute in USA published a book(2) entitled "Power Surge", in which they pointed that if, at the beginning of the next century, the highly efficient energy systems as cogeneration fueled by natural gas should be distributed, and the fuel is gradually changing to a mixture of natural gas and hydrogen. Around 2020, the gas fuel so called as "Hythane" , which is a mixture of around 15% hydrogen and 85% natural gas or methane, should be introduced. Hydrogen is to be produced by electrolysis of water, and the electricity is generated by using renewable energy as solar or hydraulic power generation. According to their scenario, CO_2 concentration within atmosphere will take a peak value of 450 ppm at around 2050, and after that it will gradually decrease as shown in Fig.10.

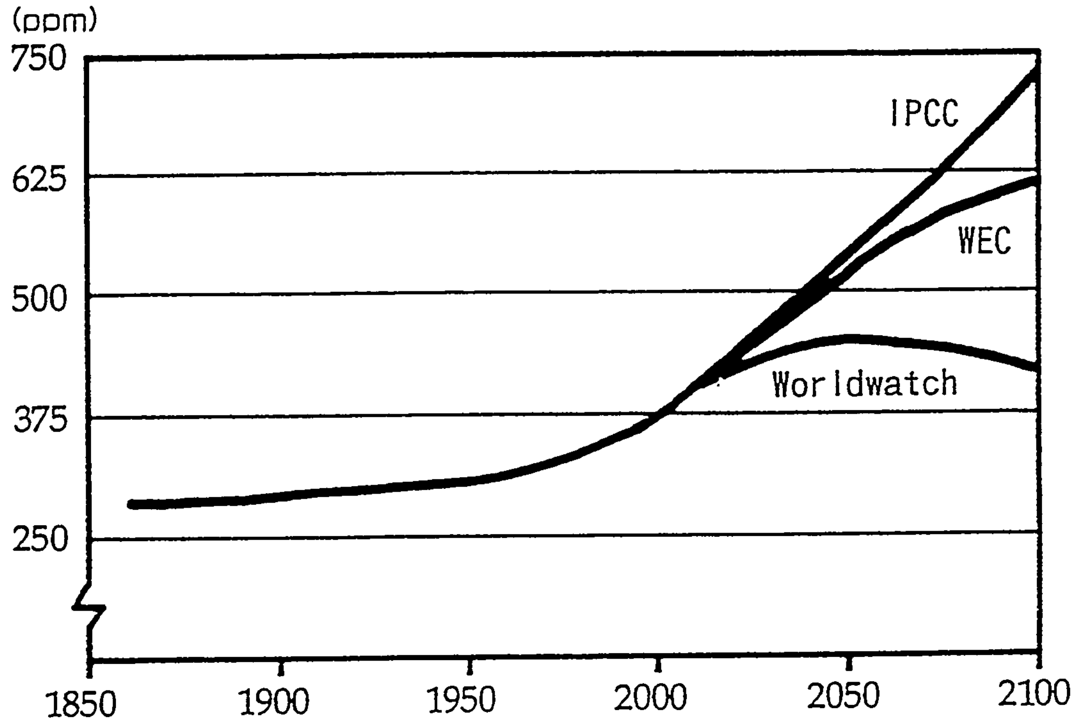


Fig.10. Forecast of CO_2 Concentration in Atmosphere by Scenario of Worldwatch Institute(2).

East Siberia has a vast potential of hydro-power generation undeveloped. For example, there are so many famous big rivers as Angara, Yenisei, Lena or Amur River, and if such potential should be developed to produce electricity and to use for the production of hydrogen, the pipelines will become most effective infrastructure for the transportation of hythane.

The Trans-Asian Natural Gas Pipeline is a public infrastructure that spans across the country. The realization of the projects will crucially depend on the cooperation of each country, or government and private sectors. In the construction phase, the required construction funds and pipeline technology will be actively transferred across the borders. Meanwhile in the operation phase, intra-regional interdependence in the field of energy will be heightened. Just as the pipeline network in Europe is a symbol of intra-regional unification, the "Trans-Asian Natural Gas Pipeline" will widely contribute to the peace and security of the Asia-Pacific region as a symbol of cooperation.

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Overview of Mitigation Policies and Measures in the Forestry Sector

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November 1996

Box 1. Criteria for Evaluation of Technologies and Measures

1. GHG and Other Environmental Consideration
- GHG Reduction Potential
  - -Tons of carbon equivalent
  - - % of IS92a baseline and range (IS92c-e)
- Other Environmental consideration
  - -Percentage Change in emissions of other gases/particulates
  - -Biodiversity, soil conservation, watershed management, indoor air quality, etc.

2. Economic and Social Considerations
- Cost-Effectiveness
  - - Average and marginal costs
- Project-Level Considerations
  - - Capital and operating costs, opportunity costs, incremental costs
- Macro-Economic Considerations
  - -GDP, jobs created or lost, effects on inflation or interest rates, implications for long-term development, foreign exchange and trade, other economic benefits or drawbacks
- Equity Considerations
  - -Different impacts on countries, income groups, or future generations

3. Administrative, Institutional and political Considerations
- Administrative Burden
  - -Institutional capabilities to undertake necessary information collection, monitoring, enforcement, permitting, etc.
- Political Considerations
  - - Capacity to pass through political and bureaucratic processes and sustain political support
  - - Consistency with other public policies
- Replicability
  - - Adaptability to different geographical and socio-economic-cultural settings.

How Important are CO_2 Emissions from Forests?

Forests:	**Carbon Flow (Gt C/yr)**
High and Mid Latitudes	0.7 +/ - 0.2
Low Latitudes	(1.6+/ - 0.4)
Energy	(5.5 +/- 0.2)

Global C that could be sequestered and conserved, and related costs (1995-2050)

Latitudinal Zone	Measure	C sequestered or conserved* (Gt C) (Col. 3)	Cost+ (US $/t C) (Col. 4)	Total cost (10^9 US$) (Col. 5)++
High	Forestation	2.4	8 (3-27)	17
Mid	Forestation	11.8	6 (1-29)	60
	Agroforestry	0.7	5	3
Low	Forestation	16.4	7 (3-26)	97
	Agroforestry	6.3	5 (2-12)	27
	Regeneration	11.5 - 28.7	2 (1-2)	**
	Slowing deforestation	10.8 - 20.8	2 (0.5-15)	44-97
	Total	60 - 87	3.7-4.6 (1-29)	250-300

Source: Based on data reported in SAR, Working Group II Report, Chapter 24 (SAR II, 24)

Table Notes

* Includes above- and below-ground vegetation, soil and litter C.

\+ Establishment or first cost (undiscounted). Average of estimates reported in the literature. Most estimates do not include land, infrastructure, protective fencing, education and training costs. Figures in parenthesis indicate the range of cost estimates.

++ Cost figures in Col. 4 are per tonne of *vegetation* carbon. Total costs (Col. 5) are thus lower than the figure obtained by multiplying t C in column 3 by $/t C in column 4.

** For slowing deforestation and enhancing regeneration combined.

Policies, Programs and Projects to Slow Deforestation and Assist Regeneration

Technical Options/Goals	Measures	Climate and Other Environmental Effects	Economic and Social Effects	Administrative, Institutional and Political Considerations
• Reduce slash and burn agriculture/ ranching • Increase field and satellite monitoring • Reduce forest fires	Enact forest conservation legislation (including bans on logging)	Maintain C density, up to 300 tC/ha Maintain biodiversity, soil conservation and watershed benefits.	- Low capital cost, high opportunity cost - Loss of agricultural and forestry jobs - Potential for equitable benefits depends on implementation approach	- High enforcement burden - Requires strong political support
• Improve boundary measures • Improve logging techniques	Eliminate subsidies for activities which encourage deforestation (cattle ranching, mining, agriculture, etc.)	As above	- Loss of sectoral jobs - Reduces government expenditure	- Low administrative costs - Strong opposition from vested interests

Slowing Deforestation and Assisting Regeneration

- **Causes of Deforestation:** Socio-economic and political pressures
- **Policies and Measures that can contribute to deforestation**
  - Short duration logging contracts
  - Royalty Structures
  - Land tenure policies
  - Settlement programs
  - Investments promoting dams and mining
  - Tax credits/deductions for cattle ranching
- **Examples of National Policies and Measures to Slow Deforestation/Assist Regeneration**
  - Brazil: Suspension of fiscal incentives for new ranching projects
  - India : Reforestation/Conservation policies and programs
  - Belize: Joint Implementation project

Policies, Programs and Projectsto Slow Deforestation and Assist Regeneration (Cont'd)

Technical Options/Goals	Measures	Climate and Other Environmental Effects	Economic and Social Effects	Administrative, Institutional and Political Considerations
• Reduce slash and burn agriculture/ ranching • Increase field and satellite monitoring • Reduce forest fires • Improve boundary measures • Improve logging techniques	Jointly implement projects with bilateral and multilateral funding (also applies to forestation and substitution management projects)	Maintain C density, up to 300 tC/ha -Potential for C trades Maintain biodiversity, soil conservation and watershed benefits.	- Concern regarding loss of sovereignty on land ownership - Increased foreign investment - Increased technology transfer	- Higher transaction costs - Lack of access to appropriate financing - Monitoring and verification uncertainty
	Promote sustainable forest management	As Above	-Higher operating costs beyond routine forest management - Sustained job creation - Monetary benefits from product sales may outweigh costs	Key requirements: - local commitment and participation - better defined tenure rights and improved forest management - Global initiatives such as ITTO can strengthen this approach

Policies, Programs and Projects to Slow Deforestation and Assist Regeneration (Cont'd)

Technical Options/ Goals	Measures	Climate and Other Environmental Effects	Economic and Social Effects	Administrative, Institutional and Political Considerations
• Fuel wood conservation and substitution - Improved stoves - Charcoal kilns	Investment incentives Government R&D&D&D Licensing/ regulation of standards	- Maintain C density, up to 300 tC/ha - Potential to reduce non-sustainably extracted share of 1.27 billion cubic meters of fuel wood	- Higher cost of efficient stoves - Creates sustained rural employment - Reduces women's drudgery and improves health - Reduces time and cost of gathering fuel wood	- Commercially and politically feasible - High replicability - Need to overcome cultural barriers -May require the establishment of formal markets for stoves
• Use of recycled and more efficient wood products	Tax incentives to industry Consumer awareness campaigns Labelling of Products	Maintain C density, up to 300 tC/ha Maintain biodiversity, soil conservation and watershed benefits - Recycling may require disposal of contaminants from treated wood products	- Cost of recycling and more efficient use is product specific. - Monetary benefit from more productive use of wood	- High replicability - Some administrative costs - Politically attractive

Forestation and Agroforestry

- Forestation and Agroforestry Measures include:
  - Government investment programs
  - Community forestry programs
  - Private plantations with financial and other government incentives
- National Programs
  - Successful programs require: coordinated land use strategy, unambiguous land tenure rights, sufficiently developed market for forest products
  - Government subsidies important to initiate and sustain private plantations
  - Examples: France and India
- Other Kinds of Forestation/Afforestation Projects
  - RUSAFOR JI project in Russia
  - Recuded Impact Logging project in Malaysia

Policies, Programs and Projects to Facilitate Adoption of Forestation and Agroforestry

Technical Options/ Goals	Measures	Climate and Other Environmental Effects	Economic and Social Effects	Administrative, Institutional and Political Considerations
• Production forestry/ agroforestry	- Promote programs on government owned land - Provide extension services for community or private forestry - Provide financial & other incentives for private plantations	- Up to 75 tC/ha in standing vegetation (additional C conservation from avoided harvesting of primary forest) - Agroforestry may have lower C density - Proper site & species selection needed for soil conservation and watershed benefits	- Capital cost $5-8 /tC - Other costs vary with type of land, soil quality and level of gov't intervention - Benefit from timber and non-timber product sales - Creates jobs - Reduces timber imports and hard currency outflow	Requires: - assured product markets - unambiguous land tenure rights - Institutions to provide extension services
•Conservation forests	- Managed for soil erosion, water catchment, windbreaks, microclimates, etc. - Managed for C sequestration	- High potential, up to 300 tC/ha, but C sequestration stops at maturity. - Has soil conservation, watershed benefits - Proper site & species selection needed for soil conservation and watershed benefits	- Capital cost $5-8 /tC - High opportunity cost of land - Can create rural jobs - Yields non-timber forest products - Capital cost as above, but may have low opportunity cost of land	Difficult to justify politically and sustain over the long term.

Substitution Management

- Forests as renewable resource to reduce fossil fuel carbon
- Greatest mitigation potential in the long term -- potential for bioenergy is very large
  - In OECD and Annex 1 countries excess cropland is available for bioenergy plantations.
  - In developing countries, bioenergy can provide electricity to rural areas
  - Substituting plantation wood for coal in the generation of electricity can avoid carbon emissions by an amount up to four times the carbon sequestered in the plantation.
- Appropriate government policies are needed to:
  - permit generation and distribution of electricity by small scale power producers
  - transfer technologies within a country or from outside
  - set a remunerative price for electricity
  - remove restrictions on growing, harvesting, transporting and processing of wood

Policies, Programs and Projects to Facilitate Adoption of Substitution Management

Technical Options/ Goals	Measures	Climate and Other Environmental Effects	Economic and Social Effects	Administrative, Institutional and Political Considerations
• Bioelectricity production from wasteland and degraded lands	Promotion and commercialization of biofuel (including biogas) Set appropriate energy prices based on cost of avoided energy	- Can avoid C emissions by an amount up to four times the C sequestered in the plantation - Can have soil conservation and watershed benefits - Biofuels/ bioelectricity generally have lower non-GHG emissions	- Capital cost of plantations is $5-8 /tC - Additional capital cost of bioenergy equipment - Low opportunity cost of land - Creates sustained rural employment and biomass opportunities - Also yields timber and non-timber forest products - May reduce fuel imports - Benefits may outweigh costs	- Requires - Energy pricing and marketing barriers need to be resolved - High potential for replicability - May need technology R&D and transfer

Carbon Conservation and Sequestration

- Potential land area for conservation and sequestration is estimated to be 700 Mha
- The total carbon that could be sequestered and conserved globally by 2050 on this land is 60-87 GtC.
- Slowing deforestation, assisting regeneration, forestation and agroforestry are the primary mitigation measures for carbon conservation and sequestration
- For long term success, enforcement to halt deforestation has to be accompanied by economic and/or other benefits to the deforesters that equal or exceed their current remuneration
- Making plantations a significant fuel for utility electricity generation will require higher biomass yeilds and thermal efficiency matching that of conventional plants
- Significant reduction of global carbon emissions requires national governments to institute measures that provide local, national, economic and other benefits while conserving and sequestering carbon

Policies, Programs and Projects to Facilitate Adoption of Substitution Management (Cont'd)

Technical Option/ Goals	Measures	Climate and Other Related Effects	Economic and Social Effects	Institutional, Administrative and Political Challenges
• Substituting sustainably grown wood for non-sustainably harvested wood and for non-wood products, (e.g., cement, steel, etc.)	Establish programs to: -Increase awareness -Increase availability of sustainably grown wood Provide tax incentives Institute wood industry policy to make its products technically and economically competitive with substitutes like steel, cement, coal, etc. Institute stumpage pricing policy favoring sustainably grown wood over substitutes	-Commensurate with the emissions avoided in the manufacture/harvest of substituted material or wood - Can have soil conservation and watershed benefits - Biofuels/ bioelectricity generally have lower non-GHG emissions	- Retooling and retraining costs - Loss of respective jobs - Creates sustained rural employment and biomass opportunities - Also yields timber and non-timber forest products - May reduce fuel imports - Benefits may outweigh costs	- Long-term product markets not assured

Prepared for

International Workshop on Greenhouse Gas Mitigation Technology Measurers
Beijing, China
12-15 November, 1996

The Role of Forestry Development in China in Alleviating Greenhouse Effects

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Abstract

Forestry development in China has gained great achievements and made great progress in realizing sustainable forest management and alleviating global climate change. The main measures to mitigate greenhouse effects through the means of forestry development include afforestation to increase the forested area, fuel wood forest development, management improvement, wise utilization, international cooperation, investment increase, forest related scientific research, strengthening the forest law enforcement system.

Climate change as well as how to alleviate the greenhouse effects is a hot topic at present. This paper describes the achievements of China's forestry development and its role to alleviate the greenhouse effects, and puts forward the measures to mitigate greenhouse effects through the means of forestry development.

1. The Achievements of Forestry Development in China

China, as the most populous and a developing country which is in shortage of forest resources, faces the dual tasks of economic development and environmental protection. On the basis of the national conditions, while advancing the modernization drive, China has taken a series of measures such as listing forest production, forestry development and "planting trees and making the country green" as a basic national policy and taking environmental, economic and social sustainable development as a significant strategy. At the same time, China has adopted a number of actions in the field of cultivation, protection and management of forest resources, development of key ecological forestry programmes, biodiversity protection, and wise utilization of forest resources.

The Government of China has decreed a series of laws, regulations and policies to enhance forestry development. China has also included forestry development into not only national economic and social development plan but also the agenda of leaders at various levels. Since 1990, China has implemented the "Nationwide Afforestation Plan Outlines 1989-2000" which was approved by the State Council. The principle of public participation in forestry and greening activities is adopted. As a result, the annual increase of plantated forest, aerial seeded forest, closing hills for natural regeneration and compulsory tree planting reaches 3.3 million ha, 1.1 million ha, 3 million ha, and 2 billion trees respectively. According to the 4th forest resources inventory conducted between 1989 and 1993, China has a total of 133.7 million ha. (of which 33.79 million ha. is planted forest, which ranks the 1st in the whole world) of forested area with a forest cover rate of 13.92% and the total standing stock volume of 11.785 billion cubic meters.

China has achieved "dual increases" in both the forest area and the forest stock volume, realized the objective of the total forest resources production greater than the total consumption and reversed the decreasing trend of the forest stock volume. All the barren mountains and hills in 12 provinces and autonomous regions in the country have been afforested. There are, in urban areas countrywide, 474,600 ha. horticultured and greened area and 57,90 ha. of public green area with urban greenery cover of 19.2%.

On the basis of attention paid to afforestation, the development of key afforestation programmes has been focused on and the results are fruitful. There are 10 key afforestation programmes across the country, including 6 key ongoing afforestation programmes of the Three-north Shelterbelt Development Programme, the Programme for Shelterbelt Development along the Upper and Middle Reaches of the Yangtze River, the Coastal Shelterbelt Development Programme, the Taihang Mountain Afforestation Programme, the Plain Farmland Shelterbelt Development Programme and the Programme to Combat Desertification and the 4 newly started key afforestation programmes of the Shelterbelt Development Programme along the Middle Reaches of the Yellow River, the Shelterbelt Development Programme in the Huaihe River and Taihu Lake Basin Area, the Shelterbelt Development Programme in the Pearl River Basin Area and the Shelterbelt Development Programme in the Liaobe River Basin Area. The land area of the 10 programmes accounts for 73.5% of the country's total, which covers the country's areas that are seriously influenced by water and soil erosion, wind and sand storms, typhoon and alkaline land. Up to now, these programmes have made great progress. Meanwhile, in a bid to protect the existing forest resources, especially the valuable natural forest, and to resolve the contradiction between timber supply and demand, the fast-growing and high-yield timber bases have been set up in suitable areas of the country, which have played a very important role in regard of economic benefits and ecological benefits.

In order to strengthen the protection and management of forest resources, all provinces, autonomous regions and municipalities across the country have set up a responsibility system for forest resources protection and development, And an allowable timber cut management system has been primarily established. The Government of China has decreed a number of laws and regulations such as the Forest Law, the Regulations on Forest Fire Management, the Regulations on the Prevention and Control of Forest Pests and Diseases and the Law for Protection of Wild Animals so as to prevent forest fire, to conservation and management of biodiversity and the scientific research as well as the forestry industry management has been enhanced.

2. The Contribution of Forestry Development in China to Alleviating Greenhouse Effects

In accordance with the 1990 statistics of Intergovernmental Panel on Climate Change (IPCC), the ground mean temperature has been increased by 0.3 to 0.6 degrees Celsius in the past 100 years. The ground mean temperature will be increased by 2.0 to 5.0 degrees Celsius until mid-21 st. century if carbon dioxide and other greenhouse gases keep the existing increase speed. In all the greenhouse gases, carbon dioxide accounts for 61%. But forest will play an active role to climate change through physiological and ecological processes.

2.1 Forest Absorbing and Fixing Carbon Dioxide but Releasing Oxygen

The matter exchange between forest and atmosphere is mainly the exchange of carbon dioxide and oxygen. Forest absorbs carbon dioxide and releases oxygen through photosynthesis of plants. This means that forest fixes and decreases the content of carbon dioxide in the atmosphere but provides and increases the content of oxygen in the atmosphere. Therefore, forest plays an important and irreplaceable role in keeping the dynamic balance of carbon dioxide and oxygen in the atmosphere, decreasing the greenhouse effects and providing the living conditions for human race. It is estimated that 90% of the carbon stored in the terrestrial ecosystem is stored in forest. The total carbon stored in forest worldwide is 400-700 billion tons and the carbon stored in fallen leaves and twigs as well as in soil is twice the figure of the carbon stored in forest. There are about 15 billion tons of carbon converted into timber through the form of carbon dioxide, which accounts for 50-70% of the total terrestrial growth quantity.

According to the research result of the sub-project of China Forest Resources Value Accounting Research of the State Science and Technology Commission project of Natural Resources Value Accounting, it needs 1.63 tons of carbon dioxide for forest to form one ton of dried matter, meanwhile 1.2 tons of oxygen can be released by using the photosynthesis formula. The annual volume increment of China's existing forest is 475 million cubic meters which is equivalent to 268 million tons of carbon dioxide and provides 322 million tons of oxygen. All of the forest in China stores 10.85 billion tons of carbon.

Based on the afforestation cost in China recently, it can be calculated at 1990 set price that to fix one ton of carbon takes 273.3 RMB Yuan as the afforestation cost and to provide one ton of oxygen takes 369.7 RMB Yuan as the afforestation cost. Therefore, it can be calculated that the total value by China's entire forest to fix carbon dioxide and provide oxygen is 119.432 billion RMB Yuan and 119.043 billion RMB Yuan respectively. From the above mentioned study, it can be calculated that the annual economic value of gases exchange (carbon dioxide and oxygen) between China's forest and atmosphere is 238.475 billion RMB Yuan which means that the annual per ha. forest can provide the economic value of 1,783.6 RMB Yuan. On the basis of 10% discount rate, the current value of China's forest resources in fixing carbon dioxide and providing oxygen is 11 times the annual value of forest in fixing carbon dioxide and providing oxygen. The above-mentioned current value is 2,623.203 billion RMB Yuan which means that the annual per ha forest can provide the economic value of 19,620 RMB Yuan.

2.2 Forest and Ozone Layer Protection

More and more attention has been paid to the global ozone layer depletion. Forest can effectively absorb nitrogen dioxide which is one the main chemical compounds destroying the ozone in stratosphere and reduces its flotation to stratosphere. It is reported that the potential of per ha. forest can absorb 0.38 tons of nitrogen dioxide. The sulfuric acid, hydrochloric acid and nitric acid in the atmosphere and vapor particles form vapor sol. Forest has a tremendous adsorb ability to particles and vapor sol. For instance, the adsorbability of the leaves of Common Papermulberry tree can reach as much as 20 grams per square meter. Additionally, forest can absorb a large amount of organic matter of chlorine and bromine as well as fluorine and sulfur dioxide so as to avoid their accumulation in the atmosphere. One pine tree can absorb 20 mg of sulfur dioxide from one cubic meter of air per day.

In summery, that afforestation, intensive management of forest, increase of forest cover and vegetation, enhancement of absorbing carbon dioxide through photosynthesis, wise harvest and utilization of forest, and increase of standing stock volume and its carbon reservoir, can greatly reduce the emission of greenhouse gases and the accumulation of carbon dioxide in the atmosphere so that forest development will play an important role to global warming and climate changes.

3. Development Strategy

Because of China's huge population, relatively backward economic development and scientific and technological level, and some other historic and social reasons, forest resources are in shortage, unevenly distributed and low quality, and their protection and management is seriously short of investment. As a result, the forestry development in China is relatively slow and falls far behind the demand of the national economic development and the environmental protection. In order to ensure the roles played by forest to improving the global climate and address the issues of deteriorated environment and increasingly economic demand, Chinese foresters have to make all possible efforts to the development of forestry.

3.1 To Enlarge Forested Area and to Protect Forest Resources

Forestry Action Plan for China's Agenda 21 puts forward the forestry development objectives of the establishment of "two systems", i.e. (1) Forestry ecological system which sets the following major goals. By 2000 increase the net forested area by 9.98 million ha. bring the forestry land utilization rate to 60% from 51%; raise the forest cover to 15.5% from 13.92% and bring the standing stock volume to 12.66 billion cubic meters resulting in a great increase of ecologically forested area. By 2010 increase the net forested area by 28.98 million ha, with a forest cover of 17.5% and raise the standing stock volume to 13.96 billion cubic meters. (2) Forestry industrial system which sets the following major goals; By 2000-- It is expected that the gross output value of forestry industries will reach 304 billion RMB Yuan from 180 billion RMB Yuan; the integrated utilization rate of timber will reach 60% from 40%; the output of wood-based panel will reach 8 million cubic meters from 6.5 million cubic meters and the output of wood pulp and paper will reach 1 million tons. By 2010--It is expected that the gross output value of forestry industries will reach 1 trillion RMB Yuan and the integrated utilization rate of timber will reach 80%. By mid-21st century, a relatively complete forestry ecological system and a quite developed forestry industrial system will be established and a modern administrative system and social service system will also be established. As a result of all of the above mentioned efforts, a sound nationwide ecological environment will take shape, which will play an active role to realizing the 3rd step strategic goals of national economic and social development.

3.2 To Enhance the Fuel Wood Forest Establishment and to Develop Clean Energy

Fueled wood forest is a renewable energy, when compared with fossil fuels, it does not or nearly not make pollution and it thus regarded as clean energy. In a bid to meet the demand of residents in both urban and countryside areas and reduce the pollution from buring coal, China puts forward a new idea of implementing the so-called "Forest Energy Project". It is planned that 3 million ha. of fuel wood forest will be established during the Ninth Five Year Plan . period and 6 million ha. will be established during the period of 2001-2010.

3.3 To Transform the Forestry Economic Increase Patterns, to Strengthen Management and Utilize Forest Resources Wisely

It is planned to transform the forestry economic increase patterns from quantity increase into quality and benefits-driven pattern. It is decided that forest will be classified into public forest and commercial forest, meanwhile, fast-growing plantations will be established. In view of present conditions of China, it is impossible to only pay attention to protection without utilization; it is also impossible to only pay attention to utilization without protection. Therefore, the forest classification management system will resolve the contradiction between protection and utilization of forest resources so that the forest resources will be progressively increased on the basis of keeping the forest ecosystem stable.

3.4 To Carry out International Cooperation

China's environmental protection influences not only its own destiny but also the global future, Challenged by the issues of global climate changes and environmental deterioration, it is necessary to have global cooperation on these issues. China will contiguously carry out the open policy to the outside world, and will actively advance the international cooperation through various ways such as bilateral, multilateral, NGOs and internation seminars. At the same time, attention will be paid to introduction of technology and sharing project management experience so as to lift China's position and influence to a higher level in global environment and development.

3.5 To Raise Funds from Various Sources

It is estimated that the total investment to forestry development during the Ninth Five-Year Plan period will be 143.974 billion RMB Yuan, of which the investment to afforestation and forest management will be 41.998 billion RMB Yuan. A diversified investment mechanism for protecting forest resources and improving the environment will be set up. The government-guided investment policies relying upon the whole society and supplemented by bank credits will be developed. It is necessary to increase the government inputs, to introduce foreign funds including grants and preferential loans.

3.6 To Strengthen the Research on the Linkages Between Forestry and Climate Change

It is quite necessary to strengthen the theoretical research on the linkages between forestry and climate change, bring forestry scientific and technological results into forestry production, improve the construction of scientific research and production facilities, consolidate and improve the scientific research and production, extension and technological monitoring system, strengthen the training of personnel on forestry, and improve the training network and training system.

3.7 To Improve the Forestry Law Enforcement Network

It is necessary to revise and inprove the Forest Law and related statutes, study and enact the regulations of property management of forest resources, compensation mechanism to pay the ecological benefits, and establish and improve law enforcement procedures and systems. It is also indispensable to strengthen the development of the forestry law enforcement organizations, to stabilize the legislative staff for forestry, and enhance the development of staff force of forest police, rangers and forest fire fighters so as to guarantee the steady increase of forest resources.

Forest is an important component of human beings and ecological environment. Only with the efforts devoted by the whole society and mankind can forest sustainable management and environmental protection be ensured. Let us try our concerted efforts to make our future brighter.

GREENHOUSE GAS MITIGATION OPTIONS IN THE FORESTRY SECTOR OF THE GAMBIA:

ANALYSIS BASED ON COMAP MODEL

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NATIONAL CLIMATE COMMITTEE OF THE GAMBIA

Results of the 1993 Greenhouse Gas Emissions Inventory of The Gambia showed net CO_2 emissions of over $1.65*10^6$ tons of CO_2 from the Land Use Change and Forestry sector of the country. About 99% of these net emissions came from forest clearing ($1.66*10^6$ tons) and 1% was due to uptake by plantations ($0.01*10^6$ tons). This is a clear indication that there is need to identify changes in the land-use policy, law and tenure that discourages forest clearing at the same time significantly influencing the sustainable distribution of land among forestry, rangeland and livestock, and agriculture. About 11% of the total area of The Gambia is either fallow or barren flats that once supported vegetation and hence is still capable of supporting vegetation.

The US Country Study Programme has provided the Government of The Gambia through the National Climate Committee funds to conduct Assessment of Mitigation Options to Reduce Greenhouse Gas Emissions. The Forestry Sector is one area for which assessment is being conducted. The assessment is expected to end in September 1996. The Comprehensive Mitigation Analysis Process (COMAP) is one of the Models supplied to the National Climate Committee by the Lawrence Berkeley Laboratory, on behalf of the US Country Study Programme, and is being used to conduct the analysis in The Gambia.

COMAP is intended to guide and analysts in undertaking a comprehensive assessment of the role of the forest sector in a country's climate change mitigation effort. The following steps are involved:

* identifying and screening mitigation options that are significant to the country;
* assessment of the availability of land suitable for supporting biomass growth for carbon sequestration;
* identifying those options which could be implemented on the available land;
* estimation of quantity of emissions reduced and/or quantity of carbon sequestered per unit area for each mitigation option;
* estimation of total and unit costs and benefits for each option;
* development of baseline and future net greenhouse gas emissions and cost scenarios;
* evaluation of the cost-effectiveness of the mitigation options; and

* exploring policies, institutional arrangements, and incentives necessary for the implementation of the options.

The first three steps of the analysis have been accomplished and a literature review of the policies and institutional arrangements have been conducted.

Because of the present strategy adopted by the Government of The Gambia in planning for the implementation of the International Conventions on Biodiversity, Climate Change and Desertification, establishment of single species plantations (e.g., fruit tree plantation) does not rate as the most beneficial mitigation option judging from the benefits gained by local people, in addition to carbon sequestration. Maintenance and development of community based natural forest plantations and reserves are surfacing as most beneficial, considering the benefits of conservation of genetics and species diversity as encouraged and promoted by the Convention on Biodiversity, as complementary to other local benefits such as collection of fuelwood. Through the strategy the community sees itself as the custodian of the forest and hence any benefits that arise from maintaining the forest.

These ideas will guide us and will serve as inputs to the next step of the study which concerns the development of the mitigation scenarios followed by the analysis of the mitigation options. A large pool of potential mitigation options have been identified and these are centered around:

* establishment of fuelwood plantation of most appropriate species;
* establishment of fruit tree plantations at village level;
* agroforestry practices in the backyard of villages and in farms, and
* Replication of Community Forest Management in the various districts and reintroducing indigenous species that are on the verge of being extinct.

Establishment of Forest Products Industry is being considered in the long-term for the marketing of products from these plantations and community forests. This idea is meant to make the mitigation options sustainable in the future.

In the analysis of the identified options, greenhouse gas flows and carbon sequestrated will be estimated for each option. The analysis will be based on historical data of regeneration rates gathered from the Department of Forestry for most of the biomass species being considered. The COPATH Model, also supplied by LBL on behalf of the USCSP, will be used to track carbon flows. The COPATH Model provides a coherent framework for tracking all the carbon flows for each mitigation scenario and is based on the LOTUS 123 Spreadsheet.

Costs and Benefits of the Mitigation Options will be evaluated based on physical, socio-economic, and other environmental factors so as to make exhaustive comparison of all identified options. Evaluation will include initial cost, endowment requirements, net present value, benefits of reducing atmospheric carbon, and inputted and non-monetary costs and benefits.

Possible risks and barriers to implementation of the mitigation options have been identified. Land availability is no barrier because of the present community based forest policy of the government and the general awareness of the need to maintain a healthy environment at the grassroots level.

Man power resources will be a barrier to development and implementation of mitigation options. The National Climate Committee has identified NGOs (also members of the National Climate Committee - thanks to AMERICAN FORESTS, and American NGO) as the institutions that should take the lead in implementing forest mitigation options because of the wealth of experience they have earned in working with grassroots-level communities. However, NGOs in The Gambia had, until recently little or no exposure to climate change issues. This institutional barrier will have to be addressed for effective implementation of the options.

The mitigation options that will be more beneficial and cost effective will be developed into Forest Mitigation Projects to be included in the National Action Plan to Mitigate Greenhouse Gas Concentrations in the Atmosphere. This Action will form part of Gambia's National Communications to United Nations Framework Convention to Climate Change.

Project Identification for Methane Reduction Options

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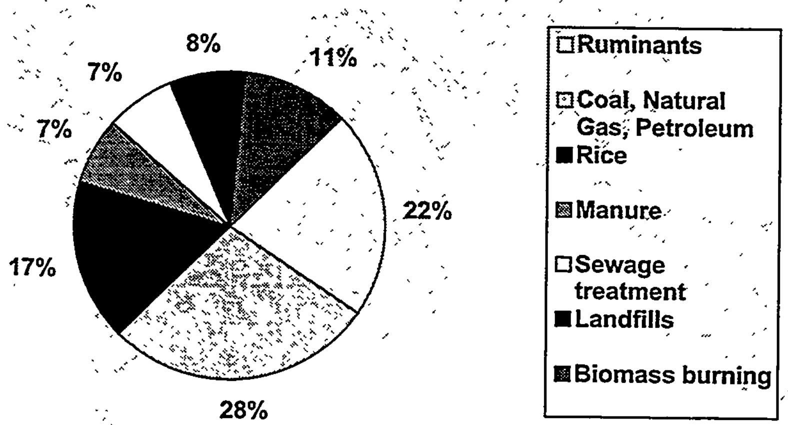
Program Overview

- Benefits of Methane Reduction
- Barriers to Overcome
- Guidance Documents - Landfills, Coal Mines, and Livestock
- Goal: Provide Technical Assistance That Leads to Concrete Project Proposals

Environmental Benefits Rapid Results

- Methane is a potent greenhouse gas
  - GWP is 24.5 over 100 years
  - 10% reduction - stabilization at current level
  - 20 year time frame CH_4 similar to CO_2
- Methane causes other problems
  - Contributes to urban smog
  - Longer lifetime of air toxics

Global Anthropogenic Methane Sources



Barriers to Overcome

- ◆ Informational

- ◆ Institutional

- ◆ Technical

- ◆ Financial

Guidance Documents

- ◆ Landfill methane recovery
- ◆ Coalbed methane recovery
- ◆ Livestock methane reduction
  - Ruminant methane reduction
  - Manure methane recovery

Landfill Gas-to-Energy

- Can recover and use 50-90% of methane
- Many low-cost options
- Uses include: power generation, steam heating and cooling, brick ovens, cement kilns
- Demonstration LFG-to-energy project exists in Taiwan; begin to replicate

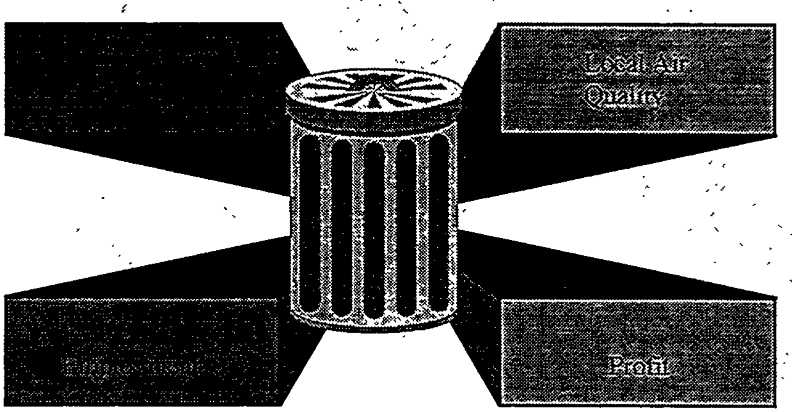
Methane Energy Recovery at Coal Mines

- Silesian Basin mines recover about 30% of methane released, 80% of which is used
- Uses - heating, drying coal, desalinization and power generation
- Polish mines could increase recovery to 60% with improved technologies
- 0.3 Tg total reductions possible in Poland
- Staszic mine, 1993 - 18.9MM^3 released, new system recovers 2.1 MM^3 uses 2.0MM^3

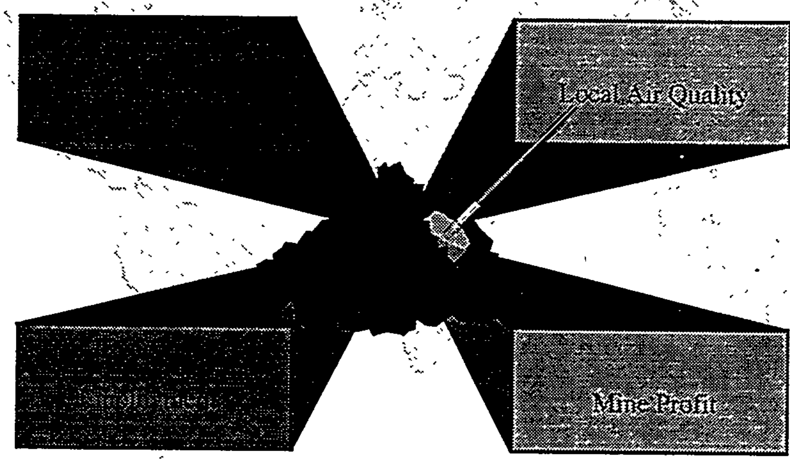
Methane Energy Recovery from Manure

- Methane recovery technologies low-cost and widely available
- Mexican farm with 700 sows produces 230 t CH_4 from manure
- Methane recovery system for $125,000 would offset annual farm energy costs at $38,000 in just 3.5 years

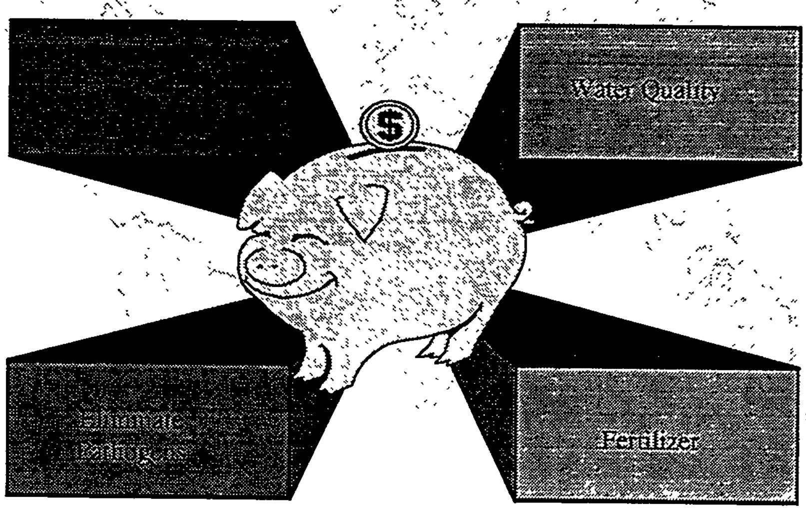
Landfills - Other Benefits



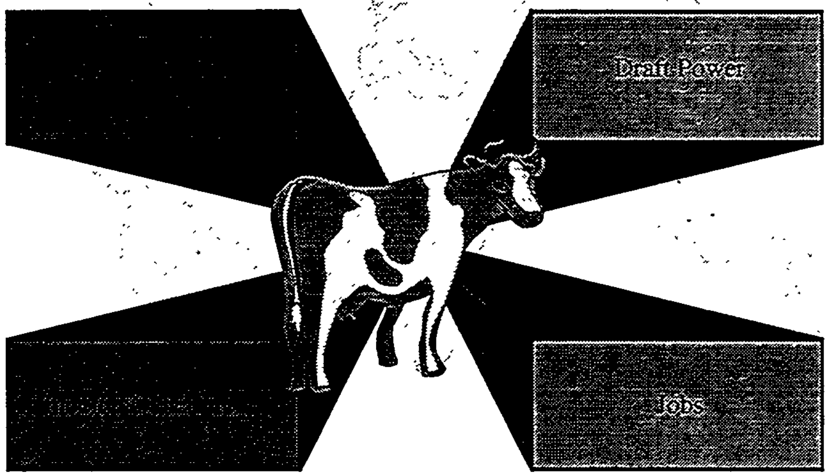
Coal Mines - Other Benefits



Manure - Other Benefits



Ruminant Livestock - Other Benefits



Next Steps

- Determine size of methane resources
- Form in-country work group(s)
- Identify project opportunities using EPA guidance document and technical assistance
- Design pilot project(s)
- Conduct economic assessment(s)
- Draft project proposal(s)

International Workshop on Greenhouse Gas Mitigation Technology Measurers
Beijing, China
12-15 November, 1996

Exploiting Coalbed Methane and Protecting the Global Environment

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ABSTRACT

The global climate change caused by greenhouse gases(GHGs) emission has received wide attention from all countries in the world. Global environmental protection as a common problem has confronted the human being.

As a main component of coalbed methane, methane is an important factor influencing the production safety of coal mine and threatens the lives of miner. The recent research on environment science shows that methane is a very harmful GHG. Although methane gas has very little proportion in the GHGs emission and its stayed period is also very short, it has very obvious impact on the climate change. From the estimation, methane emission in the coal-mining process is only 10% of the total emission from human's activities. As a clean energy, Methane has mature recovery technique before, during and after the process of mining. Thus, coalbed methane is the sole GHG generated in the human's activities and being possible to be reclaimed and utilized. Compared with the global greenhouse effect of other GHGs emission abatement, coalbed methane emission abatement can be done in very low cost with many other benefits:

1) to protect global environment;
2) to improve obviously the safety of coal mine;
3) to obtain a new kind of clean energy.

Coal is the main energy in China, and coalbed contains very rich methane. According to the exploration result in recent years, about 30000~35000 billion m^2 methane is contained in the coalbed below 2000 m in depth. China has formed a good development base in the field of reclamation and utilization of coalbed methane. We hope that wider international technical exchange and cooperation in the field will be carried out.

The major ingredient of coalbed methane is methane. It is a kind of mineral resources generated with coal and absorbed in the coalbed. From the viewpoint of safe production of coal, methane is always an important factor to threaten to the miner's lives and production safety of coal mine. So before the 80s, the goal of draining coalbed methane is to ensure safety of production. In recent years, some environment protection science researchers had done many deep researches on the global climate change. Research results affirmed that many reasons caused global climate change, while the major reason lay in the great increase of CO_2, CH_4 and other GHGs in the atmosphere coming from human's activities. Other research also attested that methane was a fierce GHG, whose function is 20 times than that of CO_2 if according to there mass. Furthermore, methane gas can be kept in the atmosphere for over 20 years, while CO_2 is over 200 years, that is to say, the climate change caused by CO_2 was accumulated during a period of one or two centuries, but that of methane was formed in recent over teen years after it is emitted to atmosphere. Recent observation data of atmosphere show that methane concentration in atmosphere has increased over one time during the past 300 years, and still increased by 10% per year at present.

Thus, there will be very apparent recent effect to alleviate global climate change through abating emission of methane.

Estimated on the basis of GHGs emission, methane emission in the coal-mining process is only 10% of the total emission from human's activities. However, mature reclamation techniques before, during or after the process of coal-mining has been developed so that coalbed methane is the only one kind of GHGs which can be reclaimed and utilized with large scale. As a kind of clean fuel, methane will not generate SO_2, smoke and dust while burning, and CO_2 emission is also only one half of coal-burning. Counted by the calorie value generated, per 1000 cubic meter methane gas can generate the same heat as one ton tce. Because its efficiency is as high as four times of coal-burning, energy conservation effect will be very obvious if it was used for fuel.

With 1000 billion ton of explored coal reserve volume and very rich coalbed methane, China is a country using coal as main energy. According to the information from geological exploration sectors, the method of coal production in China mainly adopts down-well mining. Before the 1980s, the drainage of coalbed methane aimed at the safety of coal mine. With the development of technologies and improvement of environmental protection awareness of human being, the exploitation and utilization of coalbed methane has made an active progress. At present, down-well drainage techniques have been developed to suit for different complex geological situation and different coal mining surrounding. These techniques include pre-drainage in mining bed, in neighboring bed and empty channel, and so on. Commercial tests for drilling on surface to drain coalbed methane previously have also been carried out in part of mines.

During the 1980s, China had achieved a great progress in the fields of coalbed methane drainage and utilization. Drainage volume of coalbed methane increased every year, as showed in the following table.

Year	No. of drained mine wells	Drained volume (100 million m^3)
1977	58	2.32
1980	102	3.00
1984	108	3.39
1990	110	4.30
1992	118	5.34
1994	146	5.64

Note: the concentration of coalbed methane is 100%.

In 1994, 564 million m^3 methane had been drained from coal bed in China. However, the ratio of drainage is only about 20%. It is because:

1) The penetrability of coal bed is very low in China. Most of coalbed are only 0.09~0.001 Md. The better are 0.8~3.2 Md., but these situations are very little. Penetrability is a key argument to express the difficulty degree of drainage, so it is the main reason for low drainage ratio.

2) Down-well drainage is the only drainage way at present in China. The advantage of this method is to be able to use all kind of beneficial surrounding in the coal production such as technical force, equipment, funds and so on. However, the channel digging, coal mining and drainage ratio of coalbed methane vary very greatly, and many other influencing factors exist, so it often results in unmatching proportion, no enough time and location for drainage so as to cause low drainage ratio.

3) Unitary drainage technique, backward and old-fashion equipment, no enough fund-input are the common phenomenon in the process of coalbed methane drainage. How to solve these problems is the key to improve drainage ratio.

From the above table about coalbed methane drainage, we can see that the number of mine draining coalbed methane had a great increase after 1980, while drainage volume was not increased. Therefore, the above three problems bound the development of coalbed methane in China, so that they have to be overcome. State Science and Technology Committee(SSTC) attached great importance to drainage and utilization of coalbed methane so as to abate GHGs and protect global environment. Special fund was allocated to carry out research on the above problems. After three years' hard work and cooperation of related sectors, the research, argument and commercial test on how to improve drainage ratio under the condition of low penetrability had been completed, and checked and accepted by SSTC. Contrastive tests show that drainage ratio of 18% can be achieved by traditional method while that is over 36% by new way, which can reach international advanced level. Meanwhile, according to the requirement of SSTC, a set of techniques, technologies and equipment have been put forward. It can be predicted if the new technologies and equipment are adopted in all down-well coalbed methane drainage mines, the total drainage volume of coalbed methane will be doubled and it will bring us remarkable environmental and economic benefits.

The following will introduce China's international cooperation situation in the field of exploiting coalbed methane.

Large-scale cooperation was firstly carried out by the support of Global Environment Fund(GEF) of World Bank. In the program, 10million US$ was supplied by WB, while China inputted 64 million Yuan(RMB). The program includes four parts, all of which are making their progress at present.

1. Project on assessment of coalbed methane resources
   The concrete content is, by combination of technologies and methods aboard with those of home, to determine development potential of China's coalbed methane, work out long-term development planning, build up resources database. All these are technical foundation for the future large-scale development.

2. Coalbed methane drainage project in Songzao coal mine, Sichuan province
   It includes integrated technical demonstration on down-well drainage according to geological situation, and improving automatic supervisor and control system of

drainage network. It is aiming at reaching international advanced level in the field of down-well drainage of coalbed methane.

3. Coalbed methane drainage project in Kainuan coal mine, Hebei province
   Through the way of commercial test, the research focuses mainly on using surface drilling and water pressure squeezing and other techniques to drain coalbed methane from coalbed with low penetrability. It intends to make some basis works for large-scale coalbed methane exploitation in whole country.

4. Integrated coalbed methane drainage project in Tiefa coal mine, Liaoling province
   Because of excellent geological situation of the coal mine suiting for large-scale development of coalbed methane, the project uses technology and equipment for down-well horizontal directionating long drilling hole to drain coalbed methane along the direction of coal bed, and surface drilling technology to drain coalbed methane in the empty area according to the characteristic of rich coalbed methane in empty area. The present progress of the project shows that notable effect will be gained after the completion of the project.

Excluding the above international cooperation projects on coalbed methane exploitation, other mines with rich coalbed methane, for example, Jinchen, Lu'an and Xishan mine of Shanxi province, Huainan mine of Anhui province, Pindingshan mine of Henan province, have signed cooperation agreements with overseas companies with powerful technical force. According to the above analysis, we are sure to say that great progress will be made for the development of China's coalbed methane in recent period.

Drainage and utilization of coalbed methane is a new international domain arising in recent years, and a field associated tightly with global environment protection, too. China has made the first step in this field, and laid down a good foundation for the development. Along with exploitation and utilization of coalbed methane, some other benefits can also be gained such as global environmental protection, apparent improvement of safety production situation of coal mine, and being able to obtain a new kind of clean energy and so on. We hope that technical exchange and economic cooperation will be widely carried out in the field.

Prepared for

International Workshop on Greenhouse Gas Mitigation Technology Measurers
Beijing, China
12-15 November, 1996

Methane Recovery from Landfill in China

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Abstract

GEF has approved a special project for a demonstration project for Methane Recovery from the Urban Refuse Land Fill. This paper will introduce the possibility of GHG reduction from the landfill in China, describe the activities of the GEF project, and the priorities for international copperation in this field.

The Global Environment Facility (GEF) approved the project, China Promoting Methane Recovery and Unlization from Mixed Municipal Refuse, at its Council meeting in last April. This project is the first one supported by international organization in this field.

Contribution to Global Warming Mitigation

It is now well known that human activities have been substantially increasing the atmospheric concentrations of greenhouse gas (GHG) and causing global warming. As an active member of internaitonal community, China signed the UN Framework Convention on Climate Change (FCCC) in 1992 in Rio de Janeiro and ratified it on January 1993, among the first ten countries to ratify the Convention pledging the commtment of global efforts towards sustainable development.

Methane is one of the most significant GHGs that is about 22 times more potent than carbon dioxide on a mass basis in causing global warrming. Anaerobic digestion in landfills is one of important methane sources.

Since that over 70% of China's energy supply derives from coal-burning, and this share is not expected to change significantly in the near future, thus global warming can be mitigated by methane recovery and utilization from landfills in three ways: to reduce methane emission from landfills; to decrease escape of methane from coal mining operations; and to reduce carbon dioxide from coal combustion of power plant and direct use as fuel, offset to a smaller extent by increased carbon dioxide emissions from methane combustion at landfills.

The anaerobic digestion of the biodegradable material in the solid waste releases landfill gas, about half of which is methane. It is estimated that methane emission from municipal waste in China is in excess 1.5 billion cubic meters per year. In comparison with China's stagnant natural gas production in 1993 of 17 billion cubic meters, the landfill methane emissions amount to a not insignificant figure of 8.8%. If the emitted methane could be collected and utilized, the significant effect of global warming mitigation would have been achieved.

Benefit to Local Environment and Development

With the process of economic reform, urbanization in China is proceeding at a rapid pace. At the beginning of the 1980's, there were fewer than 300 cities and only 12 percent of the national population was classified as urban. In 1994, there were 610 cities and around 30 percent of the national population was classified as urban. It is estimated that there will be around 800 cities and 40 percent of the population will be living in urban areas by year 2000.

Amount of municipal refuse is quickly increasing in China as dramatic urbanization and population growth. It was reported that by 1988, 6.6 billion tonnes of untreated waste had accumulated, occupying 55,400 hectares of land[1]. The disposed municipal refuse reached 120 million tonnes in 1993, and the total amount of the refuse produced per year is increasing at an annual rate of 6-7%. At present, two thirds of cities are surrounded by garbage[2].

Few landfills in China meet construction and environmental standards. Most China's waste sites are open pits located on urban fringes, in stream or river valleys or on "marginal lands" such as wetlands where mixed municipal wastes are deposited. This uncontrolled dumping constitutes breeding grounds for mosquitoes, other disease spreading insects, and rats. Ground water and drinking water aquifers are severely polluted in these areas, odors and trace toxic gases affect the health of the surrounding population, and the land has been rendered useless for other purposes. The release of photo-reactive hydrocarbons from landfill gas emissions is known to cause photochemical smog. Methane leaks through soil have been known to have caused dozens of fatalities in China in recent years.

In addition to caused pollutions mentioned above, accidents such as methane explosion occur from time to time due to poor management of municipal refuse, which bring about considerable economic loss and some personal injuries and deaths.

Thus, recovery and utilization methane from landfill benefit to both environmental quality improvement and economic development, even personal safety.

Possibility of the Project's Successeful Implementation

Severe pollution resulted in by poor management of municipal refuse has drawn great attention of China's government. The Solid Waste Pollution Prevention and Control Law was adopted in October 1995 and entered into force on April 1, 1996. It sets the following basic principles for solid waste management: 1) comprehensive management starting from generation, collection and transport to disposal and treatment; 2) maximization of recycling and utilizaiton of solid wastes as a resource; and 3) promotion of centralized disposal and treatment of solid wastes.

Following the Central Government's law and regulation local governments actively conduct research on and construction of municipal refuse landfill, and persue methane recovery and utilization from landfill. Pledge to provide around US $ 11.26 million equivalent cofinancing for the approved GEF project at the pilot cities illustrates these governments' initiative. This indicates that the project is a real "Country Driven" project.

Swift urbanization and population growth mentioned above, though are not very positive factors to economic development on the one hand, substantially increase the annual amount of municipal refuse year by year, on the other hand.

Rising incomes have led to higher personal consumption, which is changing the composition of the municipal waste. Previously 80% of urban solid waste was industrial in nature, mostly coal waste materials, and though the non-organic proportion of urban waste remains high, an increasing percentage is now composed of biodegradable material due to rising waste from households and restaurants and other commercial establishments.

All these make the project be of high demonstration value throughout China.

Methane harvesting from solid waste landfills in industrialized countries is mature practice. Gas from a landfill in New York is upgraded to pipeline quality and used to provide energy equivalent for heating 10,000 homes in winter. The largest US waste management firms routinely recover and use the landfill gas from all of their sites as soon as they are closed. A large landfill located in a canyon in Los Angeles accepts about 12,000 tonnes of refuse per day. Since 1987 its landfill gas has been used to generate several million kWh per year of electricity in a power plant built on site. Landfill gas recovery is actively encouraged in the US as public policy, there has been a tax incentive in place for several years for each unit of energy recovered, and soon gas recovery will be mandated for certain landifills. Methane recovery projects are being operated in many countries including Germany, UK, Sweden, France, Denmark, Japan, Brazil, and Chile. Assistance on advanced technology and equipment from these countries will help the GEF project to be implemented successfully.

However, there are two types of barriers to the practice of landfill gas capture and methane gas utilizaiton in China. The first barrier is technological since this practice has not been attempted earlier in China. Lack of any access to information on landfill gas recovery technology, lack of experience of designing, construction and operating gas recovery plants, and high costs of imported technology are some of the technical barriers that this project will address. The Chinese need to gain experience with pipe design, layout, removal of moisture and non-methane components, managing surges in gas supply, etc. The second type of barrier is institutional management of landfill gas resource in China because of lack of definition of institutional responsibility and resource ownership. It is unclear at to who owns the resource, and how the municipal, provincial and national institutions should cooperate with private industry and the households to harvest this resource to everyone's benefit. The formulation of specific laws and regulations that may govern such relations are yet to be developed fully and systematically. The current municipal waste management systems and operational mechanism cannot meet requirements of the market economy.

The Project's Activities

This GEF funded project for landfill methane recovery and utillzation will directly support the country's effort through the demonstration of new energy effecient technology and removal of institutional barriers to effective utilization of methane from municipal refuse landfill.

These barriers will be overcome by:

- gainging experience in identifying, designing, constructing and operating landfill gas recovery and utilization plants in China by constructing and operating pilot plants in different site with different characteristics;
- training national staff to undertake the above functions over time;
- building capacity through experiences gained, and bringing in conditions that will promote indigenous enterprises that will build and operate recovery systems and utilize energy. Domestic manufacturing of equipment will aim at lowering the costs of technology;
- promoting its acceptance among local decision makers and demonstrate it as a viable measure that produces energy as well as reduces air, water and land pollution. This will create essential incentives to develop further institutional and legal framework related to landfill gas recovery technologies;
- developing an action plan based on the experience from pilot plant, to promote widespread replication and adoption of landfill gas recovery technology in China;

- strengthening existing national institutes to enable them to disseminate the knowledge and techniques learned during this project.

The project mainly consists of four activites:

- Determine the best methods for efficient extraction of gas from landfills and the most appropriate energy utilization technology and equipment. Information gathered at this stage will be useful for both pilot site plant designs and for the action plan to be developed in the next stage.
- Design, construct, and operare of selected piot landfill gas recovery facilities. Based on the pre-study, three pilot sites have been selected, they are Anshan in Liaoning Province, Nanjing in Jiangsu Province, and Maanshan in Anhui Province. Demonstration of all needed aspects will be conducted at these three sites to promote methane recovery and utilization, including technology, management, regulation and policy, financing mechanism, etc.
- Strengthen the National Center for Methane Recovery Research and Dissemination. This facility will be the primary means to train personnel from cities interested in building methane recovery plants. It will disseminate knowledge, experience and techniques obtained during this project, and later, to all areas of China and other developing countries. It will keep up with world development, set up regular training programs, and manage a resource of reports, software packages, videos, and other materials from around the world. Studies on related technology, environmental and economic policies, and supervision and management might be also conducted at the Center.
- Develop an Action Plan to promote widespread adoption of landfill gas recovery technology. The action plan will have the following major elements formulating national policy, regulations and standards for methane recovery from sanitary landfills; establishing financial aid or other incentive policy for municipalities to adopt methane recovery system; providing technical assistance to municipalities and private sector entrepreneurs in the planning, design, construction, and operation of methane recovery systems.
- According to the project design, when the three landfills constructed in the pilot cities are full, the amount of landfill gas captured at those three sites would be approximately 518 million cubic meters per year.

Follow-up International Cooperation

China's Ninth Five-Year Plan for Economic and Social Development (1996-2000) sets a goal to reach 50% of environmental sound treatment rate of municipal refuse by the year 2000[3]. China National Envionmental Protection Agency (NEPA) formulated the China Trans-Century Green Program to mobilize domestic and international resources to achieve this goal. Within the Phase I (1995-2000) of the program, near 800 million US Dollars are targeted for municipal refuse disposal and treatment, accounting for 32% of the funding for pollution prevention and control of solid waste within the program. The annual environmental sound treatment amount of mumicipal refuse will be increased by 16 million tonnes after the phase I of the program is completed[4].

In order to achieve the targests, at least following two aspects of international aids are needed to make the GEF project's activities be sustainable.

1) to further perfect financing mechanism and develop economic and environmental regulations and policies to promote in dependent company's "health" operation;
2) to commercialize imported and/or domestic equipment used in methane recovery and utilization facility.

[1] The World Bank, "China Environment Strategy Paper", 1992

[2] Xie Zhenhua, "Notes on the draft of the Solid Waste Polution Prevention and Control Law of the People's Republic of China, 1996

[3] Xie Zhenhua, Report at the Fourth National Environmental Protection Conference, 1996

[4] NEPA, "China Trans Century Green Program", 1996

MITIGATION OPTIONS FOR METHANE EMISSIONS FROM RICE FIELDS IN THE PHILIPPINES

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Abstract

The contribution of Philippine rice production to global methane emission and breakthroughs in methane emission studies conducted in the country are presented in this paper. A significant impact in the reduction of GHG emissions from agriculture can be achieved if methane emissions form ricefields can be abated. Methane emissions from ricefield was calculated using the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories. Results of studies in Maligaya and Los Banos under the IRRI-UNDP Interregional Research Programme on Methane Emission from Ricefields are discussed and evaluated for possible mitigation options. This study presents the contribution of Philippine rice cultivation to global methane emission and breakthroughs in methane emission studies in the country which address the issue of mitigation.

Using the derived emission factors from local measurements, rice cultivation contributes 566.6 Gg of methane emission in the Philippines. This value is 62% of the total methane emitted from the agriculture sector. The emission factors employed which are 78% of the IPCC value for irrigated rice and 95% for rainfed rice were derived from measurements with an automatic system taken during the growth duration in the respective ecosystems.

Plots drained for 2 weeks at midtillering and before harvest gave a significant reduction in methane emission as opposed to continuously flooded plots and plots drained before harvest. The cultivar Magat reduced methane emission by 50% as compared to the check variety IR72. The application of ammonium sulfate instead of urea reduced methane emission by 10% to 34%. Addition of 6 t ha-1 phosphogypsum in combination with urea reduced emission by 74% as opposed to plots applied with urea alone.

Methane emission studies conducted in Maligaya and Los Banos were designed to estimate possible contribution of rice to methane emission in the light of dominant agricultural practices or farmers technology. It is also from the results of such measurements that abatement strategies are based as regards to modifying treatments such as water management, fertilization, and choice of rice variety. It is not easy to identify and recommend mitigation strategies that will fit a particular cropping system. However, the identified mitigation options provide focus for the abatement of methane emission from ricefields.

Modifying cultural practices and the use of certain cultivars mitigate methane eimssions without reducing rice yields. Because of a large variation in climate, soil properties, pattern of flooding, and amendments in rice cultivation mitigation options are site specific.

Introduction:

Rice is the most important and dominant commodity within the agriculture sector and the economy in general. It is the staple food of over 80% of the country's population and the main source of carbohydrates and protein. About 70% of the population depend on rice cultivation and marketing for their livelihood.

The Philippines has attained an impressive growth rates in rice production during the late 1970s; this growth allowed the country to meet the needs of the growing population. In 1993, the country produced 9.3 million tons of rice from a total area of 3.2 million hectares. The national yield average during the 90's was computed at 2.8 tons per hectare. This yield is 16% higher than the average yield during the '80s. Trends in Philippine rice production from 1975 to 1991 indicate that the area dedicated to rice production is decreasing by 0.59% while the yield level is growing by 2.93%. Rice production growth rate is 2.33% which is almost similar to population growth rate of 2.4%. Rice consumption has increased by an average of 3% per annum from 4.4 million mt in 1980 to 5.8 million mt in 1989. The current estimate of per capita rice consumption (based on the disappearance method) is 97 kg per year.

Inventory of GHG from Rice Production

Rice fields are considered major source of atmospheric methane which is a greenhouse gas. Flooding a ricefield cuts off the oxygen supply from the atmosphere to the soil which results in anaerobic fermentation of soil organic matter. Methane is a major end product of the processs.

A. Data Source

The distribution of rice production areas between irrigated and rainfed ecosystems is presented in Table 1. During the last ten years (1983-93), mean area devoted to irrigated rice is 1.9 million hectares while rainfed area is 1.4 million hectares.

Table 1. Rice production area ('000 hectares) in the Philippines by ecosystem (1983-93).

Year	Total	Irrigated	Rainfed
1983	3141	1688	1473
1984	3222	1755	1467
1985	3403	1838	1565
1986	3403	1878	1525
1987	3256	1852	1404
1988	3393	1956	1437
1989	3497	2064	1433
1990	3319	2010	1309
1991	3425	2060	1365
1992	3198	1980	1218
1993	3450	2017	1433
Mean	3337	1916	1421

Source: World Rice Statistics 1993-94, IRRI.

B. Methodology

Methane emission from rice fields were calculated using the IPCC Guidelines for National Greenhouse Gas Inventories. Estimated emissions from ricefields were obtained by multiplying the "composite emission factor" by an extrapolant which is equivalent to the product of the rice area harvested per year and the fraction of the year the fields are planted to rice.

Default emission factors, as proposed by IPCC, consider only the effect of temperature and water management. Output of research, however, revealed that other major controlling factors influence methane emission from rice field. These factors include organic and inorganic inputs (fertilizer management) and rice ecosystem.

The emission factor for rice under different water regimes was derived from the results of field experiments conducted at the IRRI-Farm, Los Banos, Laguna and PhilRice-Farm, Maligaya, Munoz, Nueva Ecija (Table 2). Mean methane emission across irrigated sites was found to be 2.3 kg per hectare-day, while at rainfed site it was found to be 0.40 kg per hectare-day. Compared to the IPCC default values, methane emissions using derived factors are 78% and 95% less for irrigated and rainfed condition. The derived emission factors were taken from actual measurements during the growth duration under tropical conditions which are based on modifying treatments such as water management and fertilization.

Table 2. Methane emission factor from ricefields in the Philippines.

Ecosystem/CH_4 Emission	Sites			Emission Factor (kg/ha-day)	
	Los Baños	Maligaya	Mean	Derived	IPCC default (T = 27°C
Irrigated					
• Mean emission, $mg/m^2/day$	233.1	225.5	229.3	2.3	5.9
• Std. deviation, $mg/m^2/d$	14.6	36.4			
• Minimum, $mg/m^2/d$	8.6	7.5			
• Maximum, mg/m^2d	669.3	591.4			
Rainfed					
• Mean emission, $mg/m^2/day$	40.3		40.3	0.4	3.54
• Std. deviation, $mg/m^2/d$					
• Minimum, $mg/m^2/d$					
• Maximum, mg/m^2d					

Source: Interregional Research Program on Methane Emission from Ricefield, IRRI, 1994.

C. Worksheet

Computation of methane emission from rice production in the Philippines is shown below:

Water Management Regime	Harvested Area (Mha)	Season Length (days)	Mega hectare-days (Mha-days)	Emission Factor (kg/ha-day) (derived)	CH_4 Emissions by Water Regime (Gg)	Emission Factor (kg/ha-day) (IPCC)	CH_4 Emissions by Water Regime (Gg)	% Decrease from IPCC
Continuously Flooded	1.916	114	218.424	2.3	502.38	5.9	1288.7	78
Intermittently Flooded	1.421	113	160.573	0.4	64.23	3.5	568.4	95
TOTAL	3.337				566.60		1857.1	

Using the derived emission factors, rice cultivation in the Philippines contributed about 566.6 gigagrams of methane which is 69% less than the estimate that results using IPCC default values. Methane emissions from rice cultivation are the highest contributing source of GHG emission from Philippine agriculture, contributing 62% of the emissions. In comparison, enteric fermentation and manure management contribute only 35.22% of the country's methane emission. This being the case, a significant the reduction of GHG emission from agriculture can be achieved if methane emission from rice fields can be abated.

Potential Mitigation Options

Varied cultural and management practices in rice cultivation are developed to suit the physical, biochemical and socioeconomic environments of the regions. Mitigation options must achieve both reduced methane emission and sustain production of rice. Water control is one of the most important factors in rice production. Prevention of submergence would be the most effective mitigation option but the potential of wetland rice production is superior to that of upland rice. Further, wetland rice is grown because fields are flooded naturally during wet season and drainage is usually impossible. Methane emission rates vary with water regime, a single midseason drainage may reduce seasonal emission rates by 50% (Sass et al 1992).

Rice plants emit 90% of the methane released from ricefields to the atmosphere (Seiler 1984, Holzapfel-Pschorn et al 1985). Root exudates and decaying roots seem to become an important carbon source for methane production with progressing plant development (Roger 1993).

The direct impact of chemical fertilizer applications is not clear. Reports on the influence of mineral fertilizer application are inconsistent. Increases in emission rates after addition of sulfate fertilizers were reported (Cicerone and Shetter, 1981) whereas decreases in emission have been noted (Yagi and Minami 1990, Sass et al. 1990).

Two research institutions are working on methane emission studies in the Philippines: The Philippine Rice Research Institute in Maligaya, Munoz, Nueva Ecija and the International Rice Research Institute in Los Banos, Laguna. Nueva Ecija is one of the provinces in Central Luzon - the rice granary of the Philippines. Los Banos and Maligaya are the two experimental stations in the Philippines where the IRRI-UNDP Program on Methane Emission from Rice Fields are undertaken. Since 1994, the stations have measured measuring methane emissions using an automatic closed chamber system. These stations have evaluated the effect of water management, rice cultivars, and fertilizer management on methane emission from irrigated rice fields. Methane emission rates were monitored with an automatic measurement system based on the closed chamber technique described in detail in Wassmann et al (1994). The system allowed 24-hour semicontinuous determination of methane emission rates during the crop growth.

Plots drained for 2 weeks at midtillering and before harvest at the IRRI-Farm, Los Banos in 1994 dry season showed a significant reduction in methane emission as opposed to continuously flooded plots and plots drained at 2 weeks before harvest (Fig. 1). Similar results were obtained when the same set of treatments were imposed during 1995 wet season. In 1995, screening of rice cultivar was done in Los Banos. IR72 rice variety consistently gave the highest methane emission for two cropping seasons as compared to the new plant type - IR65597 (Fig. 2). Other traditional variety (Dular) and improved varieties (Magat and PSBRc14) gave lower emissions as compared to the check variety (IR72).

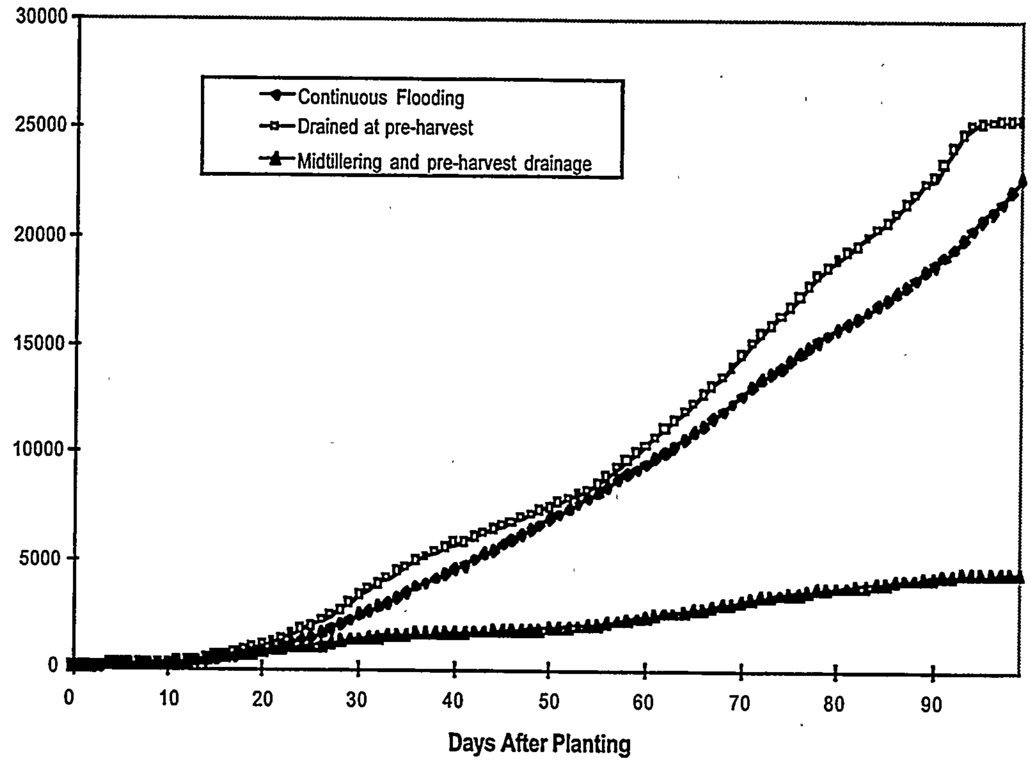
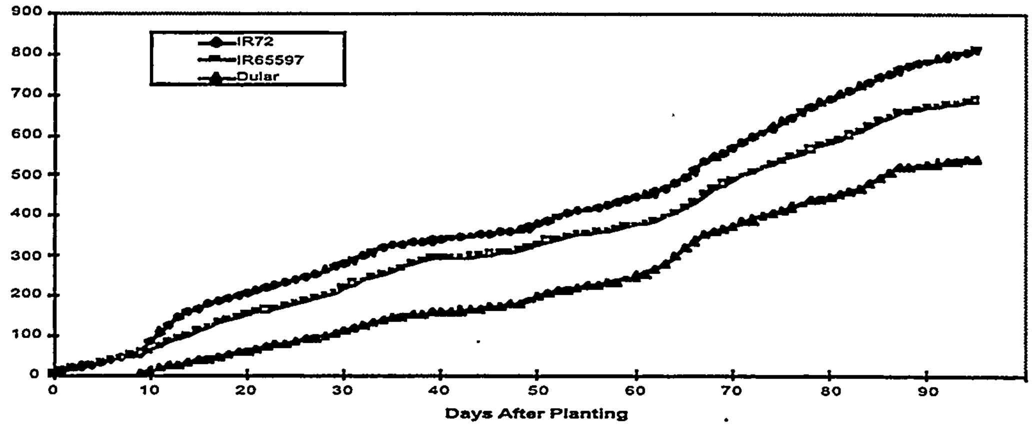
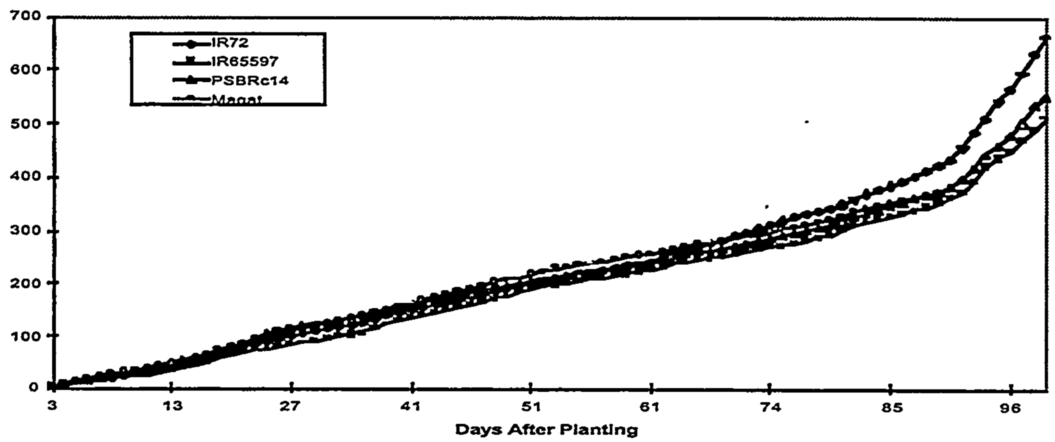


Fig. 1. Effect of water management on methane emission from an irrigated rice field at Los Banos, Laguna, Philippines during the 1994 dry season.



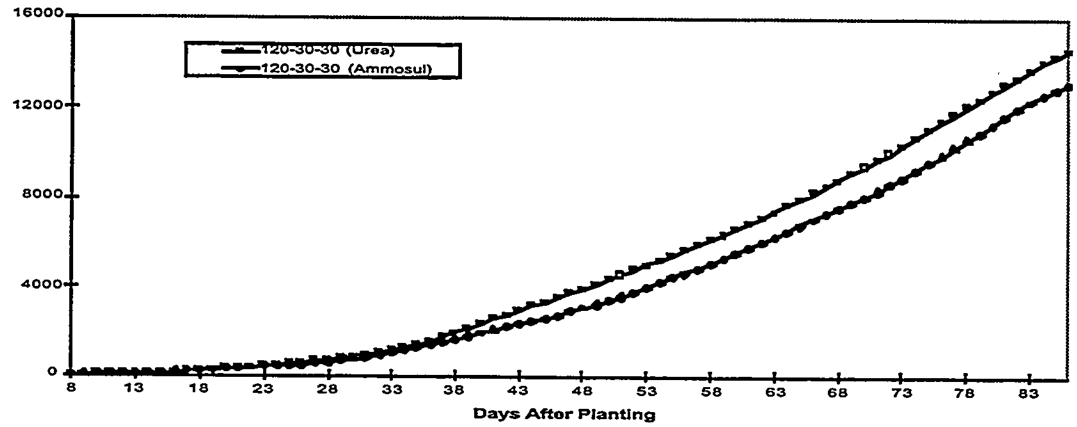
(a)



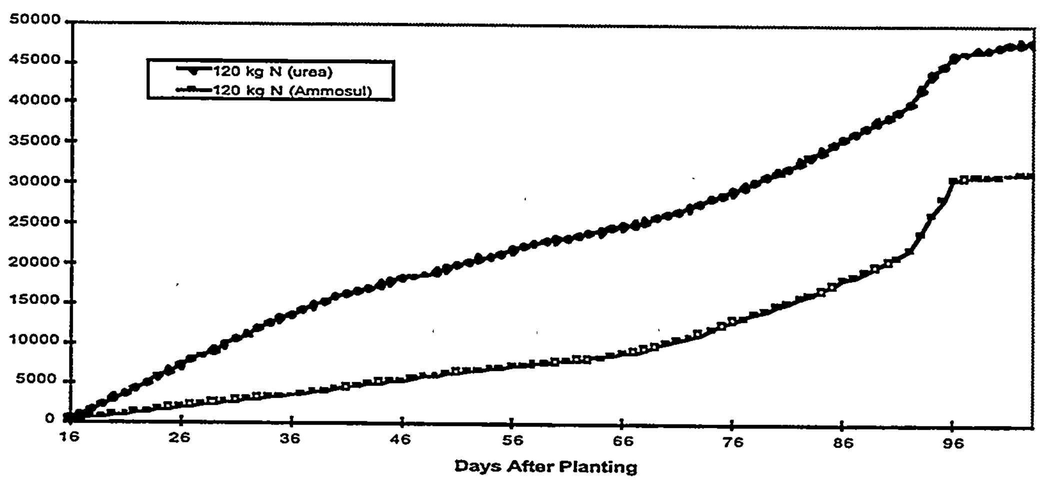
(b)

Fig. 2. Effect of cultivar on methane emission from an irrigated rice field at Los Banos, Philippines during the 1995 wet season.

In Maligaya, the effects of type and rate of fertilizer application were evaluated in 1995 cropping seasons. The application of ammonium sulfate instead of urea reduced methane emission by 10% in dry season and 34% in wet season (Fig. 3). Increasing the rate of ammonium sulfate application from 120 kg N ha^{-1} to 180 kg N ha^{-1} further reduced methane emission by 21% (Fig. 4). The effect of phosphogypsum (a gypsum obtained as by-product during production of phosphoric acid by wet process) on methane emission was also assessed. Phosphogypsum contains 44 to 46% SO_3 and has a gypsum content of 85 to 95% (Alcordo and Recheigl 1993). Addition of 6 t ha^{-1} phosphogypsum to 120 kg N ha-1 urea gave a 74% reduction in methane emission as opposed to urea-treated plots. Denier Vander Gon and Neue (1994) also reported a 55 to 70% reduction in CH_4 emission with the application of 6.66 t ha^{-1} gypsum.



(a)



(b)

Fig. 3. Effect of N source on methane emission from an irrigated rice field in Maligaya, Philippines during the 1995 wet season.

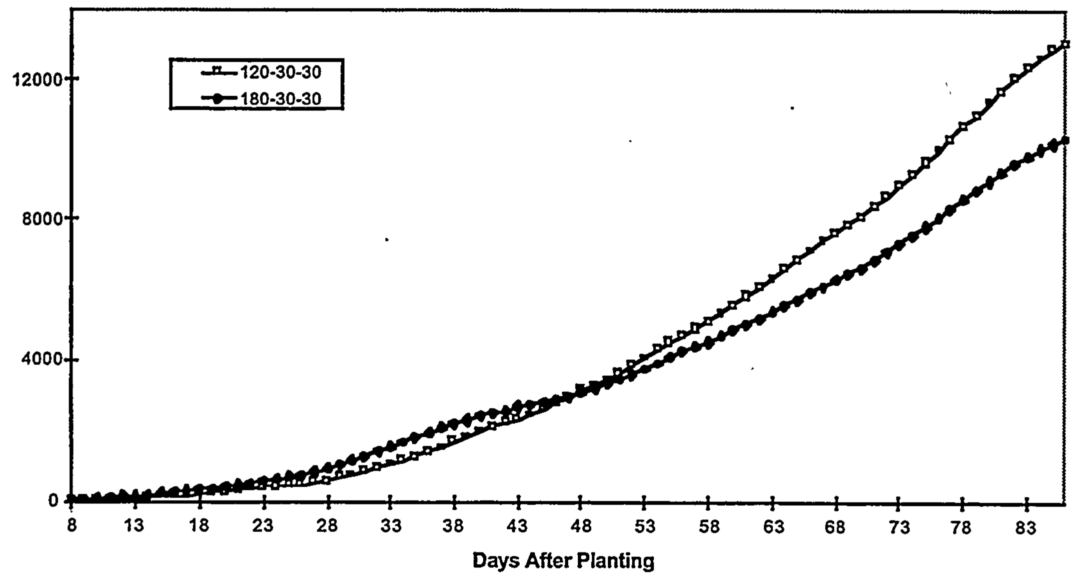


Fig. 4. Effect of increasing rate of ammonium sulfate application on methane emission from an irrigated rice field in Maligaya, Philippines during the 1995 dry season.

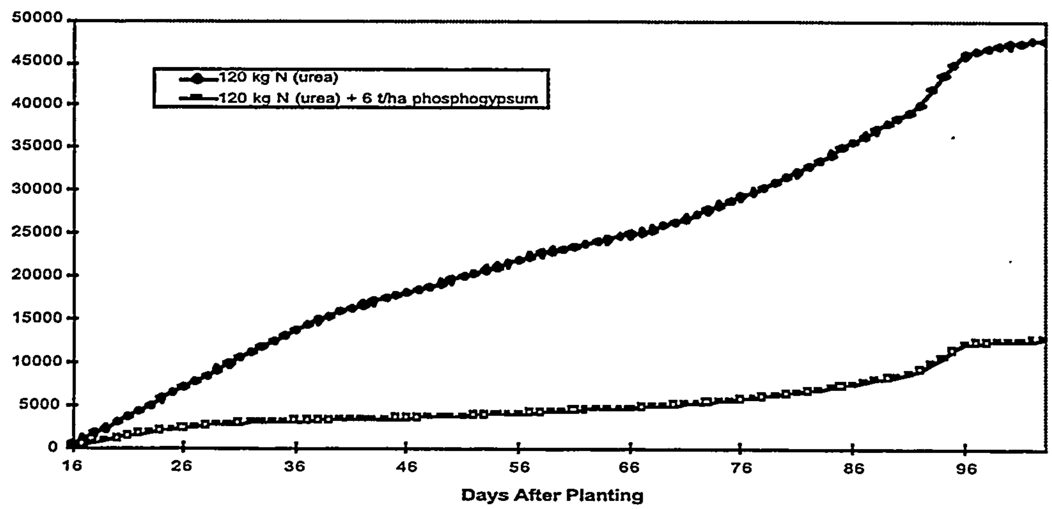


Fig. 5. Effect of phosphogypsum on methane emission from an irrigated rice field in Maligaya, Philippines during the 1995 wet season.

Table 3 presents a summary of the three potential mitigation options for methane emissions that were assessed along with the corresponding effect on grain yield--- water management, cultivar, and fertilizer management. Based on two-year results, the potential mitigation measures that can be disseminated in the region are: 2 weeks field drying at midtillering and before harvest; use of new plant type or cutivars like Magat; application of ammonium sulfate instead of urea; and application of urea in combination with phosphogypsum. Most of the mitigation strategies identified, except for rice cultivar, were observed to have no significant effect on grain yield as compared to control treatments or dominant agricultural practices. Mitigation strategies will find acceptance only if production and productivity are sustained.

Table 3. Potential mitigation options for methane emission from rice fields.

Treatment Description	Mean CH4 Emission (mg/m2/d)	% Change in Emission	Grain Yield (g/m2)	% Change in Yield
A. Water Management				
Continuous Flooding	127	-	455	-
Pre-harvest Drainage	144	13	455	0.0
Drainage at Midtillering and Pre-harvest	28	(78)	424	(6.8)
B. Cultivar				
IR72	8	-	530	-
IR65597	7	(12)	393	(26)
Dular	6	(25)	386	(27)
IR72	8	-	306	-
IR65597	6	(25)	138	(55)
PSBRc14	6	(25)	296	(3)
Magat	4	(50)	504	65
A. Fertilizer Management [a]				
Irrigated; NPK (urea)	226	-	401	-
Irrigated; NPK (ammonium sulfate)	199	(12)	400	(0.2)
Irrigated; 120N kg/ha Urea	503	-	330	-
Irrigated; 180N kg/ha Urea	516	2.5	336	1.8
Irrigated; 120 N kg/ha Urea + 6 t/ha phosphogypsum	139	(72)	378	14

Conclusion and Recommendation

Methane emission studies conducted in Maligaya and Los Banos were designed to estimate the possible contribution of rice to aggregate methane emission. Three mitigation strategies were analyzed--- modifying treatments such as water management, fertilization, and choice of rice variety. It is not easy to identify and recommend mitigation strategies that will fit a particular cropping system. However, the three identified mitigation options showed promise for the abatement of methane emission from rice fields.

On water management, existing irrigation systems in the Philippines cannot easily be modified to allow drying or reflooding the field as needed. During the dry season, water is so precious that farmers find it easy to drain the fields but reflooding becomes a problem. In wet season, drying the field is a problem because there is too much rain and drainage canals cannot accommodate excess water from the field. However, there might be areas where this type of efficient drying and reflooding is possible. In these regions, water management technologies should be investigated as a methane mitigation option as this strategy has a significant impact in reducing methane emission.

The use ammonium sulfate fertilizer instead of urea and the application of phosphogypsum, in combination with urea are all promising strategies to reduce methane emissions from rice fields. However there is a question of whether such fertilizer in regions where rice is grown. In the case of the Philippines, which is a net importer of fertilizer, about 60% of the country's fertilizer import is urea. The remaining 40% is ammonium phosphate, complete fertilizer, ammonium nitrate, and a small amount of ammonium sulfate. Phosphogypsum is not commercially available in the market. The government might be of help in negotiations with the key players in the fertilizer industry to promote the use of ammonium sulfate and phosphogypsum. This should also be complemented with research and development activities to communicate the benefit of using such technologies to fertilizer suppliers and consumers.

As for using different rice varieties as a mitigation option, more studies should be done to identify local cultivars which may have the potential to reduce methane emission without sacrificing yield. Research on varietal screening is necessary to provide farmers with a choice of varieties that reduce methane emission. Using different rice cultivars as a mitigation strategy is an adaptable option because it can easily be transferred to farmers and has the most opportunity to be of economic benefit to the end-users.

Although the research described in this article has been funded by the United Nations Development Program-Global Environmental Facility, under contract number C-92379 to the International Rice Research Institute, it has not been subject tot the Agency's review and therefore does not necessarily reflect the views of the UNDP_GEF and therefore no official endorsement should be inferred.

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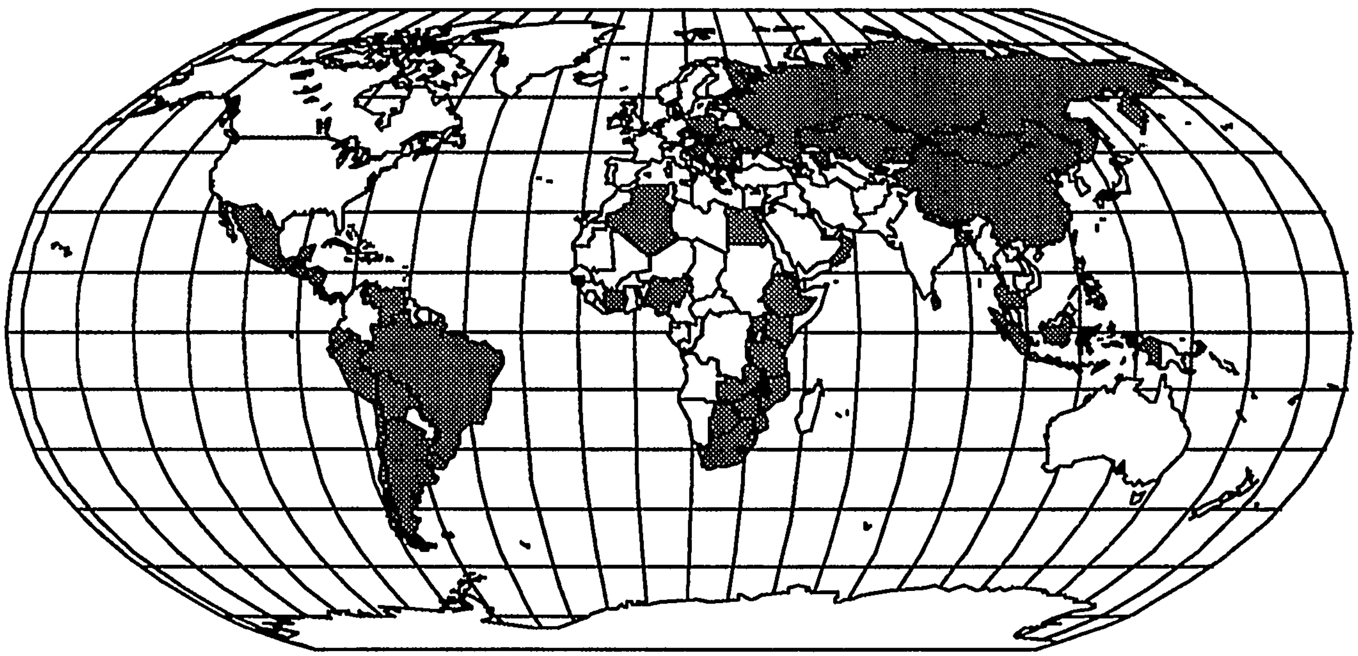
U.S. Country Studies Program:

Support for Climate Change Studies, National Plans, and Technology Assessments



Technical Support ←——→ *Cooperative Agreements*

Supporting the Principles and Objectives of the Framework Convention on Climate Change

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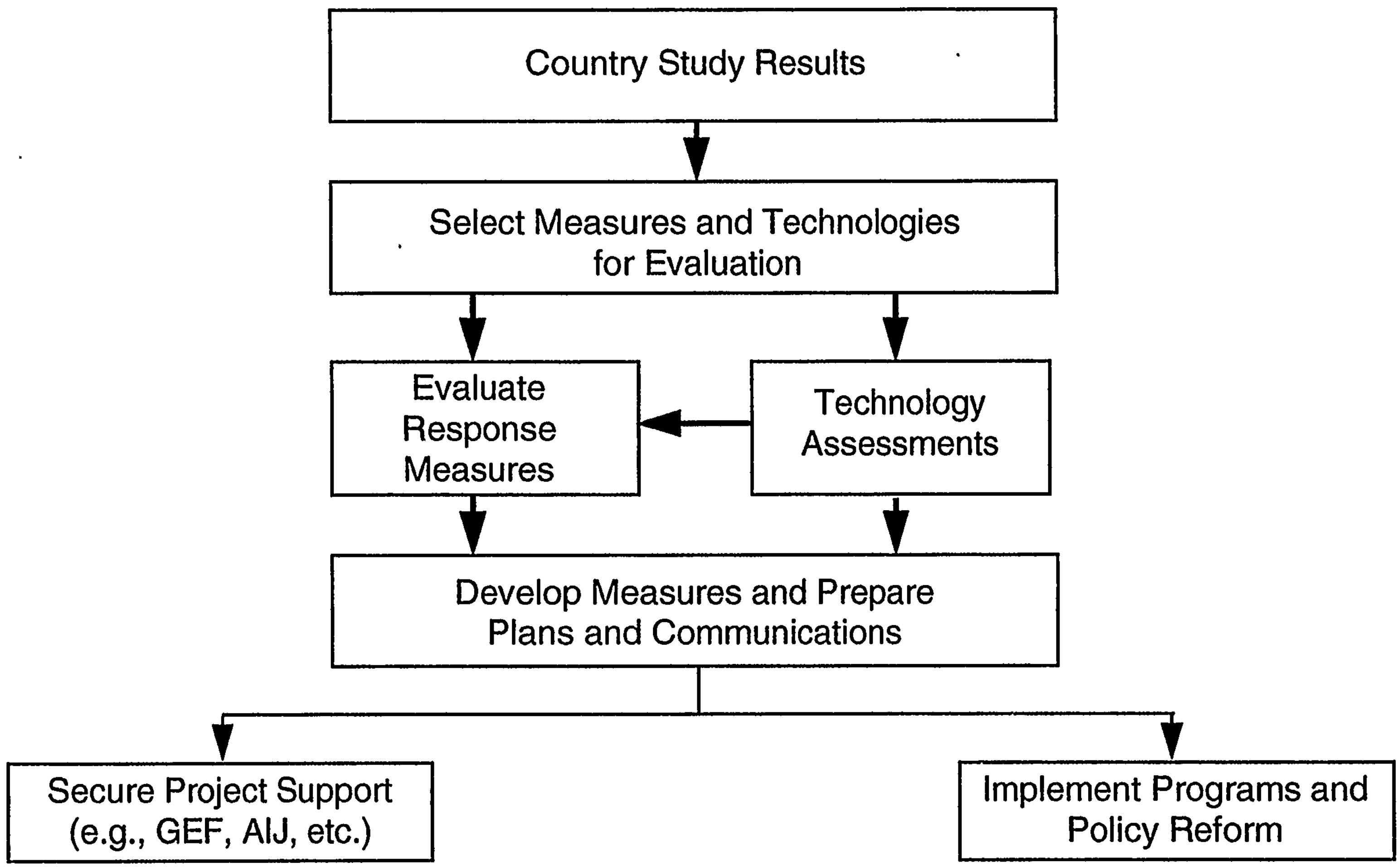
Objectives of Next Phase of U.S. Country Studies Program

- Assist countries in preparing Climate Change Action Plans
- Support technology assessments and development of technology initiatives
- Enhance exchange of information and expertise in support of FCCC

Country Activities in the Next Phase



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Five Possible Objectives of Planning Process

- Integrating climate change plans with other plans and programs
- Developing consensus and support for priority measures
- Designing effective implementation strategies
- Laying the foundation for the National Communication
- Achieving specific mitigation or adaptation goals

Launched Support for National Action Plans (SNAP) at COP-1

- Initiated support to 9 countries in late 1995:

China	Indonesia	Philippines
Czech Republic	Mexico	Russia
Egypt	Micronesia	Venezuela

- Awarded support to 9 additional countries in late 1996

Bangladesh	Hungary	Thailand
Bolivia	Kazakstan	Ukraine
Bulgaria	Tanzania	Uruguay

- Depending on funding, may provide support to 3-4 additional countries in 1997

Offering Extensive Technical Assistance

- Handbooks
  - Preparation of Climate Change Action Plans
  - Methane, Forestry, and Energy technologies and measures
- Training workshops
  - Workshop on preparation of national plans, January 6-10, 1997 (Indonesia)
  - Methane Technology workshops (Bangkok, Nov. 18-19, 1996; Feb/Mar 1997 in Central/Eastern Europe)
  - Energy Technology workshops (3-4 in different regions in 1997)

Technical Assistance cont'd

- Expert Assistance
  - Energy Measures
  - Forestry Measures
  - Methane Measures
  - Adaptation Measures
  - Project Financing

- Analytical Tools (e.g., decision models)

Supporting Exchange of Experiences between Countries

- International Workshops on Action Plans and Technologies
- Synthesis Report for COP-3
  - Inviting countries to submit papers by April/May 1997
- Electronic Network
- Visiting Analyst Program

Schedule of Future Activities

November 18-19, 1996:	Workshop on Methane Recovery from Landfills, *Bangkok, Thailand*
January 6-10, 1997:	Workshop on Climate Change Action Plans, *Jakarta, Indonesia*
February 3-7, 1997:	Country Studies Training Workshop, *Pretoria, South Africa*
February/March 1997:	Methane Workshop in Central/Eastern Europe
Mid/Late 1997:	Regional Workshops on Specific Energy Technologies and Measures

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GEF Climate Change Operational Strategy: Whither UNDP?

Dr. Richard Hosier
UNDP/GEF Climate Change Adviser

I. Introduction

II. Climate Change and GEF

III. Enabling Activities: How to Proceed?

IV. Long Term Operational Programmes

V. UNDP's Role: Toward Comparative Advantage

II. Climate Change and GEF

A. Science of Climate Change

- Caused by Accumulation of GHG's in Atmosphere
- IPCC Second Assessment Report Confirmed the Reality of Accelerated CC
- Virtually Unanimous Scientific Evidence

B. UN Framework Convention on Climate Change

- Goal: Article 2 " stablilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."
- Signed in Rio at the Earth Summit
- Ratified by 146 Countries

C. GEF as Interim Financial Mechanism

- Incremental Cost
- Pilot Phase: 1991-1993
- UNDP's Pilot Phase Portfolio ($100 million)

Strategic Information and Enabling Activities
GHG Offset (energy efficiency and carbon sequestration)
Renewable Energy

UNDP Strategic Priorities in Climate Change under GEF

- **Enabling Activities to Prepare Communications with the CoP**

  UNFCCC accords EA's the highest priority

  UNDP is seen as the lead agency for CC Enabling Activities

  Approaching Universal Coverage (Africa, Central Asia, & Central America lagging)

  UNDP must move quickly to final approval of projects and provide timely, high quality support for their implementation

- **REMOVING BARRIERS TO ...**

1) Energy Conservation and Energy Efficiency

Large set of opportunities to improve efficiency of energy use around world are not being taken by either private sector, public sector, or donor sector---What must be done to make these investments and activities sustainable? Overcome Transaction Costs of a Legal, Human, Institutional, Informational, Financial Nature

How ? Strengthening of Energy Efficiency Institutions; Working on Building Standards and Codes; Legal Work on Power Purchase Agreements; ESCO Incubators; Limited Demonstrations

Model Project: Chile or Peru Pilot Phase Projects

2) Adoption of Renewable Energy

Renewable Energy is increasingly a "win-win" option, but for a number of reasons, the adoption of these technologies are slow--Programme is to accelerate adoption & utilization of renewables

Which Renewable Sources? PV's; Ag wastes; biomass; biofuels; methane from wastes; wind; micro-hydro

Model Projects: Mauritania Windmill or Zimbabwe PV Project from Pilot Phase

GEF WILL ONLY PAY INCREMENTAL COSTS OF ABOVE ACTIVITIES

PROJECTS MUST LEAD TO FOLLOW-ON INVESTMENTS

3) **Reducing the Long-term Costs of Low Greenhouse Gas-emitting Energy Technologies**

Selected Energy Supplies Can Produce Energy with Low or No Net GHG Emissions
By increasing the demand for these supplies, their cost will drop (and therefore accessibility will rise)

Which technologies?

- No or very low GHG emissions
- Likelihood of meeting technology cost goals (cheapest option)
- GEF can make a critical contribution to meeting cost goals

Examples:

Low temperature (PEM) fuel cells for transport; Solar Thermal, initially parabolic trough; Large-scale Windfarms; possibly IGCC for coal and biomass

Model Project: Advanced gas turbines for central station power from Biomass (Brazil BIG/GT);

- **Short-Term Programme:**

(Not UNDP's priority)
Highly cost-effective projects (low $/tonne estimates)

UNDP Can Advise Countries to Make Opportunistic Use of this category, but with the caveat that it burns a GEF project "chit"

National Technology Needs Assessment for the Preparation and Implementation of Climate Change Action Plans

discussion paper
November 1996

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IVAM Environmental Research 1996
University of Amsterdam ([1])

Abstract

In the United Nations Framework Convention on Climate Change (FCCC) it is recognised that developed countries have a responsibility in assisting developing countries and countries in economic transition in building a national capacity for the development, acquisition and transfer of Climate-related Technologies (CTs). Such assistance is most likely to be successful once it is tailored to the results of a sound assessment of the country's development needs and once the results of this assessment have been endorsed by the most important stakeholders in the country. Recent insight in the opportunities and constraints for National (technology) Needs Assessments (NNAs) as planning tool for both capacity building and technology transfer regarding Environmentally Sound Technologies (ESTs) is applied here to propose a participatory Climate Change Action Planning (CCAP) process. This participatory planning process is thought to serve the dual objective of defining a national Climate Change Action Plan (CCAP) while at the same time contributing to the creation of a broad supportive basis for its acceptance and implementation among stakeholders in the developing country.

1. Introduction

Several developing countries and countries in economic transition ([2]) have prepared or are in the process of preparing national Climate Change Action Plans (CCAPs) that delineate specific measures for mitigating or adapting to climate change. A national plan is typically based on the results of an emission inventory, a mitigation assessment and a planning process [Bernioff and Warren, 1996]. An important part of the national planning process is the identification, evaluation and selection of key technologies to mitigate or adapt to climate change (known as Climate relevant Technologies (CTs) ([3])) as well as an assessment of the barriers and incentives for the adoption and diffusion of these key technologies.

The Task Force on Technology Aspects of National Plans established within the Climate Technology Initiative (CTI ([4])) aims to contribute to the improvement of methodologies for technology assessment and technology transfer, to the enhancement of capacities of countries to develop effective technology transfer and dissemination measures as part of their national climate change action plans and to facilitate the exchange of information and expertise. As part of its work plan, the Task Force wishes to explore the opportunities to apply National (technology) Needs Assessments (NNAs) to foster the transfer and implementation of Climate relevant Technologies (CTs). A NNA is interpreted as a national planning tool to improve the utilisation of Environmentally Sound Technologies (ESTs) in the development process of a developing country. The execution of a NNA encompasses surveys of socio-economic, technical and environmental trends and the establishment of a Roundtable-process among stakeholders at the national level to arrive at priority technology transfer projects and capacity building activities.

This discussion paper explores opportunities to apply NNA principles to the preparation and implementation of CCAPs. This will later be elaborated (with financial support of the Government of the Netherlands) into a practical guidance document for national planners with illustrations of - part of the - customised tool with practical experiences gained so far in preparation of national climate change action plans. This discussion paper seeks to provoke discussion among practitioners in the field of national planning on climate change issues and to gather inputs for the preparation of this practical guidance document. This paper therefore starts with a summary of the NNA approach and methodology and results of a case study evaluation regarding electrification strategies for the Republic of South Africa (section 2). Next is the description and analysis of CCAPs which results in design specifications for the participatory climate change action planning process (section 3). This proposed planning process is the elaborated in moderate detail (section 4). The final section contains a few closing remarks.

2. National Needs Assessments

As shown by an increasing number of studies (Mugabe, 1996) there is growing evidence that capacity building is most likely to be successful once capacity building projects are based on the result of a solid assessment of the technology needs of the host country and once this technology needs assessment is endorsed by the most important stakeholders of the host country. A National (technology) Needs Assessment (NNA) may therefore be undertaken to enhance technology co-operation and transfer regarding Environmentally Sound technologies. A recent Expert Meeting on the *Assessment of Technology Needs for Sustainability* agreed on the notion of NNA as "*a tool for the government or other national stakeholders of a particular developing country or country in economic transition, to define a portfolio of capacity building actions and technology transfer projects to be undertaken to facilitate, and possibly accelerate, the development, adoption and implementation of Environmentally Sound Technologies*" [van Berkel et all, 1996 a].

The function of a NNA is illustrated with a simplified process model (see figure 1). In this model the NNA is considered to be a continuous and iterative process, which can logically be organised in three phases, respectively: creating an enabling environment for NNA; assessing capacity building needs; strengthening and developing capacities. The desired outcome of this process is the improved utilisation of ESTs in the development process of the host country, which is either achieved directly through implementation of technology transfer projects, or indirectly, through the strengthening and development of capacities which facilitate, and possibly accelerate, the development, adoption and implementation of ESTs. Different activities may actually trigger the initiation of this process, such as pilot technology transfer projects, international agreements and conventions, major socio-economic and/or political changes in the host country, national environmental policies and strategies, etc.. These all create entry-points for the process of NNA and provide the process with legitimacy.

Five pilot NNA-like projects were evaluated in order to generate a preliminary insight in opportunities, constraints and potential added values of NNAs [van Berkel et all, 1996 b]. The results of the evaluation of one pilot project on appropriate energy technologies for the Republic of South Africa (RSA) have been summarised below as an illustration.

The Republic of South Africa (RSA) currently belongs to the world's largest contributors to the green house effect: it is the 7th largest producer of Green House Gases on a per capita basis, and the 18th largest producer in the world. The energy sector - which for 80% depends on coal - accounts for 75% of all national GHG emissions. The expectations are that GHG emissions will rise by approximately 3.5% per year in the medium term, in light of the following trends and developments:

- the large investments made in coal-based infrastructure hamper a rapid change in the energy mix;
- the rapid urbanisation is accompanied by a change in domestic fuel consumption from wood to coal and electricity;
- population growth (presently 2.3 % per annum);
- the present drive of the New South African Government to increase the living standards of the black communities in South Africa will lead to a higher energy consumption.

If South Africa is to embark on a sustainable development path, appropriate strategies have to be chosen to promote environmentally sound development.

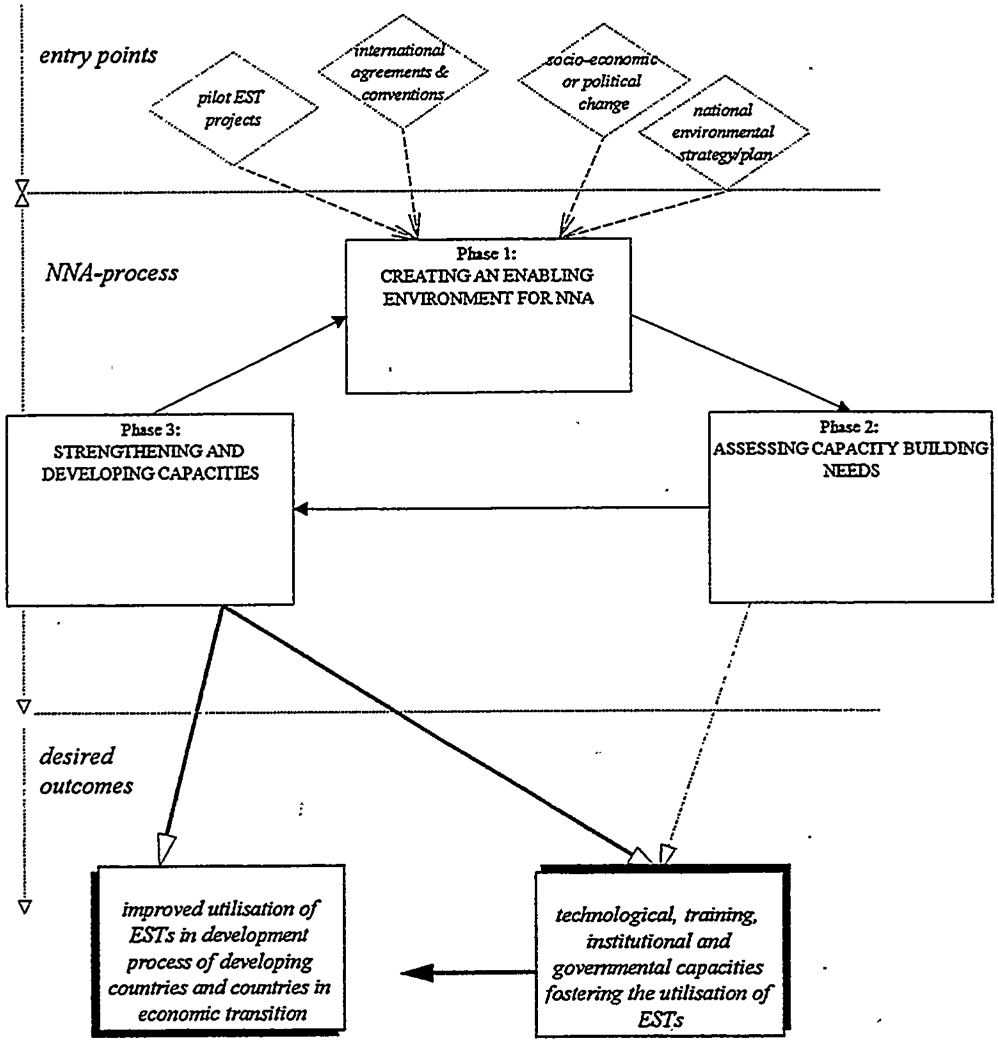

Figure 1 General model to improve the utilisation of Environmentally Sound Technologies (ESTs) through the application of National Needs Assessment (NNA) [Van Berkel et all, 1996 a].

The NNA-like process for sustainable energy options has its roots in the *Reconstruction and Development Plan* (RDP) of the new South African Government. This RDP is a policy statement and specifies desired social and economic development paths for the new South Africa. It invites the private sector, governmental agencies at all levels, academia, NGOs and other interest groups to participate and contribute to the realisation of the objectives of the RDP. The main actor for the formulation, initiation and monitoring of the RDP is the Government. However, it has drawn and will continue to draw extensively on local level participation and consultation through RDP task teams. These teams consist of senior representatives of relevant departments and provinces with some experts from civil society.

After the formulation of the RDP the conference *'Greening the RDP'* was organised to address the environmental impacts of the RDP and to identify key strategies to minimise and mitigate these. The conference was called for by the Government and organised by a national alliance of South African non-profit organisations who share a set of common values and concerns regarding the environment. The outcome of this conference was a list of resolutions endorsed by the plenary meeting. The need to shift the emphasis from nuclear and synthetic fuels research to support for the implementation of energy efficiency and renewable energy technologies was selected as one of the priority areas for the transition towards sustainable development.

Next the *Energy Policy Discussion Document* was issued. The document was derived from a series of sectorial energy policy synthesis studies and aimed to assist in accommodating and encouraging the public participation in the formulation of the Government's new energy policies. Therefore it summarised information about the energy sector, its needs and resources. It intended to lay the major issues in the energy policy debate and the available policy options to respond to those issues, before all who are involved in, or would like to contribute to, the establishment of energy policies for South Africa. The publication of this policy discussion document triggered the start of a consultative process, including invitation for submissions from interested parties and the organisation of a number of policy workshops. Particular attention was paid to involve those stakeholders who had historically had no voice in the formulation of policy. Energy policies will be selected that best support national social and economic policy and for which there is the greatest consensus. The policy choices will gradually be synthesised in an Energy White Paper which will form the basis of South Africa's new energy policy.

One of the first outcomes of the public discussion on energy policies has been the adoption of an *Energy for Development Business Plan* by the Government. This plan deals with programmes that could meet the energy needs of the poor, in such a way that it is affordable and at the same time maximises the use of ESTs. Access to energy is thought to empower the previously underprivileged and thereby contribute to their socio-economic development. The approach adopted is of an integrated nature: energy is not treated as an isolated, supply-oriented issue, but its provision is tailored to the political, socio-economic, technical and physical conditions in which the end-users are living. Projects have been started in several project areas, most importantly Remote Areas Power Supply (RAPS), low smoke stoves and sustainable utilisation of biomass. The utilisation of Photo Voltaic (PV) systems is one of the ESTs in the RAPS domain, both for basic domestic needs (so called solar home systems) as well as for powering community buildings (hospitals, schools, etc.).

This national energy planning process can be regarded as a NNA for ESTs. The starting point of the NNA has been the RDP. Following the RDP a dialogue was set in motion, which is reflected in the many forums, conferences and workshop that were held as well as the many studies carried out to address the shortcomings of the RDP, in particular the negligence of environmental issues. The RDP set the boundary conditions, in particular regarding social and economic development objectives. The Greening of RDP conference served to obtain participation of national stakeholders and to propose a preliminary set of key environmental strategies and technologies. Both activities therefore constituted the first phase of the NNA process (see also figure 2). The second phase started with the preparation of the Energy Policy Discussion Document, which surveyed implications of social and economic development trends on energy demand as well as technological options to meet these demands and policy measures to facilitate the uptake of these technological options. The consultative discussions served to strengthen capacities in the field of energy policies and resulted in the selection of prioritised technologies and capacity building needs. For different end-users this resulted in business plans, such as the Energy for Development Business Plan. This may be considered as the end result of the second phase in the NNA process. The implementation of these business plans will result in the implementation of sustainable energy technologies (third phase in the NNA process).

In the ongoing dialogue between the various stakeholders, the responsibilities for Government have been defined as 'securing access to energy services in support of the development of the nation'. With this 'luggage' the Government, in consultation with NGOs, scientists and beneficiaries, identified the need for widening the access to electricity, as a means to improve the living standard of the underprivileged, as a priority issue. The implementation of the electrification process is, however, still primarily driven by cost considerations. ESTs have been prioritised for implementation as long as these are cost effective. This turns out to be the case for the application of technologies in rural areas. This is a good example of a sustainable energy option. It not merely meets environmental objectives, but socio-economic objectives and financial criteria as well. In other words PV can meet different objectives at the same time, and as such will therefore find a sound basis for continued implementation.

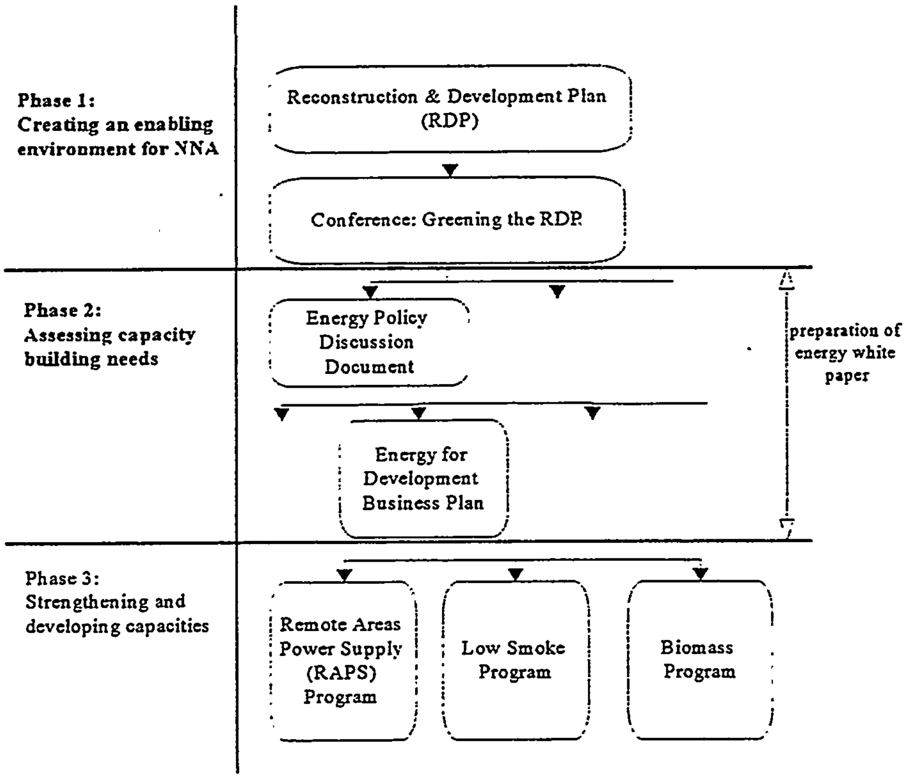

Figure 2: Overview of the NNA like process on energy planning in Republic of South Africa (van Berkel et all, 1996 b).

3. National Climate Change Action Plans

The FCCC calls on Parties to prepare a National Communication regarding its national climate change policies and strategies. Guidelines were prepared for Annex 1 Parties (in particular developed countries) and are being prepared for other Parties. In order to prepare this national communication, it has been suggested to develop national Climate Change Action Plans (CCAPs) [ref. e.g. Bernioff and Warren, 1996]. So far no guidelines have been developed for the content of a CCAP. However, from various communications a CCAP emerges as a 'living document'; i.e. an evolving list of actions in a country related to climate change issues, including the following types of actions:

- *policy measures:* actions of the national government and governmental agencies to prepare, implement and enforce regulations (including for instance environmental legislation, creation of fiscal and financial incentives, etc.) conducive to climate change mitigation and adaptation;
- *capacity building activities:* actions undertaken to create technological, institutional and other capacities in key sectors of society to create an enabling environment for implementation of policy measures and technologies conducive to climate change;
- *technology transfer projects*: actions resulting in the acquisition, introduction, integration and operation of hard and soft technologies conducive to climate change into the country.

This characterisation of the content of a CCAP does not imply that all three categories should be equally represented in a CCAP; it is merely used here as a frame of reference for the development and analysis of planning processes that may be used to develop a CCAP and secure its implementation.

Countries face many challenges in preparing CCAPs [see for instance Bernioff and Warren, 1996]. One of the major challenges is integrating climate change concerns with other policy priorities. Since climate change is not a priority for most developing countries, effective implementation of CCAPs may require the preparation and implementation of response measures that are primarily designed to achieve other development objectives. Another challenge countries will face is the need to involve a diverse set of relevant ministries and departments, provincial and local governments, regional organisations, Non Governmental Organisations (NGOs), the private sector and the public in the planning process. Their active involvement will be necessary to secure support and resources for the implementation of the CCAP.

The US Country Study Program is assisting selected developing countries and countries in economic transition (such as for instance China, Czech Republic, Venezuela and Bangladesh) in preparing CCAPs. A handbook is available with guidance for the planning process that may lead to a CCAP [Bernioff and Warren, 1996]. The handbook has been designed to:

- provide step-wise recommendations for countries to use in preparing climate change action plans;
- identify key issues that countries may need to address in preparing their plans;
- identify opportunities to integrate climate change action plans with other development or environmental plans.

The handbook provides guidance on the process that may be used to develop plans. The proposed overall planning process is summarised in box 1. Although attention is paid to the analysis of barriers and incentives for GHG mitigation and adaptation technologies and measures and increasing the awareness of different stakeholders, this proposed planning process can be characterised as largely 'technology driven' and 'government-lead'. The 'technology driven' nature is reflected in the fact that key technological options are primarily selected on the basis of their potential contribution to mitigation and adaptation to climate change and technical and economic feasibility. Other considerations, such as in particular the contribution to the social and economic development process in the developing country, seem to be treated as constraints to the planning process rather than as integral objectives of this planning process. This may be regarded as a weak part in the planning process, in particular in light of the above referred challenge to integrate climate change concerns with other policy priorities. The process is 'government lead' since the national government is expected to take the lead in the planning process and involvement of representatives of different stakeholders appears to be limited to reviewing - and approving - intermediate and draft final results of the planning process. Representatives of different stakeholders do not share the responsibility of preparing the CCAP (i.e. conduct parts of the required analysis, participate in the priority setting, etc.). This is another weak part in the planning process, in particular in light of the above referred challenge to involve other institutions (such as private sector, NGOs and academia) in the climate change action planning process.

Process for developing climate change action plans	
Step 1:	Design an effective planning process
Step 2:	Determine the overall plan objectives and sectors of interest
Step 3:	Prepare a comprehensive workplan
Step 4:	Develop and evaluate sectorial and cross-sectorial measures
Step 5:	Prepare comparative analysis of measures across sectors and refine recommended measures
Step 6:	Prepare implementation strategies for selected measures
Step 7:	Prepare and adopt climate change action plan
Step 8:	Prepare national communication
Step 9:	Integrate the plan with other development plans and programs
Step 10:	Implement plan

Box 1: Overview of the planning process for preparation of Climate Change Action Plans [Bernioff and Warren, 1996].

In light of the challenges referred to above for the planning process and the 'technology driven' and 'government lead' nature of the presently used guideline for the planning process, an attempt is made to integrate elements of NNA into a planning process for the preparation of CCAPs. This customised NNA tool for CCAPs will be outlined below. It aims in particular at:

1. integration of awareness raising, consensus building and strengthening of - institutional - capacities into the planning process;

2. active participation of the private sector as owner of technologies and source of finance in the planning process;
3. improved utilisation of CTs in the development process of the developing country.

4. A customised NNA tool for the development and implementation of CCAPs

The development and implementation of CCAPs is considered to be a continuous and iterative process which can logically be organised in three phases, respectively:

1. *creating an enabling environment for Climate Change Action Planning:* setting the stage for a participatory planning process regarding climate change mitigation and adaptation on the basis of (i) initial surveys of the present situation (regarding amongst others GHG emissions), of expected trends and developments (regarding amongst others socio-economic development) and of the perceptions among stakeholders regarding climate change issues, (ii) creating favourable conditions through awareness raising and communication with stakeholders and (iii) defining the CCAP process (set objectives, define participation of stakeholders, develop organisational framework and raise necessary funds);
2. *assessing climate change mitigation and adaptation needs and opportunities:* actual execution of the needs and opportunities assessment regarding climate change, through data analysis and consultation of national stakeholders, resulting in a portfolio of prioritised policy measures, capacity building activities and technology transfer projects;
3. *implementing and evaluating mitigation and adaptation actions*: the CCAP is elaborated and adopted on the basis of the portfolio of mitigation and adaptation actions defined in the previous phase. Meanwhile, a start is made with the introduction of the prioritised policy measures, the execution of the prioritised capacity building activities and the implementation of the prioritised technology transfer projects. This phase also includes review actions in order to sustain the continuous process of assessing climate change mitigation and adaptation needs and opportunities and implementing prioritised mitigation and adaptation actions.

The desired outcome of this planning process is the improved utilisation of CTs in the development process of the developed country and the creating and strengthening of capacities and policies conducive to climate change. Figure 3 illustrates this planning process and summarises the intermediate results of the different phases ([5]).

Each phase in the planning process is based on the insight and commitment generated in the previous phase and requires both the collection and analysis of additional data (an analytical function) and participatory priority setting activities among national stakeholders (a consensus building function). Each phase should then result in improving the insight in mitigation and adaptation needs and opportunities and growing consensus regarding mitigation and adaptation actions. These increases in both the level of insight and level of consensus are in turn necessary for the next phase in the planning process (see illustration in figure 4). With other words, the output of a phase is essential input for the next phase. At the same time, the consensus building contributes to creating or strengthening of institutional capacities to deal with climate change issues. In the following each phase is further elaborated with emphasis on the analytical and consensus building functions to be performed. It has however to be stressed that the elaboration of the different phases as presented in the following is not meant as an idealised blueprint for a participatory climate change action planning process, nor an endorsement to apply such process. It must be regarded as a step-wise procedure that provides direction for the execution of the planning process and monitoring both the analytical elements to be involved and the networking to be done. Depending on the specific situation in a country adjustments can be made.

Phase 1: Creating an enabling environment for Climate Change Action Planning

The objective of this first phase is to initiate the participatory planning process, by defining the scope, goals and course of the planning process and by selecting and motivating the proper participants for subsequent phases in the planning process. A high level of agreement among the participants on the course, the goals and their role in the next phases of the planning process is essential. This will be reflected in a proper definition of the planning process.

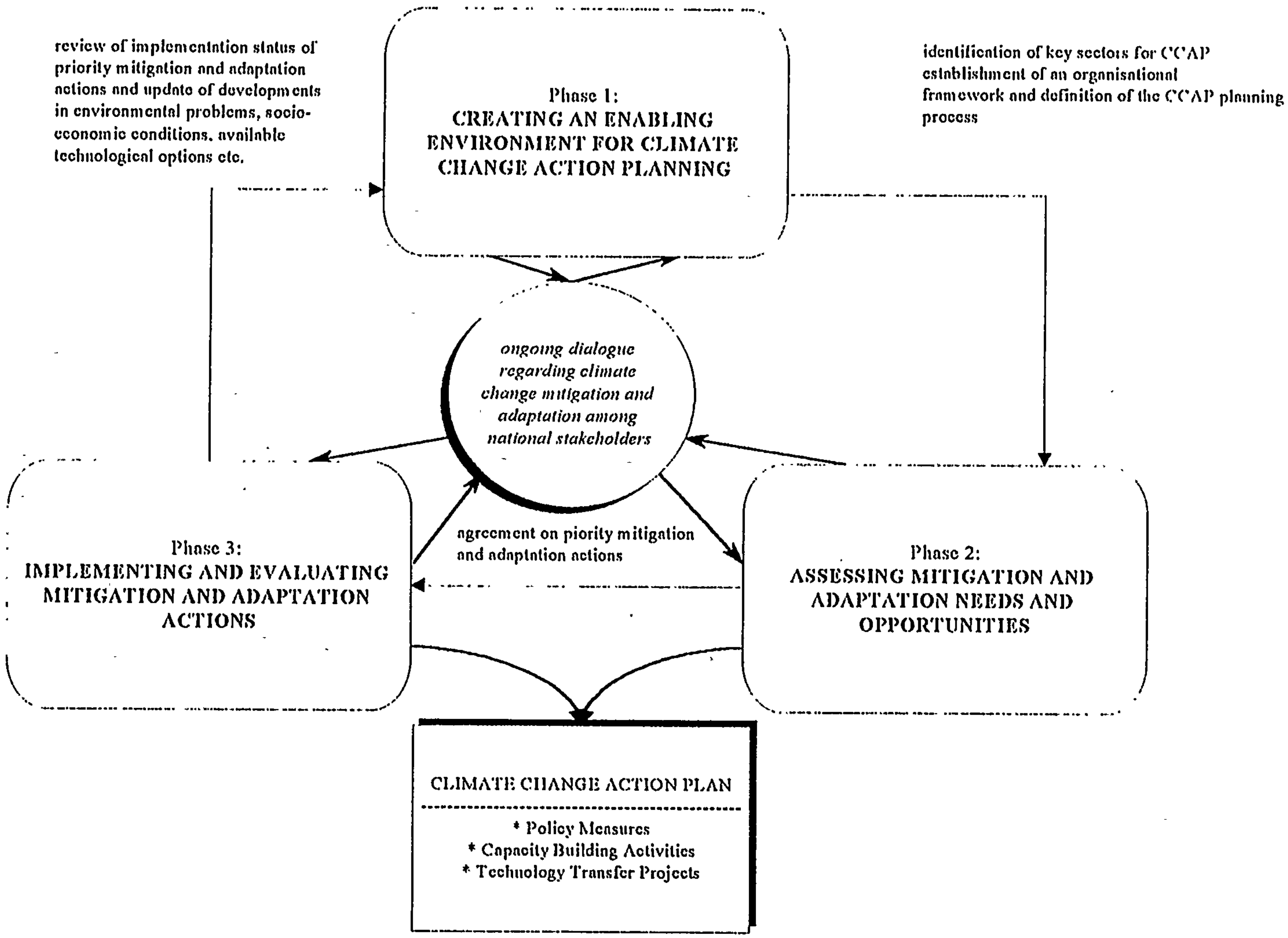

Figure 3: Overview of the proposed participatory Climate Change Action Planning Process.

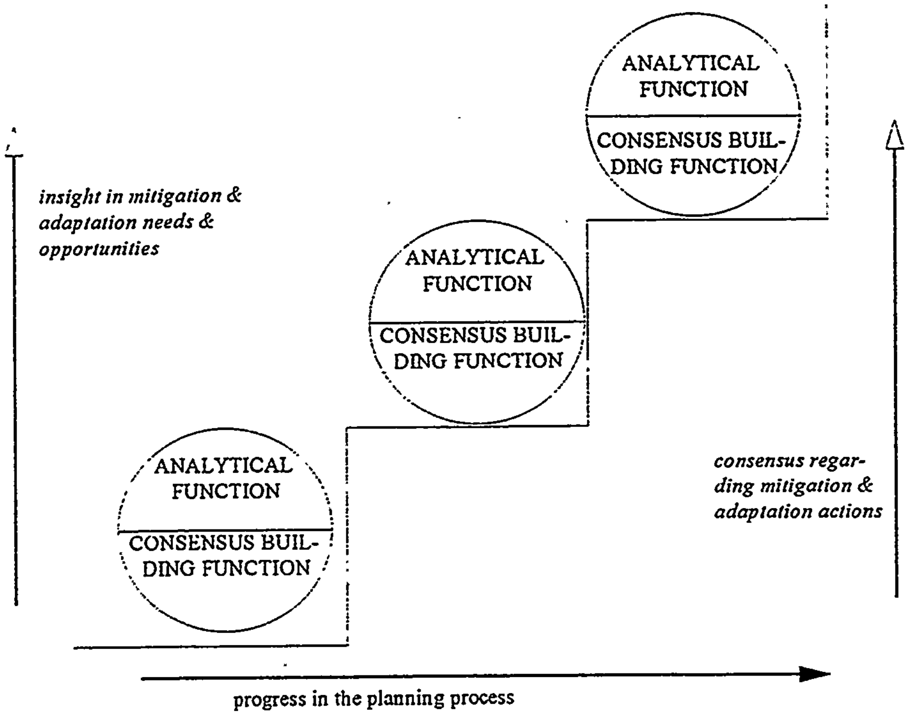

Figure 4: Schematic presentation of the inter-relatedness of analytical and consensus building functions in subsequent stages of the planning process.

The overall approach for 'creating an enabling environment for climate change action planning is illustrated in figure 5. The analytical function of this first phase should result in a preliminary insight in the priority sectors for climate change mitigation and adaptation and interests of different stakeholders in climate change issues. This is to be based on:

- *survey of the present situation*: in particular a breakdown of GHG emissions by social and economic sectors and the general situation regarding environmental protection and nature conservation (including issues related to land use);
- *survey of expected trends and desired developments*: on the basis of available action programmes regarding nature and environment and key national objectives regarding social and economic development;
- *survey of the perceptions regarding the importance of climate change issues among stakeholders.*

The insight generated through the above surveys is used to define the coverage (priority sectors to be covered) and framework (trends and developments to which improved utilisation of CTs should ideally contribute) for the next phases of the planning process.

The consensus building function of this first phase should result in the commitment of stakeholders representing the priority sectors to participate in the planning process. This will call for:

- *creating general awareness regarding climate change* (among the public in general and among stakeholders in priority sectors in particular): in particular regarding the need for mitigation and adaptation and the potential contribution of CTs to social and/or economic development objectives;
- *establishing a dialogue with stakeholders in priority sectors:* key stakeholders will have to be identified and invited to participate in the planning process. While doing so, the objectives, organisation structure and roles of participants are gradually refined and the lead implementing institution is selected
- *obtaining funds for the planning process:* this may include a preliminary assessment of the potential for funding of follow up activities from resources available in national and international, public and private sectors (to be able to tailor the planning process and likely follow up activities to realistic funding opportunities).

The above tasks are to result in the commitment of stakeholders to participate in the planning process. Furthermore, the planning process has been further defined through a set of objectives and an organisation structure with well established roles for the different participants.

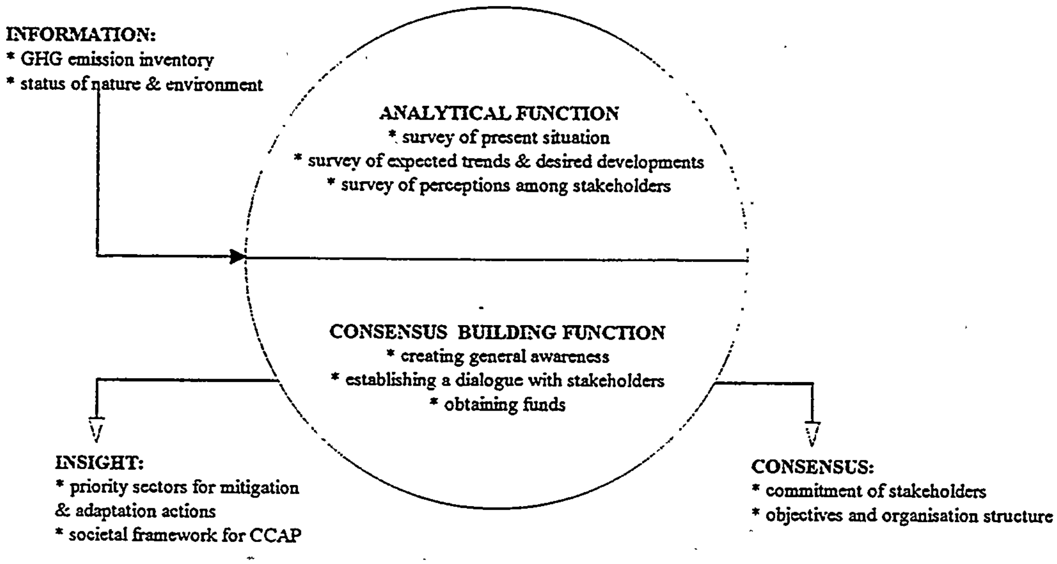

Figure 5: Summary of phase 1 ('creating an enabling environment for climate change action planning').

Phase 2: Assessing mitigation and adaptation needs and opportunities

In order to ensure implementation of follow up actions, the assessment phase should sustain, and possibly even increase, the awareness and commitment of national stakeholders and contribute to institutional capacity strengthening. This cannot be done through a blue print approach; the approach should be adapted to nationally and internationally available information sources, match to socio-economic conditions, use existing networking structures and technical and organisational capacities. In general the assessment should include three main assessment tasks, respectively:

1. *identification and selection of CT needs and opportunities*: with the objective to establish a consolidated list of prioritised CTs. A step-wise approach is recommended for this task. The selection procedure starts with an extended list of all reasonable CTs. Next a selection is made; it is proposed to select in first instance those CTs which do not have negative impacts on nature and environment and which are likely to contribute to social or economical development ('win/win options') and in second instance by evaluating the remaining CTs on expected acceptability among targeted end-users;
2. *assessment of capacities:* the present key capacities for the development, adaptation and implementation of prioritised CTs is to be evaluated. On the basis thereof, capacity building needs are identified. It is recommended to include at least the following four types of capacities: technological capacities, training capacities, institutional capacities and governmental capacities (van Berkel et all, 1996 a; b);
3. *setting priorities for policy measures, capacity building activities and technology transfer projects:* the insight gained in key mitigation and adaptation options as well as the present functioning of capacities conducive to their adoption and implementation, is used to elaborate 'activity-ideas' (outlines) for policy measures, capacity building activities and technology transfer projects. Such elaboration makes the planning process more practical and contributes in generating commitment among stakeholders (including the private sector) and safeguarding follow up. Once the list of ideas has been completed, a comparative evaluation has to take place. The comparative evaluation could be based on: contribution to GHG mitigation or adaptation; anticipated contribution to socio-economic development; anticipated contribution to environmental improvement; and anticipated commitment of national stakeholders

The completion of the above assessment tasks results in a consolidated list of prioritised policy measures, capacity building activities and technology transfer projects.

The completion of these assessment tasks is once again partially based on analytical functions and partially a consensus building functions. The analytical functions are: inventory and evaluation of CTs, assessment of present functioning of capacities conducive to climate change mitigation and adaptation and elaboration of 'activity ideas'. The capacity building functions are comparative evaluation and priority setting for - in consecutive order - CTs, capacity building needs and 'activity-ideas'. The overall functioning of phase 2 is illustrated in figure 6.

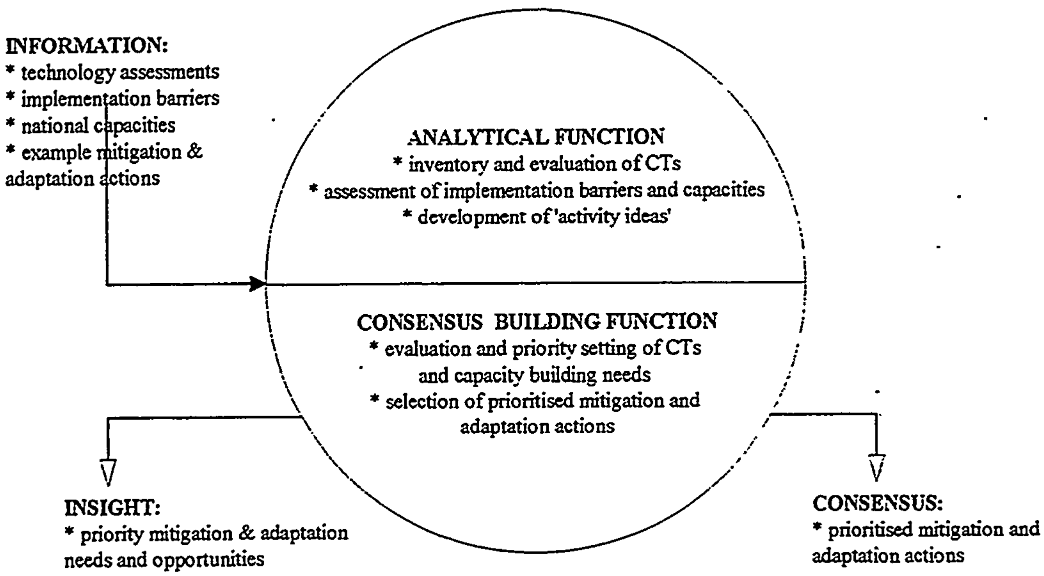

Figure 6: Summary of phase 2 ('assessing mitigation and adaptation needs and opportunities').

Phase 3: Implementing and evaluating mitigation and adaptation actions

This implementation and review phase in the planning process aims at (i) the planned and co-ordinated implementation of prioritised technology transfer projects, execution of capacity building activities and introduction of prioritised policy measures; and (ii) the continuation of the dialogue on mitigation and adaptation needs and actions between national stakeholders and the government and its agencies. The actual content of this phase is highly dependent on the types of mitigation and adaptation actions selected for implementation. In all cases, the 'activity ideas' generated during the 'assessment phase' (phase 2) are to be elaborated in detail. For policy measures this implies that the proposed regulations have to be developed in detail, political support is to be obtained for approval and resources (funds, properly trained staff, etc.) secured for the effective implementation. For technology transfer projects this implies that alternative hardware and software options have to be evaluated in detail on technical and economic feasibility. Furthermore, funding schemes may have to be developed tailored to the socio-economic situation of the targeted end-users of the particular CTs. For capacity building activities, a detailed activity schedule has to be worked out as well as a host institution selected in which the capacity will be created.

Although implementation and review of the mitigation and adaptation actions does require analytical and consensus building functions, it is obvious that this phase of the participatory planning process is primarily action-oriented, instead of planning-oriented. Analytical functions are needed for all three types of mitigation and adaptation actions (policy measures, technology transfer projects and capacity building activities) in order to prepare their implementation in detail. The consensus building function is required for the review of the implementation status of the prioritised mitigation and adaptation actions, and consequently for evaluating the progress achieved towards responding to climate change concerns. The overall structure of this phase is outlined in figure 7.

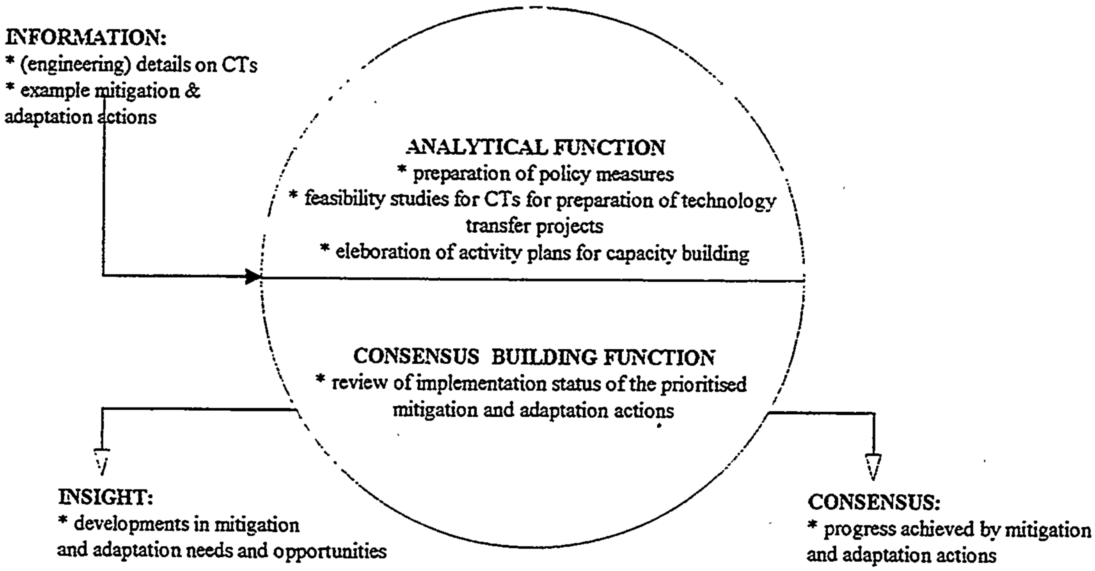

Figure 7: Summary of phase 3 ('implementing and evaluating mitigation and adaptation actions').

5. Closing remarks

This paper explored the applicability of NNA-like approaches to Climate Change Action Planning (CCAP) processes. This is aimed to result in a practical guideline for a participatory Climate Change Action Planning process, which is expected to be superior in generating support and participation of stakeholders in the CCAP process as compared to the predominantly 'technology-driven' and 'government-lead' planning processes currently applied for CCAPs. An outline for such participatory planning process has been briefly elaborated.

As with NNAs in general [van Berkel et all, 1996 b], the success of conducting a participatory climate change action planning process is likely to depend heavily on a series of success factors, including at least (in random order):

- qualification of the institution in charge of the assessment of the mitigation and adaptation needs and opportunities;
- commitment of the national government;
- commitment of the organiser (or financier) of the participatory planning process;
- participation of stakeholders throughout the process of preparation and execution of the CCAP planning process and management of its follow-up;
- transparency in approach and methodology;
- ability to generate new insights;
- ability to provide proper, and timely, follow-up to the CCAP planning process.

Whether or not the presumed added values of such participatory CCAP planning process can in practice be attained remains to be proven. Further elaboration of the proposed participatory planning process, preferably on the basis of experiences with the development and implementation of CCAPs, is therefore required as well as the trial application for the preparation of CCAPs according to the proposed participatory planning process for selected developing countries.

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Notes

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[2] In the remaining part of this paper it is assumed that 'developing countries' includes the 'countries in economic transition'.

[3] Climate relevant Technologies (CTs) are interpreted here as environmentally sound and economically viable technologies and know-how conducive to mitigating and adapting to climate change. The term "technologies and know-how" encompasses 'soft technologies' and 'hard technologies'. Examples of 'soft' technologies include capacity building, information networks, training and research, while examples of 'hard' technologies include equipment and products to control. reduce or prevent anthropogenic emissions of greenhouse gases in the energy, transportation, forestry, agriculture and industry sectors, to enhance removals by sinks, and facilitate adaptation.

[4] At the first Conference of Parties (COP) to the UN Framework Convention on Climate Change (UN FCCC), 23 countries and the European Commission jointly announced the launching of the Climate Technology Initiative (CTI). This initiative is a voluntary co-operative effort by participating governments to support the implementation of the Convention. Through CTI countries are conducting co-operative activities to evaluate and promote the use of Climate relevant Technologies. The countries involved in CTI have established several task forces, including a Task Force on Technology Aspects of National Plans.

[5] While preparing this general outline, most emphasis was given to mitigation of GHG emissions. It is presumed that the proposed step-wise procedure will at least also create a breeding ground conducive for adaptation activities.

Alois Schneider
Federal Ministry for Economic Co-operation and Development
Peking, November 1996

**Climate protection
in Germany's bilateral development co-operation
with the People's Republic of China**

Ladies and Gentlemen,

I am very pleased that thanks to this symposium I have the opportunity to present to you our climate protection measures, an important area in Germany's development co-operation with the People's Republic of China (PRC).

By signing the Framework Convention on Climate Change the PRC and Germany acceded to a binding treaty under international law which seeks to combat the global greenhouse effect.

Industrial and developing countries acknowledge in this agreement that they have a common responsibility for the preservation of the created order. In the light of the particular responsibility of the industrial countries, the duty to limit emissions of greenhouse gases is coupled with the obligation to provide the developing countries with financial support as they seek to implement the Framework Convention.

How does this task fit into the overall context of bilateral co-operation and what instruments are available?

The aim of Germany's development policy is to improve the living conditions of the people, particularly the poorer sections of the population, in our partner countries. We follow in this endeavour the model of globally sustainable development which guarantees the potential for development of the current generation without restricting the opportunities open to future generations.

For globally sustainable development to be achieved, three concerns are central: productive economic growth, social justice and ecological sustainability. Development co-operation supports the realisation of these three goals in our partner countries by helping to alleviate poverty, promote economic growth through private-sector development and protect vital natural resources. The aim of globally sustainable development can only be achieved if industrial countries too implement necessary reforms and structural adjustments at every level. Co-operation efforts with our partners must therefore be complemented by coherent policies at home. This is a matter of credibility, but also of developmental far-sightedness. Internal reforms in the industrial countries secure financial leeway for their providing foreign assistance in the longer term.

Development co-operation is help towards self-help. The ultimate responsibility for providing a domestic environment conducive to development lies with our partners. Inputs from outside are intended to provide impetus and start-up assistance, but not to replace the efforts of our partners themselves. In that sense, development co-operation can only be a contribution to sustainable development in our partner countries.

Optimum impact with scarce funds can be achieved if they are focused and used to overcome central development bottlenecks. Germany has therefore identified three priority areas in its development co-operation with the PRC: poverty alleviation, environmental and resource protection and education and training. Measures in these priority areas are most suited to reflecting the ideal of sustainable development which describes economic, social and ecological development as an indivisible whole.

Environmental and resource protection as a focal point of Germany's development co-operation with the PRC aims to preserve vital natural resources, shape economic development in our partner countries in an ecologically sound manner and put China in a position to participate in global endeavours to protect the environment.

Climate protection measures figure prominently in this area. This is justified given China's share in global CO_2 emissions and the potential for energy-saving measures and measures to increase power intensity. This potential is derived primarily from the possibility of using energy-efficient technologies, increasing the relatively low energy prices and making use of renewable sources of energy.

For all sectors with a climate protection potential a key factor has become the need to strengthen local personnel and institutional capacity. Capacity building aims to raise the performance of people and their public and private organisations in order a) for urgent measures to be carried out in the short-term and b) for environmental problems to be perceived in the medium to long term and to be dealt with increasingly in our partner's own strength. A wide range of measures are being undertaken to this end: transfer of expertise, organisational development, advisory services and training for local management and specialist personnel.

A good example are the measures being implemented under technical co-operation by the Carl Duisberg Gesellschaft in the area of efficient energy use. In addition, with the help of the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), a network of advisory activities to improve the energy efficiency of power plants has been set up. I am thinking here for example of the Centre for Power Plant Technology and the Power Industry in Xian, advisory services to the coal-fired power plants in Longkou and Lanzhou and the advisory services to improve firing technology in various thermal power plants. Besides their positive climatic impact all these measures are economically viable. The project executing organisations were able regularly to reduce their inputs for energy production by more efficient use of coal or gas.

Joint efforts to build executing capacity are complemented appropriately by measures under financial co-operation to rehabilitate coal power plants (Peking, Chongquing, Banshan), to finance new, highly effective plants (Yan and Lin Quing) and to improve the quality of the fuel used (Coke-oven gas cleaning, Peking). Currently, joint projects totalling over DM 1 billion are being implemented.

In future the use of renewable energies will increasingly be pushed ahead. The PRC has for example amongst other things a large wind power potential; Germany contributed DM 61 million to the first two wind power plants in Southern China. Almost DM 6 million is available for advisory measures on the use of renewable energies (solar energy, biomass).

According to IPCC estimates, destruction of the forest stand accounts for 14% of annual greenhouse gas emissions from anthropogenous sources. It is therefore extremely important to conserve existing forests and engage in afforestation to build up CO2 sinks. Besides the beneficial climate effects, afforestation is also necessary in order to ensure long-term protection of water and soil resources. In the Northern part of China and in the Yangtze region afforestation measures are therefore being supported with considerable grants from Germany. Projects totalling DM 146 million are currently being implemented.

In addition, Germany is financing a project to protect the tropical rain forest in Yunnan and on Hainan island for DM 12 million. Forest use strategies are being developed in these projects which give the local population a role in the planning of forest management and the revenue gained from forest use.

When the Framework Convention on Climate Change entered into force Germany made available an amount of DM 10 million for advice to partner countries on local capacity-building for them to be able to fulfil their obligations under the Convention. We are keen to ensure that local consultants carry out the advisory services. We have investigated reduction options with our Chinese partners in the provinces of Zejiang, Jianxi and Shanghai. The results have been set out in a study which was presented by one of my colleagues. I would like to thank everyone who worked on this venture for the qualified and good co-operation.

I would like to thank you, Ladies and Gentlemen, for listening.

U.S. Initiative on Joint Implementation: An Overview

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More than 150 countries are now Party to United Nations Framework Convention on Climate Change, which seeks as its ultimate objective, to stabilize atmospheric concentrations of greenhouse gases at a level that would prevent dangerous human interference with the global climate system. As a step towards that goal, all Parties are to take measures to mitigate greenhouse gas emissions and to promote cooperation in the development and diffusion of technologies and practices that control or reduce emissions and enhance sinks of greenhouse gases.

In the U.S. view, efforts between countries or entities within them to reduce net greenhouse gas emissions undertaken cooperatively, termed joint implementation (JI), holds significant potential both for reducing the threat of global climate change and for promoting sustainable development. To develop and operationalize the JI concept, the U.S. launched its Initiative on Joint Implementation (IJI) in October, 1993, and designed a program to attract private sector resources and to encourage the diffusion of innovative technologies to mitigate greenhouse gas emissions. The goals of U.S. IJI complement the principles of Decision 5, First Conference of the FCCC Parties, establishing an Activities Implemented Jointly pilot phase.

U.S. IJI provides a mechanism for investments by U.S. entities in projects to reduce greenhouse gas emissions worldwide and has developed a set of criteria for evaluating proposed projects for their potential to reduce greenhouse gas emissions. These criteria are designed to identify worthy projects and accept them into U.S. IJI. Principal criteria include:

1) Support the development goals of host country while providing greenhouse gas and other environmental benefits;

2) Produce measurable reductions in addition to reductions likely to result in the absence of the project;

3) Emission reductions or carbon sequestration can be monitored and tracked;

4) Projects will not result in net greenhouse gas emissions elsewhere or otherwise have significant secondary environmental impacts; and,

5) Projects are enduring (sustainable).

To date, U.S. IJI has received over 70 project proposals. Of these proposals, 22 projects have been accepted into the program. These projects represent a diverse set of innovative technologies and practices in nine countries. Projects include developing renewable energy sources such as solar, biomass, and hydroelectric power, improved energy efficiency, and land-use change projects leading to better forest management, forestation, and forest conservation.

Aggregating preliminary estimates presented to U.S. IJI by project developers suggests that cumulative net emission reductions as a result of these projects are expected to be over 40 million metric tons of carbon (C) equivalent. While U.S. IJI does not certify project estimates prospectively, it does set forth provisions for monitoring and verifying emissions reductions as they occur. Furthermore, accepted projects, when fully implemented, are expected to lead to significant financial and technical investments in host countries.

U.S. IJI has received a number of proposals from a host of countries which may receive consideration in future years. To test the U.S. IJI criteria and to provide input into the "Activities Implemented Jointly" pilot phase, the U.S. intends to promote the development of projects and to seek additional information on the experience of individual project developers during implementation. Regional Teams and Technical Assistant Teams in U.S. IJI provide limited support to project developers in improving or completing credible proposals. Limited technical assistance is also available to help implement projects or monitor and verify greenhouse gas emission reductions.

As a supplemental effort, U.S. IJI seeks to assist countries in developing institutional and human capacity to implement joint implementation programs and projects. U.S. IJI supports domestic and international outreach efforts (e.g., newsletters, publications, electronic communication), training and technical assistance activities (e.g., handbooks, analytical tools, workshops), and other support activities. For further information, please contact:

Telephone: 202-586-3288
FAX: 202-586-3485/3486
Hotline: 202-586-3467

World Wide Web: http://www.ji.org

Post:

U.S. IJI Secretariat
PO-6
1000 Independence Avenue, SW
Washington, DC 20585 USA

ADDRESS TO THE INTERNATIONAL WORKSHOP ON GREENHOUSE GAS MITIGATION, TECHNOLOGIES AND MEASURES

Art Kant

Netherlands AIJ Programme

Introduction

The Netherlands has a long history in combatting natural forces for its mere survival and even creation. Around half of the country was not yet existent around 2000 years ago: it was still below sea level that time. Building dikes and the discovery of eolic energy applied in windmills, allowing to pump water from one side of the dike to the other, are technologies that gradually shaped the country into its current form, a process that continues to materialize till the present day.

Water has not always been an enemy of the country. In the Hundred Year War with Spain, during which the country was occupied territory for most of the time, the water was used to drive the Spanish armies from the country. As large parts are well below sea level, breaking the dikes resulted in flooding the country which made the armoury of the Spanish army useless. In this way they had to give up the siege of several major Dutch cities that time. These events marked the gradual liberation of the Dutch territory.

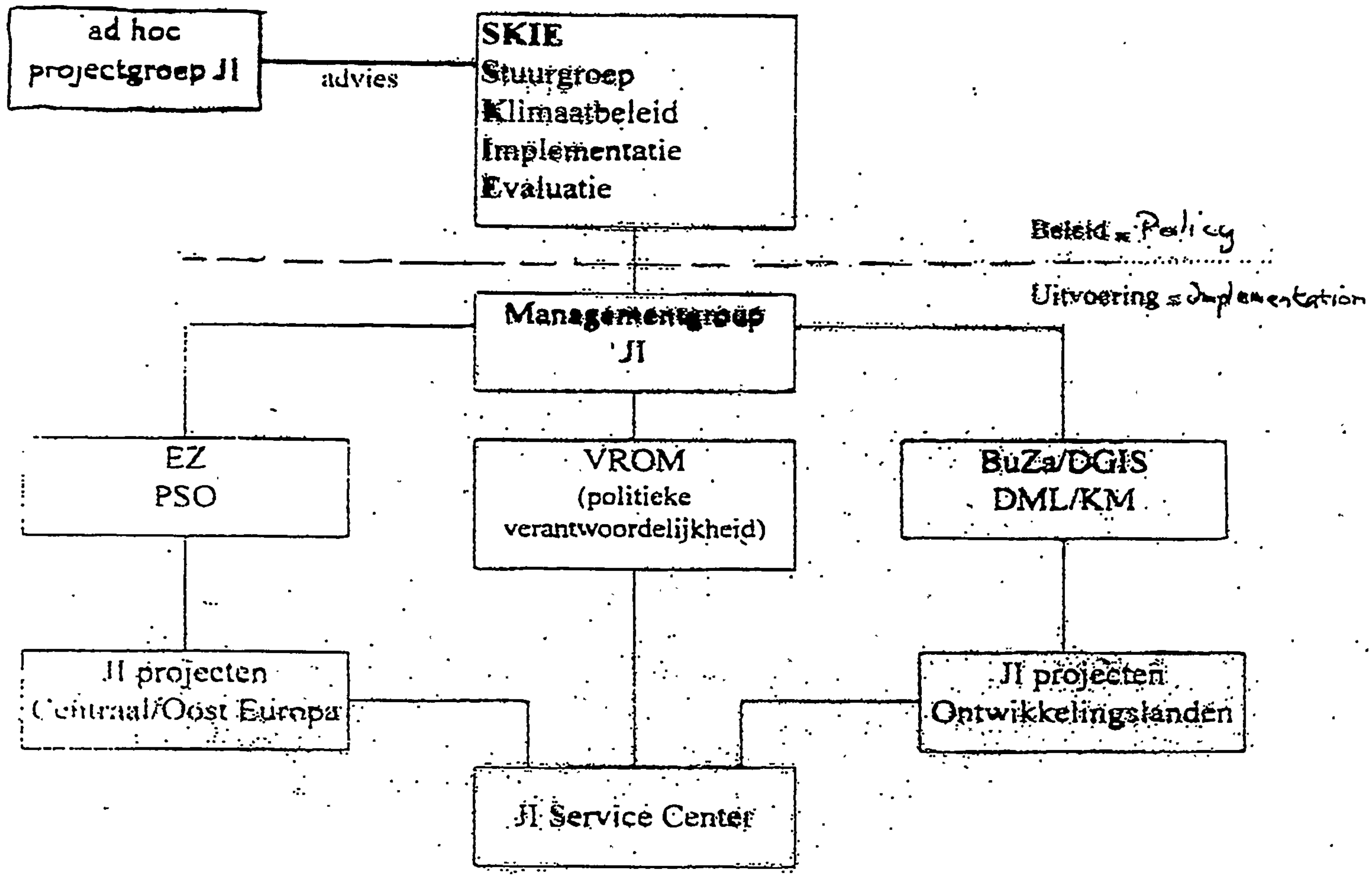
Consequently, in the discussion on adaptation and prevention of the greenhouse effect the Netherlands has a clear stand. The greenhouse effect will occur anyway, even if we deploy all possible counter measures at once. So our aim is to prevent the occurrence of the greenhouse effect to the highest extent possible, and to protect the most vulnerable areas meanwhile, especially the coastal zones. In order to reach these goals the Dutch government has established a Joint Implementation Experimental Programme in accordance with the provisions made by the Conference of Parties in Berlin (1995).

Institutional set up of the Joint Implementation Programme

The Dutch government decided to establish the Dutch Joint Implementation Programme at September 25 1995. In figure 1 the institutional set up of the programme is shown. The set up itself is the result of a long process of lengthy consultations among the most directly involved ministries, notably the Ministry of Environment (VROM), the Ministry of Economic Affairs (EZ), the Ministry of Foreign Affairs (BuZa) and the Minister for Development Cooperation (OS). In the set up a distinction is made between the policy level and the implementation level, indicated by the dotted horizontal line.

The largest box shows the Steering Committee in which the mentioned ministries

Organisatie JI



take part, together with the Ministry of Agriculture and the Ministry of Finance (SKIE). From a political point of view this committee is responsible for the implementation of the Joint Implementation Programme according to the conditions and goals set by government. This committee established a Management Group in which the most involved ministries supervise the day-to-day running of the programme, taking care of the practicalities of the implementation. Only EZ, VROM and OS are represented in this Management Group. The SKIE is also advised by an expert panel which is organized as the ad hoc project group JI.

The Ministry of Environment chairs the committee and its sub groups as it carries the responsibility for the Joint Implementation Programme in face of the Government. This includes the annual reporting on JI to the Government, Parliament and the Conference of Parties. The implementation of the Programme is given to both Economic Affairs and Development Cooperation. The former Ministry is involved because an important aspect of JI touches the interest of Dutch industry and it executes the AIJ projects in Eastern en Central Europe; the latter is involved because JI is expected to be realized, at least partially, in the Annex-I countries expressing their willingness to cooperate under the Climate Convention. The financial resources for the JI Programme are thus allocated to these two ministries. In the boxes it is indicated that EZ has institutionalized the programme under the BEB (foreign economic relationships) and BuZa/DGIS under DML/KM (Direction for Environment/Division Climate, Energy and Environmental Technology). EZ subsidises AIJ projects in countries in transition while DGIS supports AIJ projects in developing countries.

The Joint Implementation Registration Centre registers projects as Joint Implementation projects and monitors the extent of greenhouse gas emission reduction realized by the project. The proposal for certification is presented to the Minister of Environment who is entitled to grant certification.

The organization and mandates are defined in a policy document which has been negotiated between the ministries mentioned above. In fact the daily management of the Programme is given to two JI managers, one in the Ministry of Economic Affairs and one in the Ministry of Development Cooperation, the latter being the author of this contribution..

Environmental policy in the Netherlands

The Netherlands covers a densely populated area with important agricultural activities. Space is a scarce resource in the country and it has given rise to strict legislation for the use of it. The quality of the environment has been increasingly under pressure of all anthropogene activities. A lot has been done to improve the environment ever since the sixties. Hardcoal has been substituted by natural gas after large gas reserves had been detected in the national territory. The first energy crisis has induced a vast number of energy conservation measures covering all economic sub sectors, resulting in a markedly improved situation regarding the levels of acidifying emissions and the emissions of particles. National environmental planning came into existence during the late eighties, resulting in over a hundred of policy measures.

Before going into some more detail on the Dutch Joint Implementation Programme it is instructive to have a closer look at some of the policy instruments with relevance for the JI Programme.

The Ministry of Economic Affairs has been running a tender programme called Tender Industrial Energy Conservation (TIEB). The programme focused on commercial viable energy projects in Dutch industry, with a budget of around 120 million US$. A baseline study and monitoring activities are part of the programme in order to provide information about the cost effectiveness of the programme. Processing time for proposals was around half a year (from the first rough proposal to acceptance of the project). The Tender fitted well in covenants between Dutch industry branches with the Ministry of Economic Affairs.

The Ministry of Development Cooperation has two financial support programmes for environmentally benign technologies (ORET=Developmentally Relevant Export Transactions; and MILIEV=Environment and Economic Independence Programme). As environmentally benign technologies are usually not perceived to be commercially viable, these technologies will be subsidized in order to increase DC's access to these technologies so desperately needed in many occasions. Both programmes are focusing on around 55 countries the Netherlands has a development relationship with. Around 115 million US$ annually are available for this type of support to environmentally friendly technology of Dutch origin. Proposal processing time is around half a year on an average. Other ministries have an advisory role in the committees guiding both programmes.

Next figure presents the mentioned programmes together with the Joint Implementation Facility, the part of the Joint Implementation Programme dedicated to developing countries (For the countries in transition other procedures are established).

Figure 2: Comparison of some subsidy instruments in the Netherlands

	TIEB	JIF	ORET	MILIEV
Focus	The Netherlands	55 DCs + Signed Climate Convention	55 DCs	55 DCs
amount (annual)	120 M US$	50 M US$	90 M US$	25 M US$
ministries involved	Ec. Affairs	Three ministries	Development Cooperation	Development Cooperation
target	Dutch industry	Dutch industry NGO's Administrations	Dutch industry	Dutch industry
controlling for effect	yes	yes +certification	no	no

processing time	1/2 year	some months	1/2 year	1/2 year
economic evaluation	commercial	commercial	sub commer-cial	sub commer-cial
general policy fit	covenants	development objectives	development objectives	development objectives

The table shows that the Joint Implementation Facility is not a new class of instruments for the Netherlands. Considerable experience has been cumulated over the past 6 years with similar instruments. It also shows that the Netherlands government is dedicated to improve the national environment, and increasingly so with a view on the global environment. An economic argument may apply here as well. As the Netherlands has put into effect many policy measures in the field of energy conservation during the last two decades, it may become more cost effective to invest in similar measures to be taken in DC with the environmental pay-off being much larger.

Characteristics of the Joint Implementation Facility are:

- projects exclusively in countries with which the Netherlands has a development relationship, and which are willing to cooperate with the Netherlands under the Climate convention;
- with only 50 million US$ available for the entire experimental period JIF is designed such that a high leverage is looked for by using small amounts of JIF seed money to trigger private investments;
- the leverage can be realized because of the commercial nature of the projects concerning transfer of proven and adequate technologies;
- although the focus is on industrial projects (industry, energy and transport sectors) mainly, also NGO's and local administrations can apply for project support;
- an essential aspect is the provision that AIJ projects are going to be controlled on their effect and the control mechanism as well as the results are going to be checked in anticipation of the possible upcoming crediting of greenhouse gas emission reduction after the experimental period;
- processing time of the proposal is made as short as possible, preferably a few months, as investment decisions vary strongly with the economic situation of target industries;
- AIJ projects should fit into the objectives of the Dutch Development Cooperation, being:
    - poverty alleviation
    - environmental sustainability
    - not gender biased
    - demand driven
    - in line with national development objectives

The Joint Implementation programme is still in a very early stage. Procedures are not yet crystallized and development of the programme is a learning process to be characterized by 'learning by doing'. The learning process applies as much to

Dutch programme managers as to the host countries and industries involved. In the next section the principles of the Joint Implementation programme are outlined in a possible project matrix.

Example of a Joint Implementation Project Matrix

The main difficulty of the Joint Implementation concept perceived from our side is the fact that governments sign the Climate Convention while the implementation is left to other parties in the convention countries, being industrial companies, NGO's and local administrations. There is, however, for the governments only limited scope to influence the entrepreneurial activities. For example the energy conservation objectives put on paper in the covenants (Multi Annual Agreements) between Dutch industrial branches and the Ministry of Economic Affairs of the Netherlands provide an escape in case that economic growth is less than expected or if the results of the enterprises are below accepted profit margins. Despite these clauses in the covenants, established in a longlasting and sometimes painful consultative process, energy efficiency in the Netherlands is improving gradually, though not in the pace desired by many environmental NGO's which complain about the non-compulsory character of the covenants.

In the Netherlands Joint Implementation is perceived as an ongoing process of 'learning by doing'. There is not one mode of projects defined. In consultation with the parties involved every AIJ project has to be designed with the features desired by the participants. A model for AIJ projects currently under discussion with Chinese and other authorities is laid out in next figure.

The main objective is depicted in the box below in the figure: realization of a JI project with a Dutch and Chinese industrial partner in which the Chinese partner indicates the necessary support (being technical, financial or training) expected from the Dutch company. Because the trajectory to such a project is long and characterised by a number of risks, Dutch companies may be hesitant to invest in projects in DC's, irrespective of the expectation that they match profitability criteria. The JI Facility of the Netherlands government aims at facilitating projects that otherwise would not be likely to be realized. With a limited amount of seed money a leverage effect is aimed at as the investment capital has to be acquired by the industrial parties themselves: AIJ projects are commercial projects which only need support in the initial stages. That is the main reason to focus on financial support of the initial stages, being prefeasibility and feasibility stages. The initial contact or identification of the project is excluded from the Facility's support as the partners have to show commitment to the intended project. Only in exceptional cases (e.g. small and medium scale businesses) support will be considered.

As commitment towards an intended AIJ project has to be shown to both the JI Facility and to the governments, a letter of intend should define the intentions both partners have in mind. Based on the letter of intent and based on a positive out-

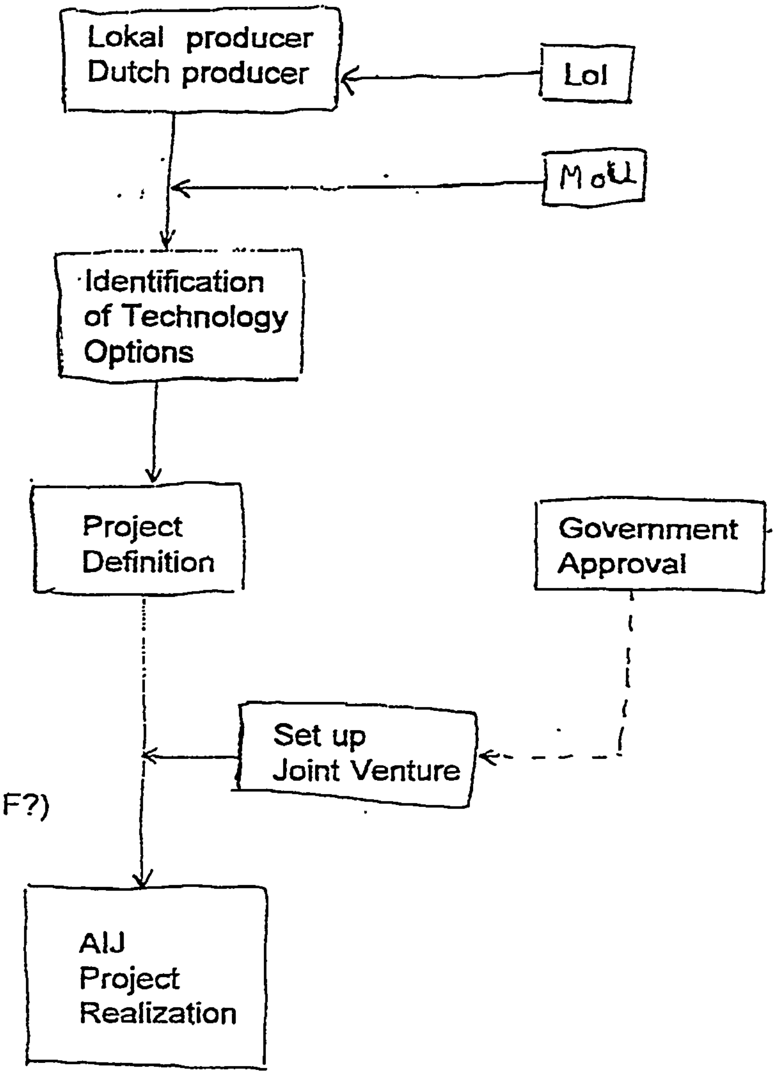
Costs:

Initial contacts:
both partners

Prefeasibility:
GON/JIF

Feasibility:
GON/JIF

Investments:
both partners
(incremental costs: JIF?)



Baseline study,
monitoring,
training:
(GON/JIF partially)

come of project proposal appraisal by the JI Facility, both governments will be requested to agree on the project as a AIJ project following the decision taken by the Parties of the Climate Convention by signing a Memorandum of Understanding. After the government approval the JI Facility can design the contracts that release the financial support under the conditions of the contract. Than the prefeasibility and feasibility can be carried out which result in a clear description of the project, including technical, economical, financial and environmental modalities. The study results are the go-no go decisive moment of the project to be carried out.

It is expected that the creation of a Joint Venture is a simple and adequate mode for many projects to be carried out between two or more industrial parties. The modalities of the Joint Venture have to be negotiated by the partners themselves, of course within the legal framework for Joint Ventures in the host country.

The Joint Venture is expected to be a set of agreements on inputs and outputs of the AIJ project. One of the outcomes is the extent of GHG emission reduction in tonnes per year. As the experimental period has the objective to investigate the possibility to reduce GHG emission at the least costs and to develop a mechanism for enduring emission reduction efforts after the experimental period, an agreement on the share in emission reduction should be part of the contract between both partners as well.

The most frequently posed question to the JI Facility is what are the conditions of the fund and how much do you pay for. As the JIF is in its fourth operational month very few has been defined yet. In principle the USIJI and Canadian AIJ conditions will be adopted with possible alterations in the areas of sinks (no funding for sinks), focus on industry, energy and transport sectors, without exclusion less focus on NGO's and administrations. The conditions of the Facility will be defined in the next couple of months.

It is considered to pay prefeasibility and feasibility costs for a large part. Identification of projects should be paid for by the participants. Baseline study and monitoring of the GHG emission reduction may be partially paid for by the fund, including training as part of an integral package being the entire project. There are no clear percentages for fund support established so far. One of the conditions will be that partners should express commitment through the allocation of financial resources to the project in several stages of the project. A 'free rider effect' has to be prevented to the extent possible: Projects that will be carried out irrespective of the JIF financial support are excluded from the programme. It is admitted that it is difficult to realize this exclusion as one has to rely strongly on the documents and arguments provided by the stakeholders. However, investment decisions in industry are the field of competence of industrial economists and banking companies and it is considered to consult both entities to provide the JIF with an analysis of the reasonability of the arguments.

A last important issue to be dealt with is the incremental cost issue. If an investment in e.g. new process technology to be provided by the Dutch partner is higher than the best conventional alternative, the difference is defined as the incremental costs. It is not envisaged that the JIF is going to finance the full incremental costs.

The new technology creates also profits as e.g. the energy intensity per unit product will be reduced. These profits have to be deducted from the incremental costs in a reasonable way. The remaining costs extend the payback period with a calculable number of months. The threshold IRR settled by the industries as the go-no go criterion for the project, may incorporate the effect of the incremental costs on the investment decision. This is a non-specialist perception of the problem which may be highly simplified. However, one cannot wait until the last theoretical obstacle is put aside; the Netherlands government is offering support to any party desiring to participate in AIJ projects under the conditions set out by the Conference of Parties. The incremental cost issue has to be carefully dealt with in discussions between parties and governments.

JIF practicalities

It should be clear that the starting point for Joint Implementation Projects is in identification of development needs of potential host countries. The focus is on demand driven projects for which adequate Dutch counterparts have to be found, with the help of the Dutch Embassy or the Facility if need be. The JIF can function as a broker between demanding and supplying parties.

The focus will be on projects in industry, energy and transport as they constitute the most important GHG emitting sectors in most developing countries.

As has been put forward during this conference: the largest resources for development do not come from traditional development aid budgets, but from private capital flows. This is an important fact that may result in technology transfer on the base of direct relationships between industries all over the world. The desired high leverage effect of the JI resources can only be realized when Dutch industries can be made interested in investments in developing countries. They are eager to do so as soon as interesting opportunities provide higher profits than the more well-known alternatives. Commercially profitable projects are a necessary precondition to initiate or to enhance this capital flow.

Training (capacity building) will be an important component in many AIJ projects, especially when the delivery of hardware is an anticipated project element. The parties involved will have to design a training plan which ensures the technology to be maintained for the recipient industry. Maintenance of appliances and equipment is a basic condition for sustainable projects. The Dutch AIJ sees upon the design of and carrying out of a training plan.

Dutch JI priorities

The design of a communication plan is most important at this stage in order to present the JIF to the broader Dutch community. Besides that, as many ministries are involved in JI in the Netherlands, the merits of the Dutch programme should be made clear as soon as possible, as well as the relationship between all types of communication from different ministries in order to prevent confusion in the target groups.

Secondly, the project approval procedures have to be made explicit. More and more industries request for detailed and specific information, notably on the application procedure to be followed. There are many industries that have indicated to be highly interested in the JIF, and they are ready to cooperate with the programme in due course.

Thirdly, Dutch industry is not all to clear to potential foreign partners. Apart from the big multinational companies, many environmentally benign technology producers have limited appearance in developing countries. This may urge the JIF to connect potential partners. The Ministry of Economic Affairs and the Dutch Embassies may play an important role in creating these bonds.

Fourthly, there are around 30 to 35 proposals put forward to the JIF. These proposals have to be screened as soon as possible. Dutch industry has indicated that a process time of two to three months is the most desired outcome. In order to speed up time consuming procedural processes, a first rough appraisal based on a project description covering maybe 3 or 4 pages, will be made within a couple of weeks, thus saving time and effort of the potential participants.

Final remark

The Netherlands government has welcomed the workshop as an opportunity to interchange views and ideas on practical projects with the Chinese authorities. the dedication and perseverance of the Chinese authorities has been a significant contribution to the success of the workshop.

ADDITIONALITY OF GLOBAL BENEFITS AND FINANCIAL ADDITIONALITY IN THE CONTEXT OF THE AIJ NEGOTIATIONS

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1. CONTEXT

The Conference of the Party at their first meeting (COP1) took a decision regarding criteria for joint implementation as indicated in Art. 4.2 (a) of the FCCC which established a pilot phase for activities implemented jointly (AIJ) under the pilot phase. Besides some more technical issues this decision specified that such measures should bring about real, measurable and long-term environmental benefits related to the mitigation of climate change that would not have occurred in the absence of such activities. It also established that the financing of AIJ shall be additional to the financial obligations of developed country parties.

These two requirements are called the additionality criteria for AIJ. The first refers to the realness of GHG emission abatement (which means reduction compared to a baseline) whereas the second describes that funds earmarked for AIJ have no other objective (i.e. profit making, export promotion) but to reduce GHG emissions to avoid the free-riding of investors and subsequently developed country parties. The reporting framework as well as the reporting requirements under national programs do not specify further the two types of additionality and even though research focuses on issues like baseline determination there has been no attempt so far to identify approaches which contribute towards defining strict and practicable methods and guidelines to frame additionality criteria.

The first FCCC assessment of pilot project reporting revealed that in the reporting of activities, emissions additionality often remained unclear, especially in cases where AIJ was only a portion of an existing or already planned project, and that there is a point about how to account for financial additionality. It subsequently proposed to develop a uniform approach to baseline determination and the assessment of emission (reduction) additionality and financial additionality.

2. WHAT IS THE RELEVANCE OF ADDITIONALITY FOR AIJ?

a) It is necessary to define and quantify the effects of climate change mitigation activities

The effective design of climate change mitigation activities requires measurement of the effects of such activities. In order to quantify the effects of AIJ activities one needs to specify what would have happened in the absence of AIJ in terms of GHG emissions and in terms of financial flows. If such additionality could be defined AIJ transactions would not be different from other types of investments: they create a commodity which is valued more than it costs to create. This argument also applies to other measures under the Climate Convention, i.e. technology transfer and financial measures. However, the definition of the AIJ commodity is not straight forward: most often the AIJ commodity is not created independent from other commodities, therefore it is difficult to single out the AIJ related part of an investment (for example in the context of a power plant investment) from other investment objectives. A method to differentiate between various investment objectives and technology choice (because it is technology choice which determines the GHG efficiency of the investment) is needed to establish the AIJ commodity that is created by such activities.

[1] The expressed opinions are those of the author and do not necessarily reflect the view of the IEA secretariat or its member countries.

If there is no answer to this problem, potential solutions to other AIJ related problems are very difficult to find: in the context of the ongoing debate on mechanisms to assign a value to the AIJ commodity and the issue of crediting the reluctance to agree on something is partly created because of the lacking definition of that commodity.

As long as strict additionality criteria are not defined, crediting would soften the commitments of Annex I countries.

First of all, non-Annex I countries donot have GHG emission target commitments under the FCCC in the foreseeable future, which means that a firm baseline which is based on an absolute amount of annual right to emit[2] cannot be established. Secondly, when baselines were then established on the project level and additionality is not clearly defined, participants in AIJ projects could and have the incentive to overstate the AIJ related achievements of their activity. If AIJ were integrated into the climate change policy mix of Annex I countries in the future, i.e. through crediting, such free-riding in which credit were given for non-additional global benefits would soften the commitments of Annex I countries.

Strict additionality criteria to limit free-riding and double dividends for commercial investors and investors with objectives different from climate change abatement

Financial additionality in the Climate Convention so far refers to ODA only. However, in the real world the majority of financial flows in sectors relevant for climate mitigation activities are private foreign direct investments. Considering that private investors potentially represent a large share of AIJ investors it is necessary to differentiate between their various investment objectives (i.e. profit making, overseas development objectives, or export promotion). If different investment objectives were not separated (within the same project), investors would potentially earn a an AIJ related return on top of a commercial return (i.e. from electricity sales) for the same dollar spent. This is not to imply that AIJ projects should not be profitable. On the contrary, projects need to be profitable to create long-term benefits, otherwise they would cease to operate. However, it is necessary to separate funds which create direct financial returns from funds that were invested to qualify for AIJ. The same argument also applies to public investors who also have different investment objectives as well as other commitments under the Climate Convention.

Experience made at various AIJ conferences suggest that there is a perception that AIJ was applied to projects which earned a very high financial rate of return after implementation. It was felt that because of those high financial returns the projects could not qualify for AIJ and that there should not be a recognition of GHG emission reduction from such projects. It was argued that the profit making objective was the sole motive for investor involvement. Associated recognition of GHG emissions reduction were perceived to resemble potential additional windfall profits (if there were a value to the recognition).

This perception is caused by a lack of differentiation between investment motives over the life-cycle of the project, especially in the early phase of project development: in the absence of AIJ such projects usually donot come forward because of the perceived risks and because of the lack of an initial effort to identify the project which then created the interest of commercial investors.[3]

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[2] This is not to suggest that Annex I countries only consider absolute targets as their climate change commitment. It should be explored how AIJ should be designed to be compatible with other forms of commitments.

[3] This type of observation can be made for those types of projects which are often called "no-regret options to mitigate climate change". Neoclassical economists do not realise that there can be a real cost to implement them when certain informational and institutional barriers need to be overcome prior to

However, the language of the Convention is not very specific about the financial additionality for public investors including various forms of government agencies (Export Credit/Guarantee Agencies, Development Aid Agencies) and does not deal with financial additionality for private investors at all.

b) Without strict additionality definitions the perceived free-riding and double earnings prohibits further progress on integrating Annex I climate change policy responses with the AIJ instrument

Because the two issues outlined above were not addressed properly in already existing pilot projects, the role and nature of the involvement of AIJ investors was not realised which is attributed to the lack of clearly defined additionality criteria in the reporting framework for AIJ under the pilot phase.

Applying a possible approach based on real additionality to the above case of "no-regret projects" the activity of those early actors which removed the initial implementation barriers could qualify as AIJ activity. The associated costs are usually not recovered through a financial return from the project, and in theory it is those parties who deserve the recognition for having carried out that activity. In the real world, this is of course subject to negotiation.

If the additionality issue were clearly understood and translated into clear rules in the reporting framework, AIJ could be perceived as a commodity creating activity. This could open the way for negotiators to advance the process and make the AIJ commodity subject of similar rules of trade which are applied to other commodities as well.

In this context it should be pointed out that there is a price for no action: a power plant that is constructed now without AIJ and a low GHG efficiency represents a foregone opportunity to create that AIJ commodity. In the case of energy sector investments with a high level of baseline activities, AIJ commodities cannot be stored and donot remain available over time but they can only be created when the need for energy related infrastructure investments opens a window of opportunity.

c) Conclusion

A strict definition of additionality criteria would allow to reduce the inflation of the AIJ commodity and overcome the perception that projects can not be AIJ projects and be profitable at the same time. The additionality of GHG abatement is already important under the pilot phase to build the necessary support for the instrument. It becomes even more important when AIJ evolves into an instrument that allows crediting against GHG emission targets of Annex I countries. In that case it is crucial that the commodity that is defined through an allowance to emit a certain amount of GHG emissions per year is equal to the commodity which has been created by crediting a real and additional GHG emission reduction from on AIJ project (or to define a proper exchange rate between the two currencies). It will not be possible to establish crediting for AIJ when the currency which is defined through the emission limitation of Annex I countries is exchanged with another currency that is highly inflated, at least not without taking into proper account an "exchange rate" between the two currencies.

The question that needs to be addressed by negotiators is how to establish additionality which needs to be strict and enforceable enough to avoid free-riding on the one hand and is practicable and cheap enough to make AIJ attractive to potential investors. Other AIJ related issues can be resolved subsequently when an approach to

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project implementation. In other cases, the removal of such barriers does not suffice for project take-off, but the additional reduction of project capital costs through AIJ investors is required.

define the AIJ commodity has been found.

3 THE WAY FORWARD

Agreement on flexible instruments to mitigate climate change will be key to establish quantified emission limitations and reduction objectives. An instrument to access the large and cheap GHG emission reduction offsets in non-Annex I countries while emphasising local development objectives of project-site countries is also a strong incentive for all to go on with the AIJ related negotiations. However, for reasons outlined above, such an agreement depends on refining additionality criteria for AIJ that are acceptable to non-Annex I countries. Climate negotiators in non-Annex I should be a driving force to push for strict additionality criteria when AIJ were to be integrated into the climate change policy instrument mix of Annex I countries including crediting. However, non-Annex I countries donot have the capacity and the primary responsibility to develop such criteria. Annex I countries need to take a leading role in the development of such criteria and find the agreement of non-Annex I negotiators.

The strictness of additionality criteria in the reporting framework mainly depends on the extent of the integration of AIJ into the national climate change policy instrument mix. If Annex I countries aim to credit the AIJ commodity against their national commitment to limit GHG emissions under the FCCC they have to be very strict. They also have to be strict if they aim to implement AIJ under a non-quantative type of commitment under the FCCC, but use a quantative type of domestic regulation (to involve the private sector). The need to measure the associated effects of climate change mitigation projects only disappears when there is no interest to evaluate at all.

The strictness of additionality criteria will also depend on the envisaged scope for AIJ. If AIJ is meant to remain an instrument for good-will and small scale projects, less strict criteria will be sufficient to keep monitoring costs low. If however, financial flows and project size are meant to increase to significant levels rather precise definitions and monitoring is necessary.

A clear definition of additionality criteria is not only needed for AIJ but for technology transfer and other activities under the Climate Convention as well. There is little reason to develop different criteria for AIJ, technology transfer and financial measures in respect to establish the additionality of global benefits. In addition, there is no need to negotiate new language before new ideas on this issue can be developed. However, in respect to financial additionality it is necessary to negotiate new language on the treatment of private investments for climate change mitigation. Whether the same rules can apply for AIJ, technology transfer and other measures under the Climate Convention needs to be evaluated.

However, AIJ and other measures under the Climate Convention are not the same even under the pilot phase for AIJ: it is established that AIJ creates a liability to generate a climate related commodity that was agreed upon in private contracts between the project participants (whether or not it is truly additional). This is not the case i.e. for technology transfer. The effects of technology transfer should be monitored but there is no liability in the case of non-performance.[4]

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[4] This issue would deserve greater attention: it could be argued that if there is no liability to perform on the receiving end, the performance will be lower because of lack of responsibility. This would reduce climate and local benefits, the contribution to the objectives of the Convention as well as the cost-effectiveness of this measure.

4 How to find additionality for AIJ projects?

After having said that additionality criteria are needed one needs to explore how additionality criteria could be established. That additionality is "out there" can be illustrated by pointing to investment opportunities which would increase GHG efficiency of energy sector projects, i.e. in power generation (through fuel-switching, and increasing supply-side and end-use efficiency) which are not taking place now. This potential has also been demonstrated by several case-studies which were carried out by the IEA and other organisations.

a) Where does additionality come from?

What is it that AIJ investors could do additional (in an implementation, reality oriented way) to implement more climate friendly projects? The approach the IEA has taken to establish additionality is by identifying barriers to those more GHG efficient projects: it was argued that i.e. for the case of the power sector the market delivers certain types of investments which represent a careful weighing of several different parameters in the decision-making process. This process is constrained by the institutional environment for those investments, the local availability of and operating experience with power generation technologies and their capital costs (also taking into account the need for imported technology, associated foreign costs and exchange rate risks, the costs of domestic long-maturity financing) as well as technology related risk perceptions of financial organisations or project sponsors. In the case of investments in energy efficiency in Central and Eastern European countries it is most often the lack and deficiencies in the institutional framework which leads to the delay of otherwise beneficial projects. Barriers can therefore comprise certain transaction costs for otherwise profitable investments as well as higher capital costs for advanced and more GHG efficient technologies.

Following this approach, additionality is defined through a lack of certain ingredients to push a more GHG efficient project into implementation when compared to the baseline investment. AIJ would supply those ingredients and allow project implementation. Such a project would still include a range of other investors (commercial, ODA, export promoters), but it is the contribution of the AIJ investor who pushes the project off the ground and towards a higher GHG efficiency while at the same time all investors achieve their respective investment objective. The scope for additional measures and AIJ is of course limited by the priority of national development objectives, which means that besides its GHG efficiency impact this "upgrade" needs to contribute towards national development objectives.

b) What types of additional measures are available?

The type of measure that is needed to push more GHG efficient projects into implementation will largely depend on the type of project as well as the institutional context in which the project will be implemented. This means that first of all, the potential for certain types of projects must be identified. Climate change mitigation plans suggest that investors in the Indian or Chinese power sector consider projects to improve the thermal efficiency of coal-fired power generation, the substitution of high carbon fuels, cogeneration, increasing the share of renewable energy in the power generation mix and transport sector improvements. African countries could consider projects to improve the performance of industrial technologies, power generation systems, and renewable energy utilisation. Latin American countries consider projects to replace oil for power generation, increasing utilisation of various renewable energies, as well as transport sector projects.

In a next step, policy makers in the respective countries together with policy makers from Annex I countries and potential AIJ investors, need to identify additional measures that are needed to overcome the existing barriers to those project types taking into account the constraints to such investment.

Several studies have already been carried out to describe such constraints and the type of needed additional measures for various types of projects in the power, transport, industrial and household sector. Such constraints are usually technology or country related and they can be addressed on the project level to various degrees. Ongoing changes in institutional systems, relative prices, technological change, the behaviour of pioneer investors, and the involvement of MDBs change the playing field and risk perceptions of potential investors constantly. This means that such constraints are removed and added constantly. Based on this observation, measures that would qualify as additional today might not qualify tomorrow. The rules by which additionality could be defined have to allow for this flexibility either by creating very explicit rules which take into account the dynamics of change in the system of constraints or by reviewing the rules in specified time periods. Best available judgement could be a sufficient monitoring mechanism while keeping monitoring costs low.

c) Who would execute and finance additional measures and in which form?

Depending on the type of additional measure needed, they should be implemented by those who can do it best. This means that there should be a strong role for technology manufacturers, project developers and the financial community in AIJ projects. Taking into account the strong role of green NGOs in the context of developing environmental projects in developing countries, they need to be integrated as well. In terms of financing AIJ investment, the type of involved actors will largely depend on the type of schemes implemented by Annex I governments to channel funds into such projects. This could mean that projects are directly financed through government funds, government intermediaries (i.e. bilateral and multilateral banks), or through the private sector.

It should be mentioned again that it is important to account for AIJ funds in the project separate from other project funds that serve other purposes like, i.e. profit making. AIJ funds are not meant to create a financial return but GHG emission reductions, whereas commercial funds are meant to earn a financial rate of return. However, investors could reduce interest rates of their commercial investments to below commercial rates as their AIJ related contribution.

5 WHAT IS THE ROLE OF AIJ IN THE CONTEXT OF OTHER CLIMATE CHANGE RELATED MEASURES?

AIJ is not the only vehicle that should be considered to remove the barriers to more GHG efficient projects: new RD&D, tradeable permits, CO2 taxation, institutional reforms, new programmes by MDBs and bilateral aid donors in the context of their developmental activities could bring similar results.

What is needed is an integrated mix of climate change related policy instruments. Various vehicles to mitigate climate change should co-exist. The instrument of choice will often depend on some political odds. In addition, the total impact of a single instrument will be limited depending on its scope and the range of measures which can be addressed, i.e. the total need for a certain type of technology. An AIJ regime should be compatible to those instruments to allow the integration of domestic policy initiatives in Annex I countries with the international focus of AIJ.