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Report to the Congress of the United States

A Compendium of Options for Government Policy to Encourage Private Sector Responses to Potential Climate Change

Executive Summary

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U.S. Department of Energy
Office of Environmental Analysis
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Safety and Health
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ACKNOWLEDGEMENTS

In report language accompanying the Energy and Water Appropriations Act, 1989, four studies on policy-related aspects of global climate change were requested. This report describes one of those four studies. Responsibility for conducting the studies was assigned to the Office of the Assistant Secretary for Environment, Safety and Health. Within that office, the Office of Environmental Analysis was tasked with performing the analysis. Each major programmatic element within the Department of Energy reviewed this report and made valuable suggestions which have improved its final content.

The analysis of policy options for encouraging private sector initiatives in response to possible climate change was directed by the DOE Technical Project Manager, Dr. Richard A. Bradley. The U.S. Department of Energy's Oak Ridge National Laboratory (ORNL) provided support for the project. As the list of authors contained in the appendix to each volume indicates, many people at ORNL contributed extensively to researching and writing the report. The ORNL team was directed by Dr. Steve Rayner. Dr. Rayner's team had just over four months to produce this report and I want especially to express my appreciation for their dedication which extended to endless weekends and evenings.

Edward R. Williams, Director
Office of Environmental Analysis

PREFACE TO THE EXECUTIVE SUMMARY

The structure of this executive summary invites a word of explanation for the reader. Conventionally, such a summary presents the principal findings of a study and summarizes the research design and procedures by which the results were obtained. This report, however, is designed as a reference document consisting of a compendium of generic policy instruments and specific policy options that are available to the U.S. Government in the event that it decides to encourage significant private sector activity to prevent, mitigate, or adapt to climate change. As such, most of the body of this report consists of summaries of existing knowledge about and experience with these policy instruments, and identifies opportunities and constraints for their application. The study did not attempt to establish a bottom-line recommendation, therefore, one cannot be presented here.

Our aim in this executive summary, therefore, is not to present a summary of findings so much as an annotated directory to the summaries contained in the body of the report. The structure of the summary closely follows that of the report and is intended to assist the reader in identifying and locating which parts of the report contain the information that is sought on particular policy instruments or options for various components of the private sector.

In addition to identifying policy options, the Congressional charge indicated that, "The study should suggest strategies that will mobilize the resources of the private sector toward addressing the issue of global climate change." It is clear to us that there presently exists insufficient information to identify, on technical ground alone, a self-evident course of efficient and equitable action that would achieve the goals of an effective private-sector response to climate change. The selection of any particular package, therefore, is largely a political choice of preferred means to achieve the overall policy goal.

In the absence of unambiguous technical criteria, such a choice is properly the prerogative of the President and the Congress. However, in the final chapter we identify two alternative (although not entirely mutually exclusive) strategic principles and eight technical criteria that our research indicates would be of value in selecting a strategic package of policy options. Other studies mandated by the Congress and currently in progress by the Department of Energy are attempting to reduce the technical uncertainties surrounding the selection of a strategic policy package. Chief among these is the Greenhouse Gas Inventory and Policy Study that will be completed early in 1990.

E.1 CONGRESSIONAL REQUEST FOR REPORTS AND SCIENCE OVERVIEW

E.1.1 Requests for Reports

The possibility of anthropogenic climate change is rapidly becoming an issue of significant public concern. Recent scientific research results combined with a very warm decade have led to growing apprehension that we may be on the brink of global warming inadvertently induced by human activity.

As one manifestation of increasing concern, several Congressional Committee hearings on issues deriving from potential climate change have been held. Additionally, in 1986 the Congress requested two studies by the Environmental Protection Agency (EPA) on the effects of climate change and on policy options to stabilize the atmosphere. Those reports currently are being reviewed by Federal agencies prior to submission to the Congress.

In the report language accompanying the Energy and Water Appropriations Act, 1989, the Senate Committee on Appropriations and the Conference Committee requested four studies on climate change from the Department of Energy (DOE). The four reports are:

(1) **Alternative Energy R&D**—to assess the state and direction of Federal R&D on alternative energy sources, including conservation.

(2) **Greenhouse Gas Data Collection**—to assess how greenhouse gas emission and climate trends data is coordinated, archived, and made available to scientists, both within and outside of government.

(3) **Carbon Dioxide Inventory and Policy**—to analyze policies to achieve a 20% reduction in CO_2 emissions in 5-10 years and a 50% reduction in 15-20 years as well as provide an inventory of emission sources.

(4) **Study of Options to Mobilize the Private Sector**—to assess policy options for encouraging the private sector to cooperate in mitigating, adapting, and preventing global climate change.

This report fulfills the Congressional request to assess policy options to mobilize the private sector (the fourth study above). Specifically, the report of the Senate Committee on Appropriations (S. REP. 100-381) requested a study of:

> "...policy options that will encourage the private sector to cooperate in mitigating, adapting, and preventing global climate change. The study should suggest strategies that will mobilize the resources of the private sector toward addressing the issue of global climate change. This report should be completed within 6 months."

This Administration is developing an active program in response to increasing domestic and international concern about the potential for climate change. During the 1988 election campaign, President Bush highlighted climate change as an environmental issue of important concern. The U.S. has participated actively in the development of the Intergovernmental Panel on Climate Change (IPCC) and chairs its working group on response strategies. Through that process, international consensus on policy responses is expected to develop.

E.1.2 Emissions and Climate Trends

Human societies as they exist today have not experienced the historic changes in the earth's climate that have been caused by natural forces. Humanity has come to expect reasonably consistent climatic conditions, although these often require successful adaptation to regional and seasonal patterns of climate and occasional adverse conditions like decade-long droughts or several successive cold winters.

It has been recognized for decades that local changes produced by humans in an environment influence weather. More recently, a scientific consensus has been developing that humans also are responsible for changing the composition of the atmosphere in such a way that the global climate may change. Some climate warming already may have occurred, and further warming may occur during the next century. There are several plausible causes for warming, including natural factors, such as slight changes in the intensity of the sun; and human activities, such as deforestation and the combustion of fossil fuels (oil, gas, coal, and other solids) and wood used to produce heat and energy.

Several climatically important gases are released when fossil fuels and wood are burned. They persist in the atmosphere and can influence the chemistry and radiative balance of the earth's atmosphere. They have a negligible effect on the sun's very-short-wavelength ultraviolet radiation entering the earth's atmosphere, but they absorb and radiate the longer wavelength infrared (heat) radiation reflected from the earth that otherwise would escape into space. This phenomenon is referred to as the *greenhouse effect.*

Carbon dioxide is released into the atmosphere when fossil fuels are burned. In addition to its potential effect on climate, CO_2 also may influence the natural exchange of carbon between the atmosphere and the terrestrial biosphere (vegetation and soils). Other gases, not related so directly to global energy consumption, also contribute to the greenhouse effect. Methane is produced mainly by biological processes in livestock and in wet rice cultivation. Nitrous oxides are associated mainly with agriculture. The family of gases known as chlorofluorocarbons (CFCs) and halons are used in refrigerants, solvents, foam products such as insulation and fast-food containers, and fire extinguishers.

Other trace gases may influence global warming either directly, as greenhouse gases, or indirectly, by affecting atmospheric chemistry that affects the lifetimes of greenhouse gases in the atmosphere. These gases include ozone in the troposphere, carbon monoxide, water vapor, OH radicals, and oxides of nitrogen other than N_2O. The net effects of present concentrations and trends in concentrations of these gases on global warming remain highly uncertain, but they are sufficient to be grounds for serious concern.

E.1.2.1 CO_2 Concentration, Fossil-Fuel Consumption, and Carbon Emissions

The amount of CO_2 in the atmosphere prior to 1958 can be estimated reasonably well back to the mid-1800s and with somewhat less precision for much earlier times. When industrialization began to spread throughout the world, the atmospheric CO_2 concentration probably was about 280 ppmv, or 25% lower than in 1986.

The gradual increase in atmospheric CO_2 during the late 19th century and early 20th century probably was due to a combination of carbon releases from fossil-fuel consumption and carbon releases from deforestation as large-scale land use changes occurred to accommodate industrialization, mainly in North American and Europe. Deforestation remains a source of carbon emissions, but global fossil fuel consumption is recognized as the principal source of increasing atmospheric CO_2 during most of the 20th century.

The increase in the atmospheric CO_2 concentration that has accompanied increasing carbon emissions to the atmosphere from burning fossil fuels since the mid-19th century suggests an association between these indicators. To the extent that an increasing atmospheric CO_2 concentration also is associated with climate change through the greenhouse effect, the possibility of such an association can be examined more closely by studying records of recent climate.

E.1.2.2 Global Warming and Climate Data

Monitoring the earth's climate is an important part of the international effort to understand the greenhouse effect. Analyzing climate records eventually may provide indications of long-term global warming of the earth's average temperature attributable to human activities. Trends indicating a consistent global warming are not yet apparent, however. For example, there appears to be no increase in temperature for the U.S. during the last 100 years.

Many natural factors influence climate, and can produce years of cooling or warming. Major volcanic eruptions and changes in ocean currents are examples. Air temperature records undoubtedly exhibit the cumulative effect of many natural factors on the climate system. Averaging air temperature yearly over the entire globe may portray climate too broadly for detecting warming due to the greenhouse effect.

In summary, current knowledge of the climate system and climate records compiled thus far are not now sufficient to determine whether human activities are significantly influencing the global climate. There are indications generally of global warming since 1850, and northern hemisphere air temperatures seem to have warmed about 0.6°C between 1880 and 1980. However, there apparently have been decade-long periods of cooling as well as decade-long periods of warming within that century. The increment of warming has been larger during winter than during summer, and there is evidence of a larger increment of warming at the higher latitudes of the northern hemisphere. The relative contributions of human activities and natural climatic variation to the fluctuations exhibited by the global climate records are not well understood.

E.1.3 Climate Change and GCMs

In the absence of laboratory models and with only limited historical experience of climate changes, global circulation models (GCMs) have been developed to simulate the Earth's climate system. These computer models are sets of mathematical equations that combine information from observations, experiments and well established physical and chemical processes to represent climate. Models are used first to reproduce known climatic conditions of the past. Then factors of interest are changed (e.g., atmospheric CO_2 concentration) and the model is used again to estimate the sensitivity of the climate to the selected changes.

Available climate models are calibrated to represent the general character of the present global climate. They typically estimate a globally averaged temperature within about 1.6°C of that obtained from the observational records, however, problems with model validation remain outstanding. There is less agreement with precipitation records. Model estimates of monthly precipitation typically are 10%-20% higher than records suggest is the case. However, because precipitation records are incomplete, the disagreement does not necessarily imply that the ability of models to estimate precipitation is poor. There are substantial inconsistencies among model estimates of average temperatures on less-than-global scales.

The observational record indicates that the average temperature over the northern hemisphere land mass warmed incrementally by about 0.6°C between 1880 and 1970. The warming was not continuous, however; there were periods of cooling as long as several decades. Based on the estimated increase in atmospheric CO_2 during that 100-year period, climate models predict an ultimate warming of 1.1°-1.7°C globally without further increase in the atmospheric CO_2 concentration beyond 1970. The models do not account for periods of cooling that appear in the record.

E.1.3.1 Estimating Future Climate Change

The range of year-round globally averaged warming estimated by climate models for a doubling of the atmospheric CO_2 concentration from 300 ppmv to 600 ppmv has gradually decreased as models have improved. The range is now about 1.5°-4.5°C. The estimated increase in globally averaged precipitation associated with CO_2 doubling is in the range of 7%-11%. Climate models consistently produce relatively large temperature increases in each hemisphere at high latitudes (more so during winter than summer) for a doubling of the atmospheric CO_2 concentration.

The current state of scientific knowledge is the principal factor now limiting the utility of models. Present knowledge permits estimating current climatic conditions and those of the recent past on global scales within about 2°C for yearly-averaged temperature and 10%-20% for yearly averaged precipitation. Estimates are less precise at small geographic scales, and for seasonally averaged indicators like winter temperature and summer precipitation.

Models currently provide a perspective about how the global climate might change if the concentration of CO_2 and other radiatively important gases in the atmosphere continue to increase. As more is learned about how the climate system works and its sensitivity to human-related perturbations, models will become more useful for providing insights about regional and seasonal changes in the future climate that are attributable to human activity. Until present scientific uncertainties are overcome, the principal value of climate models lies in identifying research needed to advance the state of knowledge, rather than in predicting future regional-scale climate change.

E.1.4 The Global Exchange of Carbon

Carbon is exchanged constantly between three large storage reservoirs: the atmosphere, the oceans, and the terrestrial biosphere. Many processes are involved in carbon exchanges, and few are understood fully. In the absence of human influences, the exchanges between the reservoirs tend to balance over short periods, such that the proportion of global carbon stored in each remains fairly constant. However, over the course of many centuries some fluctuations have occurred in the storage ratio.

Carbon cycling is a factor in determining the amount of carbon found in the atmosphere. Thus global models are useful for estimating CO_2 concentrations that might be expected in the future. In order to do so, models must account for human influences on carbon storage and exchange as well as for natural processes.

The amounts of carbon contained historically in the Earth's three large storage reservoirs are known approximately. Changes in stored amounts due to human influences can be estimated from historic records. Theoretical uncertainties about these amounts and assumptions about natural carbon exchanges produce a wide range of estimates of the amount of CO_2 now in the atmosphere. The ability to predict future atmospheric CO_2 concentrations reliably and, therefore, the ability to estimate future climatic conditions reliably will be limited until knowledge of the Earth's carbon system improves.

E.1.5 Consequences of Global Warming

The potential risks to society from anthropogenic greenhouse gas emissions should be examined in developing future research needs and priorities for overcoming remaining unknowns and resolving uncertainties. Identifying potential climate-related risks also can be helpful in developing long-range plans for ensuring adequate energy supplies and allocating other resources.

E.1.5.1 Sea-Level Rise

Sea level around the world could rise if radiatively active gases accumulate in the atmosphere and produce global warming sufficient to reduce the mass of glaciers and the amount of land now covered by snow and ice (DOE 1985). Ocean warming also would be a factor, since water volume expands when warming occurs. Melting sea ice would not be a contributing factor, because sea ice already accounts for some of the volume of the global oceans.

Determining changes in sea level and attributing causes is difficult. Climate influences sea level but so do tectonic activity, continental rebound, and subsidence along coastal zones. Estimates of the rate of sea-level rise since the mid-1800s range from 11 to 30 centimeters (4 to 12 inches) per century due to all these factors. Improving estimates of sea-level rise from climate change requires increased knowledge of the oceans, the world's large masses of ice, and other causes of changes in sea levels. Ocean circulation near Antarctica also must be better defined, and more needs to be learned about ice dynamics. However, should significant sea-level rise occur, it could require billions of dollars to protect or replace coastal infrastructure and result in the loss of large portions of the nation's coastal wetlands.

E.1.5.2 Agriculture

Decision making affecting agriculture in a world of changing climate may require shifting priorities for knowledge. For example, reliable estimates of climate over periods of decades may become essential; nations and regions may require extensive data bases for identifying and protecting lands suitable for agriculture; the demand for and availability of good quality water may become increasingly important. Changes in soil moisture associated with climate change could significantly alter crop yields. The benefits of longer growing seasons may be offset by increased pest populations. Agriculture-related industries and research may require some reorientation in response to future market demands for genetic qualities, pest and disease control, and environmental adaptation. Also, changes in world food trade and agricultural productivity may affect the types of crops in demand. For example, industrial and energy crops may displace some food crops. These possibilities suggest a need to continue research on regional and seasonal climate modeling and agricultural systems modeling as high priorities.

Plants obtain CO_2 from the atmosphere by the process of photosynthesis. Commercial growers have recognized that abundant CO_2 acts as a fertilizer and often increase CO_2 in greenhouses by factors of 2 or 3 to enhance plant growth. However weeds might benefit more than crops under high atmospheric CO_2 conditions, making more intensive agricultural management necessary. Evidence also is available that suggest pest management practices may have to be modified. For example, larvae of the soybean looper consume more leaf material from plants exposed to elevated CO_2 concentrations.

E.1.5.3 Forests

The environmental fate of forests under conditions of gradual climate change and CO_2 fertilization may be determined largely by human management of forest resources, which is much like agricultural management. For example, the goal of both is maximizing short-term productivity consistent with maintaining and possibly improving the resource over the long term. However, forest productivity may be measured in diverse ways. The production of wood products, opportunities for recreation, protection of certain species of wildlife and plants, watershed conservation, and other interests influence decision-making and forest-management practices.

The fate of unmanaged forests and other vegetation under conditions of climate change and CO_2 fertilization is uncertain. Whereas warmer and wetter conditions might be beneficial to some species, others might be affected adversely. Likewise, warmer and drier conditions could influence species favorably or unfavorably according to their ability to adapt to changing environmental conditions. However, it is quite possible that forests along the southern portions of current ranges will die back or be unable to regenerate. Forests may not be able to migrate northward at the same rate at which climate zones could shift and inhabited ranges could be reduced. There is greater uncertainty about the resulting effect on natural succession of unmanaged than managed forest resources.

E.1.5.4 Water Resources

The availability of water is determined by a host of natural environmental factors including climate. Managing water is essential in developed regions, and includes apportioning water equitably among diverse users, controlling its quality, and possibly ensuring adequate water storage. The availability, use, and recycling of water are especially sensitive to climatic variables where water-resource management is limited.

A gradually warming climate would influence water resources and their uses. Global warming could result in earlier snowmelt and an increase in potential evapotranspiration, leading to shifts in the seasonality of runoff in snowfed water basins. Consequently, supplies could be reduced in the summer months. Warmer temperatures in summer could increase energy demand for space conditioning in some well developed regions of the world, possibly increasing demand for power-plant cooling water and hydro power. By the same token, warmer winters could reduce demand for space heating and increased precipitation in some areas may actually increase summer stream flows. Planning for adequate energy production to satisfy future needs is a long-range process, and it may be appropriate to consider climate-induced changes in energy demand in the process. The information could then be used to develop future priorities for water resource management.

E.1.5.5 Oceans and Fisheries

Oceans are an integral component of the Earth's climate system. They absorb heat from the atmosphere, they exchange CO_2 with the atmosphere, and they are the largest source of evaporation to the atmosphere. Models currently account for ocean processes in relatively simple ways and are inadequate for quantitatively estimating changes in oceans that might result from global climate damage.

Oceans will become warmer if atmospheric temperatures increase globally, salinity will be reduced if runoff occurs from melting land ice, and the pH and other chemical properties of oceans may change. Effects on ocean fisheries, therefore, could have wide-ranging societal ramifications. Unfortunately, little is known about the sensitivity of ocean fisheries to environmental and climatic perturbation. Nonetheless, effects on spawning and migration, species diversity and dominance, and the marine food chain can be envisioned.

E.1.5.6 Human Health

Increasing atmospheric CO_2 would have no direct influence on human health, but mortality from both heat and cold stress could change from current patterns. Global warming also may affect the distribution of parasite vectors and influence resources, such as food and drinking water, that are important to human health (White and Hertz-Picciotto 1985).

E.1.6 Implications of the State of the Science for Policy Making

The theory of the greenhouse effect, that radiatively active gases warm the atmosphere, is well established and accepted. However, the discussion of the scientific findings and uncertainties above indicates that there are considerable uncertainties concerning the relationship between man's activities and climate change. Model results agree that the accumulation of various greenhouse gases equivalent to a doubling of atmospheric CO_2 will lead to global warming. Given projections of greenhouse gas emissions which have been made, in the absence of policy intervention or technological advances, an equivalent doubling of CO_2 is projected to occur sometime near the middle of the next century.

In addition to the uncertainty surrounding emissions forecasts, the magnitude and timing of attendant warming, and the extent of the effects of climate change, there is considerable uncertainty about the effectiveness and costs of policy actions. Very little policy analysis has been done. Just now such work is beginning. The EPA Stabilization Report (1989) is one example, and some private efforts have been conducted. In general, these analyses have focussed on infra-structure changes and technology potential analysis. They have identified technologies which may penetrate the market over some period of time and then assumed some penetration rate for the technologies. Emissions reductions are then estimated.

Such analysis is a useful initial effort, but not adequate for policy making for at least three reasons. First, secondary impacts from the new technologies are not estimated. Only EPA has made an effort to capture these effects. Secondly, such analysis does not address the issue of the policy measure or instrument which will effect the technology penetration. In some cases, market intervention will be required to reach market-penetration rates assumed in these studies. Thirdly, if large reductions are sought, multiple policy instruments will be attempted at the same time. Simultaneous use of several policy options may produce interactive effects influencing the effectiveness of the policy instruments. The following chapters attempt to advance our policy understanding concerning climate change by addressing the second limitation of existing policy analysis noted above, namely the absence of analysis of policy options or instruments.

E.2 METHODOLOGICAL JUSTIFICATION

E.2.1 Internalizing the True Costs of Private Activities

This report is designed to identify a range of policy instruments and options that could be available to the United States Government to encourage the private sector of the national economy to participate in preventing, mitigating, and adapting to global climate change. We strictly confine ourselves to discussion of possible policy tools for achieving desirable goals. We do not attempt to assess what those goals should be. Furthermore, there are no technology assessments in this report. The emphasis is rather on discussion of alternative means by which the government could accelerate or otherwise facilitate wide ranging technological and behavioral changes should they be deemed desirable. The need for government policy may arise if free-market decisions under current regulations and market rules are leading to what many people in the scientific and policy communities consider excessive greenhouse gas emissions. As with particulates from the smokestacks of large manufacturing plants or the pollution from private cars, the social cost of greenhouse gas emissions from private sector activities may not be included adequately in the profit-loss calculations of their operators, who even may be unaware of the potential effects of their actions. Therefore, current private sector activities may produce an acceptable amount of greenhouse gas from the viewpoint of their operators, but, possibly, excessive amounts from the viewpoint of society. The costs of global warming and other side effects of increased greenhouse gases in the atmosphere are neglected when such market failures exist.

Market failure is the term economists use to describe the situation where market prices do not reflect the correct social information to traders, or certain conditions exist such that prices are completely absent. Thus, market failure provides policy makers, and the analysts who serve them, with an *a priori* reason for considering alternatives or supplements to the current market process for allocating resources in a more efficient and acceptable manner. The associated policy problem is to do nothing or to design alternative exchange rules to correct the market failure.

This report systematically reviews various tools that could be used to address the issue of market failure in relation to greenhouse gas emissions and potential climate change. However, the nation's goals regarding these issues have yet to be defined by the Congress and the President. For this reason, we stop short of recommending any particular policy goals or package of options to achieve them. In that sense, this report has no bottom line and, therefore, no narrative account of the route by which one would have been reached. Rather, we offer a reference document designed to identify areas for more detailed policy analysis in the future and to facilitate decision making about the relative advantages and disadvantages of various means by which the government may pursue whatever goals it sets for itself and the private sector.

E.2.2 Types of Policy Instrument

Government policy to correct for market failure can take many forms. Policies to influence or control market behavior may range from strict prohibition of certain activities to dissemination of information about socially preferable behavior, perhaps by example. In this report, four broad categories of policy are identified generically as instruments that the government could consider to encourage the support of the private sector for a national response to the prospect of climate change. These are: *regulation*, *fiscal incentives*, *information*, and *research development and demonstration*. The current wisdom concerning the strengths and weaknesses of each of the instruments that fall under these types and prior experience of their efficacy in other contexts are reviewed in Chapters 3 through 6 of this report.

The review of each generic instrument considers five attributes: *efficiency*, *information requirements*, *distributional effects*, *political sustainability*, and *applicability to greenhouse gas issues*.

Efficiency

Efficiency refers to the capability of the instrument to achieve its intended goal with a minimum of economic losses from attendant resource misallocations.

Informational Requirements

Information may be required on characteristics and behavior of firms, on the relationships between emissions and damages, and between abatement and abatement costs, etc. Information collection can be costly and can impair the efficiency of an instrument.

Distributional Effects

The distributional effects of an instrument are its relative costs and benefits to different categories of consumers and taxpayers.

Political Sustainability

The political sustainability of an instrument is the ability of the instrument to pass the legislative and bureaucratic implementation processes and its capacity to retain sufficient support to continue in active force so long as is justified.

Applicability to Greenhouse Gas Issues

Under applicability, we assess whether the instrument could modify behavior that may lead to global warming (prevention), to warming reduction (mitigation) or to accommodation with a potentially changed climate (adaptation).

Chapters 3 through 6 aim to provide the reader with an overview of the policy toolkit from which the government could select relevant options should the need arise. The systematic application of these policy instruments to specific activities of each component of the private sector to generate specific policies and implementation options is not presented here but is reserved for Chapters 7 through 11 (Volume 2) where additional screening criteria are used.

E.2.3 Policy Strategies: Prevention, Mitigation, and Adaptation

The principal focus of the policy options reviewed in Chapters 7 through 11 (Volume 2) under each category is on measures that would encourage changed patterns of energy production and use that, in turn, would contribute to reduced emissions of greenhouse gases in the wide variety of activities that compose the private sector. The policy strategy of reducing or eliminating greenhouse gas emissions is one of *prevention*. Attention also is given to ways of mitigating the effects of greenhouse gas emissions that cannot be eliminated efficiently. *Mitigation* is a somewhat ambiguous category of strategies. It may include the removal of CO_2

from the atmosphere by planting trees to offset emissions. Long-term actions to cope with the consequences of global warming constitute the third policy strategy, that of *adaptation*. Some level of adaptation to global warming may prove to be inevitable because of accumulated greenhouse gas emissions prior to the effect of any preventive policies.

It is recognized that the net effects of intervention vary widely across policy alternatives, therefore, careful attention must be paid to the direct and indirect effects of such actions and their interactions with existing market constraints and opportunities. In particular, it may be desirable to operate some of the policies only for temporary periods to induce desired changes.

E.2.4 Constraints and Opportunities for Private Sector Response

The description of the private sector in this report is confined to qualitative analysis of the constraints and opportunities arising from existing *materials*, *processes*, *markets*, and *regulatory frameworks* that are likely to shape its response to the prospect of global warming. *Materials* include fuels as well as other substantive material and energy inputs and outputs for the sector. *Processes* are the activities by which a sector satisfies demands for its goods and services. *Markets* in this context include both capital markets which finance the activities of the private sector and the markets in which commodities and services are traded and consumed. The *regulatory framework* quite simply is the nexus of legal constraints on entry to an activity and the rules by which the government, or alternative regulatory agency, controls the activities of a sector.

E.2.5 Components of the Private Sector

Because constraints and opportunities for response to potential climate change vary greatly across the whole spectrum of private sector activities, this report distinguishes five components of the private sector for separate consideration. These are: *utilities*, *manufacturing*, *transportation*, *agriculture*, and *residential/commercial*. Energy extraction industries are not considered separately as they will be responsive to demand from the sectors that are considered. Supply-side measures in this case do not seem to be plausible options when demand-side options are available. The relevant characteristics of each of the five sectors examined in the report are analyzed in Chapters 7 through 11. In addition to characterizing the activities of each sector that could be relevant to greenhouse gas policy decisions, each of these chapters presents a menu of potential policies and policy options that could be used to modify those activities.

Utilities

The component of the utility industry considered in our analysis is the electric utilities, since these directly produce greenhouse gas emissions. The electric utility industry is a major source of emissions by virtue of its large size and the number of processes through which it can generate emissions. Although some components of the utility industry are publicly owned, and all are publicly regulated, most are privately owned and operated. Even the publicly owned parts of the industry operate according to the same broad sets of principles and constraints as the private sector.

Transportation

The transportation industry includes providers of infrastructure such as roads, railbeds, and airports as well as manufacturers and operators of transportation equipment such as cars, *trucks, and planes. Although much of the infrastructure is publicly owned, it is designed and built by private firms. Transportation equipment is manufactured by a relatively small number of firms, but operators range from the owners of family cars to large airlines. The natural gas pipeline and petroleum refining industries also are included in the transportation sector for our purposes.*

Manufacturing

The immense diversity of manufacturing processes defies adequate summary here. However, this sector is a major consumer of energy from carbon-based sources and a producer of greenhouse gases other than CO_2, *both as end products and byproducts of manufacture. The industries that receive specific attention in our analysis are: chemicals (other than petroleum refining which is discussed under transportation), pulp and paper, steel, glass and stone, cement, and aluminum.*

Agriculture and Forestry

Crop and livestock production are the principal activities of the agricultural sector. Methane emissions from enteric fermentation in livestock are a significant source of greenhouse gas. Other activities important to greenhouse gas policy may be fertilizer production and silviculture. Agriculture is conducted on many scales from weekend hobby farms to agribusiness conglomerates.

Residential and Commercial

The residential and commercial sector is comprised of a very large number of relatively small energy users. However, the architects and builders who design and construct homes and commercial buildings, the providers of energy conservation services, and suppliers and consumers of domestic appliances also are considered in the analysis of this sector.

E.2.6 Limitations

The characterizations of economic sectors are of limited scope. There is great diversity of scale and decision making within each sector which merits more detailed examination than space permits here. Furthermore, we were unable to perform detailed benefit-cost analyses of the effects of the various policy options on each sector. This will be necessary once potential policy packages have been selected from the menu for further detailed evaluation.

Second, it readily is acknowledged that we have confined ourselves solely to the private sector in the United States. One implication of an institutional view of technologies is that the way they are constituted, operated, and regulated may differ fundamentally among nations. An analysis of the private sector with international scope would be a vast undertaking beyond the resources allocated for this study.

Third, in the short time period available to complete this review it was not possible to conduct a major collection and analysis of original data. The report, therefore, relies almost entirely on the relevant scholarly and technical literatures. Nine topical literature reviews were conducted to provide the input to this report. These consisted of separate reviews of the published discussions and evaluations of each of the four policy instruments as well as the five sectors. Additionally, a limited number of interviews and discussions were conducted with decision makers in each sector and with industry analysts.

Another significant limitation was the unavailability of detailed emissions figures for each sector projected over the relevant time period. There is no systematic attempt to inventory the quantity of greenhouse gas emissions from each activity within a sector. That task is being conducted by DOE in a separate study of longer duration as required by the Congress. Hence, we have not attempted to assess specific goals for greenhouse gas and global warming policy, but have focussed on identifying the range of means by which the United States might achieve whatever goals the Congress establishes.

Some selectivity has been exercised in this process to eliminate obviously irrelevant options or those that have proved ineffective at correcting analogous market failures in the past. Some options are emphasized where they appear to be particularly promising or novel in their application to the greenhouse gas issue. *However, this report does not recommend any particular package of options for consideration by the Congress.* Without accurate quantitative information on emissions and, thus, the reduction potential of each sector, it would be premature to advocate specific actions. Furthermore, each of the options presented has characteristics that are of varying appeal to policy makers, private sector decision makers, and public-interest groups. We recognize that balancing these preferences is a potential task for the President, Congress, and state and local legislators. Such balancing, if done, should draw on additional quantitative information on emissions as will be contained in the forthcoming DOE Emissions Inventory and Policy Study. For these reasons, rather than a recipe for a national greenhouse gas policy, we have sought to offer a menu of the options that are evaluated based on an initial systematic screening. We intend that the product we offer here be treated as an encyclopedia or compendium of policy options and not as a narrative leading to a particular conclusion. Our aim is to facilitate, not preempt the political process by which policies will be chosen.

E.2.7 Screening Criteria for Policy Options

Seven general criteria are used to screen and evaluate the policies and implementation options identified for each sector in Volume 2. These differ from the five attributes used to consider generic instruments so as to account for the introduction of the sectoral context. The seven criteria are *applicability*, *efficacy*, *time frame*, *focus*, *decisionmaker sensitivity*, *current level of knowledge*, and *linkage to other goals.*

Applicability

First is the general criterion of applicability. Does the option apply to an activity identified in one of the sector chapters as contributing to greenhouse gas emissions or as having the potential to mitigate or help adaptation to climate change?

Efficacy

There may be some qualitative indications of which policies are most and least promising candidates to produce significant cost-effective results when enforcement and administrative costs are taken into account.

Time Frame

Wherever possible, we identify the time frame within which any policy for prevention, mitigation, or adaptation might be expected to achieve its goal, not just be put into place. Four time frames are adopted in this report for the purpose of evaluating policies. The first three are as defined by the Congress in mandating the four DOE studies. These are short-

term (5-10 years), medium-term (10-15 years) and long-term (15-20 years). However, we have added an extended-term time frame for any policy that is likely to have to be maintained in excess of 20 years or would be initiated so that the substantial effect would begin post-2010.

Focus

We have adopted a microanalytic focus for evaluating policy options. That is to say, we deliberately favor surgical interventions over blunt instruments. By conducting a micro analysis of policies we are able to match them to specific sector activities where they may prove most effective. Any national response strategy for potential climate change is likely to combine a variety of these focused options, and may even result in broad changes to energy and other systems of production.

Decisionmaker Sensitivity

The success of a policy in internalizing the costs of greenhouse gas emissions may depend also on characteristics of the decision makers faced with responding to a regulation or fiscal incentive, or evaluating information. We indicate where we believe that the success of a policy option will be sensitive to this sort of variation.

Current Level of Knowledge

We indicate the level of knowledge we have about the application of each policy to a sector activity and, where possible, identify research needs that would have to be met for the policy to become a serious candidate for a national climate policy package.

Linkage to Other Goals

Many of the policies that are identified in this volume offer potential benefits in addition to greenhouse gas reduction or adaptation to climate change (such as ozone preservation). Alternatively they may conflict with other goals (such as energy security through increased coal use).

E.2.8 Activities, Policies, Instruments, and Options

The policies for each component of the private sector are grouped under the principal activities in which each engages, for example, *choice of generating capacity addition and replacement* in the utility sector. A *policy* is defined as a general course of action to achieve a goal, such as encouraging fuel switching. The term *policy option* is used to describe a specific form of that general course of action, indicating what *policy instrument* is to be used; for example, a tax on emissions. More than one specific policy option may be available as an alternative or complementary means to achieve a goal. For example, a tax directly on the carbon content of fuels or a fee for emissions might be alternative options to pursue the policy of fuel switching through taxation.

As stated above, Chapters 3 through 6 describe generic policy instruments falling into four types, *regulation*, *fiscal incentives*, *information*, and *demonstration*. Candidate policies are presented in Chapters 7 through 11 according to the sectors to which each would apply. In part, this approach is justified by the microanalytic focus that does not consider blunt measures that could be invoked without regard to sector. Each of Chapters 3 through 11 begins with an annotated table of contents to assist the reader in locating a particular instrument or policy option. Chapters 3 through 6 each contain a summary table of the attributes of each instrument. Each of Chapters 7 through 11 contains a reference matrix that summarizes the policies for each sector.

E.3 REGULATION

Regulation is defined as legislation or rules, supported by sanctions and having the force of law, that are designed to limit the discretion that may be exercised by public and private decision makers. Such legal and administrative means of forcing private firms to incorporate some or all of the social costs of their contribution to global warming are exemplified by rigorous effluent standards with large, effective penalties. The major benefit of regulatory programs is that they tend to help managers and consumers rapidly incorporate the social as well as private costs and benefits of their actions. However, the effectiveness of regulatory programs may depend heavily on the quality of information available to the regulator. Furthermore, they may be administratively quite costly and inflexible. For example, certain restrictive standards, particularly those that specify the technological means to achieve environmental ends, may hinder the progress of new technologies.

Two kinds of regulation can be identified: controls and standards. Controls are quantity limitations on such variables as inputs, outputs, prices, or profits in production processes. Standards are rules for directing the quality or type of personnel, processes, or outputs so that the desired regulatory outcome results. Examples include process standards, equipment standards, certification and licensing, and performance and product standards. Eight regulatory instruments are discussed: six controls and two types of standards. All are listed below and subsequently evaluated for application to greenhouse gas issues, efficiency and incidence, informational requirements, distributional effects, and political sustainability. These evaluations are summarized briefly in Table E.3.1.

CONTROLS

Bans (Section 3.2.1)

Bans are strict, explicit prohibitions of certain activities that produce undesired social effects. Costs of substitute processes or products are crucial in determining the effectiveness and severity of a ban.

Emissions Controls (Section 3.2.2)

Emissions controls attempt to reduce environmental damage directly, by establishing limits on the quantity of a pollutant that specific activities can discharge. The limit may be an absolute quantity or an allowable concentration in a discharge flow.

Input Controls (Section 3.2.3)

Input controls restrict the use of production inputs that could lead to environmental damage either through processing and release or by inappropriate disposal. Prominent examples include restriction of lead in gasoline, CFCs in refrigerants, and sulfur content of coal.

Consumption Controls (Section 3.2.4)

Consumption controls restrict the use of final products rather than production inputs. Recent gasoline rationing and water rationing, the latter sometimes according to use, are prominent examples, as well as wartime food rationing.

Price Controls (Section 3.2.5)

Price controls are usually maximum allowable prices that sellers can charge, but could include minimum allowable prices. These price ceilings and floors are specified directly rather than achieved indirectly with taxes or subsidies.

Rate-of-Return Regulation (Section 3.2.6)

Rate-of-return regulation limits the profits that a natural monopoly may earn on its capital investment. This regulation also usually involves supervision of prices by a public commission.

STANDARDS

Technology Standards (Section 3.3.1)

Technology standards include process standards, equipment and design standards, performance standards, and product standards. These standards specify minimum operational, quality or content characteristics that equipment or consumer products must satisfy.

Licensing and Certification (Section 3.3.2)

Licensing and certification restrict the practice of an occupation or the provision of a service to individuals or facilities that meet certain qualifications. They are intended to protect consumers in circumstances in which they would be unable to evaluate product or service quality themselves.

Controls range from conceptually simple devices such as bans to devices that are more complex and harder to administer, such as emission quotas, input controls, consumption limits (rationing), price controls, and rate-of-return regulation. An essential element to both the acceptability and economic efficiency of regulation lies in the degree of freedom allowed the regulated party in meeting the legal stipulation. Many of these regulatory devices are common in the economic landscape of the United States. Price and rate-of-return regulation have been common since the turn of the twentieth century. While consumer price controls and rationing are famous for their application in World War II, the United States has had various forms of price controls off and on since that period: during the Korean War, the Nixon wage and price guidelines, petroleum and natural gas price controls, and until recently, airline, rail, and interstate trucking rates regulations.

Controls, while sometimes onerous in practice, can be specified to allow the regulated party to choose methods of compliance. For example, a pollution emission limit (often confusingly called a standard) can be specified while allowing the regulated industry to choose how to conform to the limit, whether by reducing the output of the primary product, installing pollution control equipment, or substituting inputs that result in less pollution.

Retaining choice in meeting regulatory controls gives two important advantages to society. First, it is more likely that the regulated party will comply with the control in a least-cost fashion if given the flexibility to choose inputs and output levels to meet the regulation. Second, if the method for compliance with the limit is left open, the incentive to innovate in meeting the regulation remains, and new, more efficient technologies may evolve. The disadvantage of regulatory control strategies for pollution is that there is no incentive to reduce pollution further once an emissions or air concentration limit has been met.

Standards, rather than regulating the ends, restrict the means by which a regulatory outcome is reached. Equipment standards are a straightforward example; they have been used to reduce SO_2 emissions from utility stacks. Process standards direct the method by which inputs are combined and quite often are used to ensure health and safety in manufacturing. Certification or licensing is used both to control the quality of people practicing a profession and to make sure that a firm or one of its operating units meets a list of operating criteria. An example of the latter is the licensing of nuclear power plants.

Standards can have several shortcomings. First, unlike certain quantity controls, they restrict the regulated party's freedom in the method of achieving the desired regulatory end. As a result, costs may be raised and innovation may be stifled. Second, approval processes for certification and licensing as well as oversight of equipment, process, or performance standards can be costly for government and burdensome for the regulated party (e.g., in the form of time delays, increased personnel to handle paperwork, etc.). Regulation of operations is used nevertheless in areas where no substitute (in the form of controls) exists, or where the perception that the quality of the outcome would be socially undesirable if left to unfettered private implementation. Licensing can induce wasteful competition for scarce licenses or overinvestment in qualifying for a license, while certification can delay the market penetration of innovations.

Regulation in general (both quantity control and standards) can be contrasted with fiscal incentives. Generally, regulation may be considered superior to the use of fiscal instruments when the regulatory goal is nonmonetary in nature, when information costs of setting up or monitoring a fiscal instrument are much higher than using a set of regulations, when regulations require only administrative action while fiscal incentives would require legislative action, where banning an activity is the only politically acceptable route, or where affected parties would perceive rules as equitable but would not perceive fiscal incentives to be so.

Also, regulations sometimes may be put into effect more rapidly than fiscal incentives, or more effectively if the preferences of the regulated to which an incentive program would be applied are in flux. Regulations, if simple, may have low administrative costs in comparison to incentives, as well as be more easily understood by the regulated, since they address the regulated object directly rather than indirectly through fiscal incentives.

Enforcement may be easier with regulation than with fiscal means because firms cannot escape regulations except by violation; on the other hand, positive incentives may lose their effectiveness through satiation. These advantages of regulation are offset by some of the disadvantages already mentioned (not allowing a least-cost solution, stifling innovation), as well as the disadvantages of sometimes imposing inequities (e.g., when new firms or facilities are required to use the best available technology while older ones are not) or having high administrative costs where, to approximate an efficient solution, different sets of rules are promulgated for different categories of the regulated parties.

Table E.3.1. Summary of evaluation of regulatory instruments

Regulations	Applicability to GHGI	Efficiency	Information Requirements	Distributional Effects	Political Sustainability
CONTROLS					
Bans	Bans on CFCs or CFCs in certain products; bans on coal-burning forest clear-cutting	Possible major efficiency losses because price system is bypassed	Simple: requires no calculation of marginal costs or benefits or discrimination among individuals	Depends on the product or processes banned and the available substitutes	Possible objections to CFC bans; appeals to directness in perceived emergency. Strong objectives likely for coal bans
Emissions Controls	Motor vehicle CO_2 or NO_x controls; GHG controls on power plants, industry	Possible efficiency losses from differential control costs across emitters	Monitoring necessary--could be costly because of numerous emitters, variations in emissions, and emissions can be costly to measure	Difficult to assess; costs can be partially shifted to suppliers or consumers; impacts can vary geographically as well as by income category and input supplier group	Could be acceptable; environmentalists could like its directness, and emitters could accept it if control technology is available at reasonable costs
Input Controls	Controls over fossil fuel or CFC inputs	Possible efficiency losses from ignoring lower cost abatement methods; can retard innovation	Monitoring necessary--could be relatively simple because of greater observability of inputs than of byproduct outputs	Most strongly affects immobile factors in the industry supplying the controlled input	Could face concentrated industry opposition, particularly from industries that supply the controlled inputs
Consumption Controls	Restrict residential or commercial uses of CFCs or certain fuels	Possible large efficiency losses--more restrictive than input controls	Monitoring necessary--could be relatively simple because of the observability of the items likely to be candidates for consumption controls	Tends to be regressive, but depends on product controlled	Could face broad opposition; industry could see demand for its products constrained, and consumers could see their costs increased
Price Controls	Price floors for GHG-intensive products; ceilings for GHG product substitutes	Possible major efficiency losses because prices no longer reflect market forces	Monitoring necessary--possibly complicated because of intricate cost pass-through allowances, profit maintenance provisions, diversion of production from controlled to noncontrolled firms or industries	Difficult to assess; depends on supply and demand characteristics of the goods whose prices are controlled	Directness has appeal in perceived emergency; otherwise could face both broad and concentrated opposition

Table E.3.1. Continued

Regulations	Applicability to GHGI	Efficiency	Information Requirements	Distributional Effects	Political Sustainability
Rate-of-Return Regulation	Include r-o-r energy efficient equipment, consumer education, reforestation in utility rate bases; exclude CO_2 or coal use fees	Better than most alternatives for natural monopolies; possibilities for improvement exist	Major; expensive. Extensive and highly intricate provisions for pricing and allowable capital expenses require considerable documentation for justifications	With a wide range of programs targeting diverse audiences, the overall impact of regulatory revisions on different income or geographical groups is difficult to assess	There is considerable experience with r-o-r regulation; delegated to state authority
STANDARDS					
Technology Standards	Process, design, performance standards for carbon emissions (e.g., power plants, vehicles) or for CFC-based products	Can be more efficient than price instruments in some circumstances involving uncertainty and complicated abatement cost and damage relationships	Can conserve on information costs; design monitoring can substitute for operational performance monitoring; calculation of marginal costs and benefits, while still desirable, can be less detailed than with emission charges or taxes	Difficult to assess--possibly as much variation geographically as by income	Directness is appealing relative to the indirectness of taxes and emissions charges
Licensing and Certification	Certification of CFC-based products	Can cause efficiency losses because of unproductive competition for scarce licenses, monopoly, and time lags in approvals. In some cases, it can create markets for difficult-to-observe characteristics of products and services	Can be costly. The required information can be extensive and difficult to interpret, leading to the need for even further information	Can be regressive; benefits licensees. If lower-quality product markets are improved by certifications, lower-income individuals could benefit therefrom	Could obtain concentrated lobbying support from industry associations representing potential beneficiaries

E.4 FISCAL INCENTIVES

In some instances the behavior of private agents in pursuit of private objectives creates an undesired side effect called an externality, with added social costs. Fiscal instruments can be used to correct these externalities. These kinds of policy generally are designed to ensure that consumers and producers face the true costs of their decisions, but allow them a high level of discretion about how to deal with those costs.

The definition of a fiscal incentive consists of two parts: (1) any tax, fee, loan, subsidy, or rule change that is designed to alter the consumption of a good or activity by changing its price relative to the prices of other items that consumers might choose freely; and (2) direct government expenditures. Eleven fiscal instruments are discussed: three instruments affecting prices, five involving the use of general taxes, and three in the categories of subsidies and direct expenditures. All are summarized below and subsequently evaluated for applicability to greenhouse gas reduction, efficiency and incidence, informational requirements, distributional effects, and political sustainability. These evaluations are summarized briefly in Table E.4.1.

INSTRUMENTS AFFECTING PRICES

Emission Fees (Section 4.2)

Emission fees confront a discharger with the social cost of emitting pollutants, making him pay the full cost of disposal of unwanted wastes or byproducts. Pollution charges can, theoretically, fully internalize negative externalities, but their application faces two major problems: potentially large information requirements and the perception that they are purchasable licenses to pollute. Although technically a form of tax, emission fees are treated here alongside other fiscal instruments primarily designed to internalize environmental externalities, and separately from the general system of taxation whose primary objective is to raise revenue.

Tradeable Emission Rights (Section 4.3)

A system of tradeable emission rights begins with the government determining an overall amount or rate of emissions it will allow an industry to generate. The emission of this quantity or rate becomes a right, the total of which is allocated to firms in the industry, perhaps by auction, but ordinarily according to size. Since some firms can reduce emissions more cheaply than others, the rights are more valuable to some firms than to others, and some firms can purchase rights from others when emission control is more expensive than purchasing rights. A tradable rights system can minimize the total cost of achieving a given level of pollution, but it still requires government monitoring.

Deposit-Refund Systems (Section 4.4)

A deposit-refund system requires a deposit to be made by a consumer upon purchase of a good which, if disposed of improperly, would impose a social cost. If the consumer satisfies return requirements when consumption of the good is finished, the deposit is returned, possibly with interest if the good was expensive and long-lived. If returning the good costs more than the value of the returned deposit, the consumer has already paid the social cost that the improper disposal imposes. Deposit-refund systems have operated with glass *beverage bottles in the United States and automobiles and vacation tour packages in Sweden.*

TAXES

Excise Taxes (Section 4.5.2)

Excise taxes are levied on specific products and ordinarily are paid by the producer. They are far more specific than retail sales taxes. Excise taxes on products that involve greenhouse gas emissions would reduce the quantities of those goods demanded, reduce greenhouse gas emissions, and permit consumers to pay at least part of the social cost of the remaining greenhouse gas emissions associated with their consumption.

Taxes on Firms (Section 4.5.3)

The corporate income tax is the principal tax on firms. Through depreciation and investment allowances, the corporate income tax can affect the cost of capital and alter investment choices. Taxes on specific inputs and manufacturing processes also could be applied to firms.

The Personal Income Tax (Section 4.5.4)

Tax credit and deduction provisions in the personal income tax code could be used to encourage purchase of consumer durables that entail lower greenhouse gas emissions in their production, operation, or both. Tax credits in force in the late 1970s and early 1980s for solar household appliances were at least partially successful in encouraging purchases and in offering support to infant industries.

Property Taxes (Section 4.5.5)

Property taxes generally are under authority of local governments and are applied, often uniformly, to land and improvements. Although property tax allowances offer wide scope for encouraging biotic carbon fixing and adoption of lower-emission building equipment, the large number of property tax authorities offers potential for large inefficiencies induced by variations in local allowances. Additionally, local governments are less likely than higher levels of government to see benefits from local efforts to reduce a global externality.

Tariffs (Section 4.5.6)

Foreign and domestically made final products could be taxed at identical rates in the United States without directly harming American international competitiveness, but higher American indirect taxation on production processes could quickly erode the United States' industrial base through imports if compensating tariffs were not applied. Care would have to be taken to coordinate such tariffs internationally to avoid retaliation and potential trade war.

SUBSIDIES (Section 4.6)

Rather than target emissions as emission fees do, subsidies could be offered to privately undersupplied control activities. Subsidies such as rebates or reduced interest rates on lower-emission building equipment would target consumers and increase their demands for those products. Producer or operator subsidies could be applied to cleaner industrial *equipment and pollution control devices. Subsidies could have large budgetary implications, and they can create their own political constituencies.*

DIRECT GOVERNMENT EXPENDITURES

Research and Development Support (Section 4.7.1)

Any firm may find it difficult to appropriate the full value of some types of R&D, particularly but not exclusively more basic research, and consequently too little of those types of R&D will be undertaken privately. Other researchable problems are subject to common property "overfishing" problems, with too much private R&D exhausting the social gains from the results. Government support of the former is warranted to increase its supply, and restriction of the latter would save R&D resources for better uses.

Direct Government Purchases (Section 4.7.2)

Direct government purchases of cleaner products and equipment can reduce greenhouse gas externalities directly as well as offer stable markets for industries developing new, cleaner products. Such a market could give producers an opportunity to field test the performance of new products. Some resistance could be met from long-time government contractors who supply older, competing products.

An often-cited problem with traditional regulatory standards is that they restrict all firms to the same maximum emissions level or the same control technology, regardless of the specific costs of achieving that level, or using that technology. When the effects of emissions are independent of source locations, a socially efficient (cost-minimizing) emissions-control system requires that the cost of the last unit of emissions reduction be equal across all emission sites. Some of the proposed fiscal alternatives to uniform emission controls are designed to recognize the differences among firms and better achieve cost minimization. In theory, non-uniform (site or firm-specific) controls, charges or subsidies, and the assignment of property rights each can attain the goal of marginal-cost equalization across firms. However, non-uniform controls, charges or subsidies, and property rights differ widely in their degree of centralized control; their informational requirements; their allocation of costs and benefits among participating firms, consumers and the general public; and their practicality and political sustainability.

The major instruments affecting prices are emission fees, tradeable emission rights, and deposit-refund systems. Emission fees operate much as a price system would, by putting a price on pollution and confronting the emitter with the full cost of his or her actions. This has considerable political appeal as well as widely recognized properties of economic efficiency. However, uncertainty about costs of damages, emission control costs, and effectiveness of such a system to influence decisions reduces much of the advantage of emission fees over regulatory control measures such as standards. Additionally, the concept of paying to pollute may be unacceptable to an array of environmental advocates, while the sudden rearrangement of property rights may be highly objectionable to manufacturing interests.

Tradeable emission rights have been used in the United States for several years and show potential for expanded use. It has been suggested that quantity regulation through marketable permits generally is preferable to price regulation through emission fees, given uncertainty about the cost of emission controls and pollution damages. Permit systems reduce uncertainty regarding overall pollution reductions. Generally, in instances where regulatory standards are preferred to charges, we would expect tradeable permits to be preferred to either, except by those who consider trading in pollution rights to be as objectionable because it allows parties to pay to pollute. Otherwise, by creating a market in rights to pollute a fixed, total amount, firms are free to decide how much they are willing to pay to pollute by buying as many pollution rights as they wish at the market price. Monitoring and enforcement issues remain with tradeable permits.

Deposit-refund schemes have worked to date with such potential pollutants as returnable bottles and also have potential for expanded use. When purchasing a product, the consumer pays a deposit equivalent to the potential pollution damage, or at least the costs inherent in redemption, and, if proper disposal behavior is followed, can claim the deposit as a reward for not polluting. Deposit-refund systems are especially suited to forms of pollution (disposal) where the costs of control and proper disposal are not large, but the sources are too numerous, diffuse, or otherwise unsuited for effective monitoring under a fee or emission control. Technical means to collect and redeem the targeted substance must exist for a deposit-refund system to differ effectively from a tax. The system is self-funding and requires minimal government intervention.

The tax system offers a number of opportunities to alter market prices to reflect full social costs of polluting activities, but the political acceptability of using taxes in this fashion is problematic. The most likely tax candidates for reducing global climate externalities are excise taxes on certain goods and services that are major greenhouse gas emitters, such as coal-fired electricity generation, petroleum products, carbon and CFC content of products, etc. These taxes are somewhat like emission fees, but are fixed to products rather than to the emissions of particular processes that may be hard to measure. Additionally, personal income tax credits for investments in cleaner products, e.g., heating and air conditioning systems that do not use CFCs, or insulation, might prove politically acceptable but could have relatively small effects. Use of depreciation allowances and investment tax credits in the corporate income tax, while logically attractive, could face considerable political opposition.

Subsidies are structurally equivalent to negative taxes. In a period of government budget retrenchment, they are not likely to be attractive. They require use of revenue obtained elsewhere in the economy, and, historically, they create interest groups that can widen, deepen, and prolong the subsidy. Direct government expenditures also must be weighed carefully during a tight budget period, but current levels of expenditures could be rearranged to reflect changes in social benefits from different programs. Politically, subsidies and the taxes necessary to support them might be seen as redistributive rather than as enhancing social efficiency. Viewed by foreign competitors, American subsidies designed to internalize externalities could appear to be violations of GATT (General Agreement on Tariffs and Trade) provisions.

We do not make recommendations among the incentives we identify, although some clearly have more desirable characteristics than others. Rather, many are discussed in the interest of completeness. Included are some which are commonly known and possibly well-regarded in some circles, but that may not be particularly suitable from one or more perspectives. Additionally, in the exploration of fee or tax devices that could reduce greenhouse gas emissions, we do not address the issue of how large a fee or tax would be required to reduce emissions to some target extent, although we acknowledge that others have not been sanguine about the ability of taxes to prevent climatic change.

Table E.4.1. Summary of evaluation of fiscal instruments

Fiscal Instruments	Applicability to GHGI	Efficiency	Information Requirements	Distributional Effects	Political Sustainability
EMISSION FEES	Charges on CO_2, CFC, N_2, methane emissions from factories, commercial establishments, cattle farms, vehicles	Can be very efficient if monitoring and enforcement costs can be contained	Could be detailed, extensive, and expensive	Can place much of social cost of pollution on polluter; the ability of the producer to pass costs on to consumers depends on demand and supply characteristics of the product	Questionable--can be perceived as a license to pollute; can be viewed as placing excessive financial responsibility on polluter
TRADEABLE EMISSION RIGHTS	Tradeable CFC, CO_2 emission permits. Tradeable deforestation permits and afforestation credits	Can offer major efficiency gains over regulatory devices	Can simplify information requirements by creating a market	Initial assignment of rights can create valuable assets for firms in industry at time of rights creation; auctions could transfer some part of the windfall to government	Can be perceived as a license to pollute; could be well-received by industry for its flexibility
DEPOSIT-REFUND SYSTEMS	CFC refrigerant and carbon deposit-refund schemes	Could create large efficiency gains; lets polluter take lower-cost option of abating or paying; self-funding--minimal budgetary implications; could have large dynamic effects by changing habits and expectations	Relatively simple; self-monitoring; requires technology for recovering and returning targeted substances or products	Probably small	Could be acceptable to a wide range of consumers and industries; possibility of some specific industry opposition
TAXES					
Excise Taxes	Taxes on CFC foam insulation, hydrocarbon fuels, other products utilizing GHG-intensive processes	Could improve efficiency even if social cost is difficult to measure, if social cost is high relative to private cost	Could be expensive to obtain exact internalization, but much of the information requirement could be circumvented if taxes did not aim to recover full social costs	Depends on product, consumption taxes tend to be regressive	Could be acceptable to consumers and to industry if global warming is believed to be important and if taxes appear to be fairly distributed across products of different industries and the products consumed by different income groups

Table E.4.1. Continued

Fiscal Instruments	Applicability to GHGI	Efficiency	Information Requirements	Distributional Effects	Political Sustainability
Corporate Income Tax	Accelerated depreciation on reduced-GHG generating equipment; tax credit for GHG R&D	There is no firm consensus on the effectiveness of corporate income tax provisions in stimulating investment; it is also possible that much of the burden of capital taxation can be shifted to other factors of production	Roughly same as current requirements	Depends on distribution of capital ownership and ability of taxed producers to shift the burden of the tax to others	Differential tax allowances on equipment could be difficult to sell politically; additional complications of tax codes
Personal Income Tax	Tax credits/deductions for reduced-GHG generating consumer durables	Could have complicated effects because of effects on savings and sensitivity of household investment behavior	Roughly same as current requirements	Could be regressive	Similar provisions were passed in the 1970s
Property Taxes	Property tax reductions for energy-efficient, reduced-CFC-containing buildings, or planting trees	Could produce distortions; many different authorities involved	Probably not beyond current capabilities of local tax assessment departments	Could be regressive	Incentives for local governments could be weak
SUBSIDIES	Retrofit or experimental energy-efficient or GHG-capturing equipment	Could improve efficiency; could sustain inefficiencies	Same as for excise taxes	Potential windfalls for specific firms and industries; possibly regressive effects on consumers	Could be difficult to sell in a tight budget era
DIRECT EXPENDITURES	Federal GHG R&D grants, prizes; purchases of reduced-GHG products	Could improve efficiency--encourage new markets and technologies	Roughly same as current requirements	Potential windfalls for specific firms	Could face opposition from nonfavored vendors

E.5 INFORMATION

Information is a commodity that is especially subject to problems of market failure. With much information, once it is produced, it is very difficult for the producer to capture its full value. Consequently, the markets for some types of information can fail to exist, or can function poorly. As a result, economic agents often are forced to make decisions with far less information than could be available to them if information markets worked better. Government can influence private sector actors to alter their behavior by improving the information available to them. Four major types of informational programs are identified and summarized below: advertising, education, moral suasion, and signalling. These programs are more effective when combined with other types of incentives, e.g., with fiscal, regulatory, or RD&D programs, but they can improve the effectiveness of those other programs by strengthening or creating informational markets that are weak or nonexistent. Table E.5.1 at the end of this section summarizes our evaluations of the informational instruments on five attributes: applicability to greenhouse gas issues, efficiency, informational requirements, distributional effects, and political sustainability.

Information is used in a progression of steps, from awareness, through comprehension, retention and retrieval, decision making, and finally, to evaluation. Information programs can intervene at a number of points and to various ends. The government may wish to increase the volume of information available or the rate at which it moves from producers to final users; it may wish to bolster memory capacity or facilitate learning, both altering the effective stock of knowledge; and it also may want to influence evaluative activities by improving information feedback loops.

Advertising and Labeling (Section 5.3)

Mass and targeted advertising can raise awareness of general and quite specific information. Labeling provides specific information about a product or service at the point of purchase or use. Advertising generally must be used in conjunction with other policies to be an effective instrument in fostering energy conservation. Labeling may be a low-cost method of influencing home investment decisions. Both instruments operate in the early phases of the transmission of new information, known as notification.

Education (Section 5.4)

Education programs focus on subsequent stages of information transmission, in which principles are taught. Education programs seek to produce long-term changes in motivations and include general education programs, audit programs, short-term training programs, long-term training and education, networks, and community energy management programs.

Moral Suasion (Section 5.5)

Moral suasion is an adversarial information policy by which the government attempts to persuade a firm or industry to do something under the veiled threat of retaliation if it does not comply. It can avoid time lags of legislation but can fail to attain the political legitimacy of legislated regulation. It may be useful for infrequent, short-term, acute *problems but is unsatisfactory as long-term policy. Also known as* jawboning, *moral suasion has been used in attempts to restrain inflation.*

Signalling (Section 5.6)

In signalling, the government sends a message to private agents about the desired alignment of their behavior with policy goals. The major methods of sending such signals are nonstatutory standards, registration, certification, advanced notice of proposed rule making, and changes in commercial law and policy. Some of these signals are not legally binding, but others are more powerful.

Advertising can reach large populations quickly, but its effectiveness in changing behavior, particularly long-term behavior, is limited. Targeted advertising and labeling can be useful for changing some maintenance and investment behavior. However, even well targeted advertising is best used as a supplemental instrument to reinforce other types of incentive programs. Advertising requires considerable information, and labeling requires careful attention to design to be effective.

Educational strategies can make more lasting changes in people's information sets and consequently in their economic behavior. Educational programs can be targeted at specific information gaps and at groups with quite different characteristics. Program design, therefore, requires considerable care. Changing strongly held prior beliefs can require continuing programs to enhance retention and retrieval of the newer information. Cultural differences, ranging from ethnic to corporate and professional, among target groups can require intricate program design in order to get the program's message across.

Moral suasion, sometimes called *jawboning*, is a deliberate but informal informational instrument. In the use of this instrument, the government attempts to persuade individuals or, more usually, firms to alter their behavior without directly providing them with market incentives that make it in their direct interest to do so. Government leverage with this instrument is the implicit threat to harm a firm's reputation if it does not comply with the national interest. Moral suasion does not have the legitimacy or legal force of legislated or bureaucratic regulation, and can be used only to deal with short-term critical problems. It sometimes serves as a stopgap measure until legislative processes can put more lasting regulations into force. Moral suasion may be more effective when applied to compact, high profile targets such as large, highly concentrated industries. The use of various advertising and educational programs in conjunction with moral suasion can give this informal instrument greater sanction power by bringing the issue under consideration and the individual's or firm's reputation into wider and sharper public view.

Signalling is a varied category of informational instruments, which includes patent and commercial laws, nonstatutory standards and certification, and advanced notice of intent to litigate. Patent laws may give information on the technologies available for conservation, emissions reduction, and other aspects of climate policy. Changes in these laws signal new needs of the government and society for technologies and technological change. Changes in commercial law, such as changes in antitrust law, can signal new directions in industrial development and even technology. Nonstatutory standards indicate to the public desired directions of government policy, and advanced notice of the intent to regulate gives industry signals about new government objectives. These instruments often require interpretation by recipients, and the information they give may not be as clear as direct legislation, but may help prepare both the government and society for legislative changes.

There is a wide range of instruments that government can wield to improve the information base of private economic decisions. Different types of information can suffer different market failures and consequently may require distinct informational instruments to correct the failures. Information is a commodity that must be processed by both producers and users, and each instrument operates at a specific stage of information processing. Some instruments may be quite expensive, but others may be relatively inexpensive, and their effectiveness is strongly influenced by program design and targeting.

Table E.5.1. Summary of evaluation of informational instruments

Regulations	Applicability to GHGI	Efficiency	Information Requirements	Distributional Effects	Political Sustainability
ADVERTISING					
Mass Media Advertising	Stimulate public support for other GHG policy instruments or develop new constituencies	Good for incremental behavior change, but poor inducement for denial or curtailment behavior	Minimal audience information needed. Message itself should be simple and vivid	Income redistributed from public at large to users of information. Public also benefits from reduction of GHG externality	Very good. Viewed as nonintrusive form of behavior modification
Targeted Advertising	Aim at producer or consumer groups to reduce greenhouse effect	Good for promoting maintenance or investment decisions	Market segmentation information to identify target audience needed	Same as above, except users of information more concentrated in target group	Same as above
Affirmative Disclosure (labeling)	Labeling of consumer goods for CFC content, directions for CFC disposal, energy efficiency ratings	Controversial how well information is understood and used	Proper label design necessary	Costs may fall more on corporations if they generate information, or may remain with public if government does	Same as above. Also, opposition may arise if firms must bear large costs of information gathering
EDUCATION					
General Education Programs	Make reports, pamphlets, information hotlines available to public on GHG facts	Behavior effects beyond short term uncertain	Basic technical information on problem required. Must consider cognitive limitations of users	Generally public pays through tax dollars and public reaps benefit from reduced GHG externality	Appealing, because low cost, consistent with informed consent, easily implemented
Audit Programs	Home energy audits, industrial energy audits	Produces results in short to medium term. Less certain long-term results. Results often limited to curtailment and maintenance	State-of-the-art equipment or structure information and skilled auditors	Work best with high income, highly educated people	Good because of voluntary nature. May lose support if issue loses urgency in public opinion
Short-Term Training	Workshops on energy and CFC conservation and technology transfer	Very effective in increasing knowledge of already-aware participants. Results short-term without updating of information	Must match information conveyed with technical and responsibility level of audience	Minimal	Same as above
Long-Term Training	Support of research/education programs such as SERI. Support of university education in GHG-related fields	Poor short- to medium-term effects; possible significant effects in long-term	Minimal information needed by government. Grant programs require review of proposals	Direct beneficiaries are recipients of long-term training. Public reaps benefits of raising collective knowledge	Problems arise because benefits are diffuse and long-term
Networks	Networks of GHG researchers at public and private laboratories; networks of energy technology inventors, investors, etc.	Very efficient, since educational means are low cost; newsletters, journals, conferences, etc.	List of interested agents, especially a few initial key contact people	No notable effects	Good. Nonintrusive method of information transfer and education

Table E.5.1. Continued

Regulations	Applicability to GHGI	Efficiency	Information Requirements	Distributional Effects	Political Sustainability
Community Energy Management Programs	Programs to identify energy conservation options for jurisdictions or buildings, support services for implementing energy codes, etc.	Effective in short through long term. Good spillover effects	Similar to audit programs	Cost of programs borne by taxpayers and those who must alter behavior due to changes in community rules	Generating community interest may have problems
MORAL SUASION	Jawboning by government on industry emissions, persuasion of key decisionmakers, threatened industry reputation loss	Good efficiency if used infrequently. Low-cost method that avoids time lags	Information on current practice (prices, emissions, profits, inputs, etc.) to monitor, persuade, and potentially disclose	Income generally redistributed from sector of economy that is subject to moral suasion to public at large	Sustainable if not overused and if information disclosure done judiciously
SIGNALLING					
Nonstatutory Standards, Registration, and Certification	Nonstatutory equipment standards for GHG emissions. Government certification of equipment or personnel	Nonstatutory standards have low cost. Certification can have obsolescence problems	Potentially extensive depending on complexity of process or profession	Income redistributed from sector involved to general public, unless nonstatutory standards already widely adopted	Good, if handled as a noncoercive initial step
Advanced Notices of Proposed Rulemaking (ANPRMs)	ANPRMs on greenhouse gas regulations or fiscal incentives	Efficient since allow development of non-rulemaking solutions	Minimal, unless proposed rules are actually drafted	Income redistributed from sector involved to general public	Good, if used selectively
Changes in Commercial Law and Policy	Petty patent system. Change in antitrust law to allow GHG research collaboration	Good. Increases information flow	Minimal for change to petty patents. Monitoring information required for changes in antitrust law	Minimal	Potential opposition from users of current patent system. Minimal opposition likely to GHG research collaboration

E.6 RESEARCH, DEVELOPMENT, AND DEMONSTRATION

Research, development, and demonstration activities are peculiarly prone to market failure, to a large extent by virtue of their public-good characteristics. It is difficult, if not impossible, for an individual or firm undertaking basic research to appropriate the full benefits and to exclude others from using the knowledge derived from it. Consequently, private agents will tend to undertake less basic research than is desirable from a society-wide perspective. Applied research, on the other hand, sometimes suffers from a common-property problem associated with the possible capture of a valuable patent by the first party to develop an invention or innovation. In these common-property situations, there is a tendency for too much research to be undertaken by multiple private parties, with the society-wide benefits from the eventual discovery being dissipated in competitive research to get the patent rights. Demonstrations can suffer from high risks associated with expensive projects that may or may not be capable of commercialization and from attendant free-rider problems. Once the technology is demonstrated successfully, agents who did not share in the costs and risks of the demonstration usually can use it, at least at a license fee which may fail to capture the full social value of the new technology. A major goal of the RD&D strategies discussed in this chapter is to reduce risk and uncertainty, including: technological uncertainty, cost uncertainty, demand uncertainty, institutional uncertainty, and uncertainty about external and indirect effects of the technology on, for example, health, safety, and the environment.

Research, development, and demonstration strategies can be used to accelerate technological change through its three main phases, invention, innovation, and diffusion, with the ultimate goal of moving inventions to commercialization. *Invention* is an addition to the stock of knowledge in the form of a new product or process; *innovation* is its first use; and *diffusion* is its penetration into the marketplace. We identify several RD&D instruments that can be employed at specific phases of technological change: public invention-support programs, commercialization education, provision of specialized information, and demonstrations. These are summarized below and Table E.6.1 at the end of this section summarizes evaluations of these instruments on five criteria: applicability to the greenhouse issue, efficiency, informational requirements, distributional effects, and political sustainability.

Public Invention-Support Programs (Section 6.2)

Public invention-support programs award a combination of financial and other assistance to inventors and entrepreneurs involved in commercializing inventions. These programs foster the commercialization of inventions, but they can have large information requirements.

Commercialization Education (Section 6.3)

Commercialization education programs teach inventors, innovators, and entrepreneurs how to bring inventions to the marketplace. These programs are intended to raise the proportion of inventions making it to market and to accelerate their commercialization. They are thought to require less information than public invention-support programs, but they operate at different stages of the technological innovation process.

Provision of Specialized Information (Section 6.4)

Provision of specialized information by the government can take the form of business-plan development, extension programs, and experiment stations, among others. These programs are intended to accelerate and redirect technological change. Considerable experience exists in extension programs and experiment stations, and they have been important change agents in agriculture.

Demonstrations (Section 6.5)

A demonstration is a full-scale application of a new technology or practice under ordinary working conditions, but it includes testing and monitoring not ordinarily found in commercial operation. Demonstrations can be expensive and highly risky for private undertakings, and government sharing of these risks could be important. Dissemination of information collected in a demonstration is crucial to its success in encouraging commercialization.

Public invention-support programs generally award a combination of financial and other assistance to inventors and entrepreneurs trying to commercialize inventions. Their aim is to identify worthy inventions and accelerate their progress to commercialization, for example DOE's Clean Coal Technology Program. Experiences with the Energy-Related Inventions Program, the Innovative Concepts Program, and the Small Business Innovation Research Program suggest that successful public invention-support programs should provide more than one-time-only financial aid. The information requirements of these programs are substantial. Designing invention-support programs requires an understanding of the state of technology, characteristics of the industry, and the prospects for private financing in the absence of public support. These programs, through their selective support of certain inventors and innovators, carry the potential for strong, individualized distributional effects, possibly even windfalls, to a small number of inventors.

Commercialization education teaches inventors, innovators, and entrepreneurs how to bring inventions out of the laboratory and into the marketplace. These programs alter those agents' perceptions of the commercial opportunities available to them. This instrument may be less effective than public invention-support programs because of its focus on a more limited aspect of new-product development, but its information requirements are commensurately less, and it would have less pronounced and individualized distributional effects.

Government can provide specialized information to accelerate or focus technological change by means of business-plan development, extension programs, and experiment stations, among other mechanisms. Small firms or individuals with a good technological idea or product, but without adequate marketing sophistication, could be helped in their efforts to find private capital by assistance in putting together a business plan. Extension programs have a long history in the United States as well as other countries. They bring university, government, and other research to the individual decision maker at the household and small firm level through educational programs, field testing, demonstrations, and experiment stations. Assistance with business plans could be relatively low-cost, but full-fledged extension services entail considerable infrastructure. Agricultural extension in the United States has been highly effective in introducing technological change into agriculture. Both the extension and business-plan programs could have generally neutral to progressive distributional effects. Historically, extension programs of this nature have received considerable political support.

Demonstrations are full-scale applications of a new technology or practice under ordinary operating conditions in order to determine suitability for full commercial application. They concentrate on proving technical feasibility and providing cost estimates, resolving uncertainty about market response, and developing institutional and organizational infrastructure. Unfortunately, demonstration projects have been less successful at encouraging institutional change. They are most effective when non-federal participants share costs and risks, when there is a well-defined, high-potential initial market, and when a supply and support industry is already in existence. Effective demonstrations require third-party monitoring and evaluation, and the widespread dissemination of results through informational programs.

These RD&D programs aim at various stages in the technological change process. Their audiences range from lone inventors to multimillion dollar corporations with well-established R&D and production facilities. They all need to be highly tailored to particular audiences and technologies to ensure their effectiveness.

Table E.6.1. Summary of evaluation of research, development, and demonstration strategies

Research, Development, and Demonstration	Applicability to GHGI	Efficiency	Information Requirements	Distributional Effects	Political Sustainability
PUBLIC INVENTION-SUPPORT PROGRAMS	Could be applied to many stages of technological change. Could apply in form of an inventions program across most fields related to greenhouse gas issues	Could improve the speed and direction of technological change and choice, hence, could improve overall dynamic efficiency	Generally quite large -- may vary with type of program	Transfer of wealth from taxpayers to supported inventions. Competing inventions may be crowded out. Inventions may benefit one group of individuals over another. Long-term distributional effects are complex and uncertain	Could be accepted for a wide variety of uses. Existence of a successful program at DOE and NIST may help the case
COMMERCIALIZATION EDUCATION	Same as above. Best applied at innovation and diffusion stages to inventions which need no other support	Same as above. May be less effective than public invention-support programs because it has a more limited focus -- it targets education for bringing inventions to the marketplace	Requirements less than for public invention-support programs. Could still be considerable	Same as above, but could have less complicated distributional effects due to its less encompassing scope	Could be accepted for a wide variety of uses. Workshops, conferences, and panels and trade shows supported by DOE and others have proven successful
PROVISION OF SPECIALIZED INFORMATION	Could have wide variety of applications. Best applied at innovation and diffusion stage in form of extension programs and business plans for inventions needing no other support	Could improve overall dynamic efficiency. May be more effective than commercialization education because it is often more project-specific	May be large in some applications, small in others. It depends on the type of specialized information provided	Same as above, but distributional effects may be more controlled because of higher degree of specificity	Could be accepted for a wide variety of uses. Has been successful in the development of industries in a wide variety of fields, particularly agriculture
DEMONSTRATIONS	Applicable to a broad range of remediation options involving technically mature technologies that lack performance information and market awareness	Could improve overall dynamic efficiency. Most effective when non-federal participants share costs and risks, there is a well-defined high-potential initial market, and there is a supply and support industry in place	Effective demonstrations require third-party monitoring and evaluation. Widespread dissemination of results is necessary to promote adoption of the technology	Probably small, but depends on technology. Competing technologies may be crowded out	Could be acceptable. Might be viewed as distorting the free market

E.7 ELECTRIC UTILITIES SECTOR

E.7.1 Overview of the Constraints and Opportunities

Electricity generation contributes about 35% of the total U.S. CO_2 emissions. This amount is approximately 8% of worldwide anthropogenic CO_2 emissions. The electric utilities also contribute to the nation's emissions of another significant greenhouse gas, N_2O.

Both the electric utility industry and its emission sources are highly concentrated by comparison to the other economic sectors discussed in this report. Most U.S. fossil fuel generating capacity is accounted for by a little over 2,000 generating units operated by approximately 300 utilities.

While the utility industry is a producer of CO_2 it also may need to adapt to any future climate change, irrespective of whether the origins are anthropogenic or the result of long-term natural processes. The adaptive potential of utilities to global climate change could become a factor in maintaining the security of the U.S. energy supply. Potential adaptation measures might include resiting power plants away from coastal areas, redirecting supply options to reflect possible changes in weather-sensitive demand in some regions, improving transmission interties among utilities, and adjusting to possible changes in precipitation and streamflow which may affect the availability of hydro power and cooling water for thermal technologies.

Since the number of electric utility firms is small, compared to other sectors, there is a greater opportunity for communication and effective planning of focused policies. Furthermore, since the sector's greenhouse gas emissions are concentrated at a limited number of sites (fossil fuel generating plants), and utilities already are subject to extensive record-keeping and reporting requirements, monitoring compliance and policy performance is eased. This is not to deny that the utility sector is varied and complex, including many diverse actors. Utilities range from large private holding companies to small publicly run distributors. Their regulatory and planning context includes public utility commissions, state licensing boards, the Federal Energy Regulatory Commission, the Nuclear Regulatory Commission, the financial community, equipment vendors, environmental regulators, architectural and engineering firm, ratepayers, and independent power producers. Major planning decisions can be slow and uncertain.

Responding to potential climate change will require long planning horizons, for which the utility industry is particularly well adapted. The industry also has experience with controlling various emissions such as SO_x and NO_x dating back to the late 1960s. This experience may be a resource for developing and implementing technological controls for CO_2 and N_2O emissions. A new form of planning known as least-cost utility planning (LCUP) is particularly appropriate to addressing greenhouse gas emission due to its flexibility, inclusion of a diversity of resources (including demand management), public involvement, and explicit treatment of uncertainty.

The objective of reducing greenhouse gas emissions is consistent with other common utility policies, such as promoting efficiency and the pursuit of a diverse portfolio of supply options. However, other objectives, such as the control of non-greenhouse gas emissions with conventional abatement equipment, may reduce energy efficiency and constrain progress on CO_2 emissions. Energy security objectives may directly conflict with the long- to extended-term objective of switching away from coal. Consequently, utility decision makers currently receive contradictory policy signals.

Another constraint is that the industry is the most capital intensive in the U.S. Furthermore, the rate of capital turnover is very slow, perhaps the single greatest constraint in reducing greenhouse gas emissions. Given the high capital costs, long construction and licensing lead times (10-15 years) and economic and regulatory uncertainty, there are few incentives for utilities to invest in new, more environmentally benign, power plant construction for capacity additions or replacement. Most forecasts indicate that fossil-fueled plants (particularly coal-fired) will continue to be a major component of generation in the foreseeable future, and that much new generating capacity will be built by independent power producers, while utilities move in the direction of becoming common carriers. While it is possible that the growth of IPPs will enhance the rate of capital turnover in the industry, such developments undoubtedly would complicate policy making in this sector. The development of small-scale generating technologies with low net greenhouse gas emissions (such as photovoltaics and biomass) may prove particularly attractive to IPPs.

E.7.2 Activities, Policies, and Options

This study identifies four principal activities in the electric utilities sector: generating capacity addition and replacement; maintenance and use of existing equipment; emissions abatement; and demand side management. Policies pertaining to these activities and various options for their implementation are listed below.

Generating Capacity Addition and Replacement (Section 7.4.1)

Construction of new generating capacity, either to replace existing plants or to satisfy additional demand for electricity has the most direct implications for greenhouse gas emissions. If a prevention strategy is pursued, it will be necessary to speed the replacement rate, encourage the choice of technologies that emit less CO_2, *and improve the utility planning process so that it considers additional alternatives.*

Policy: Promote the Use of Least-Cost Utility Planning (LCUP) as a Means of Formulating Utility Responses to Greenhouse Gas Emissions

Least-cost utility planning studies a wide range of options for meeting anticipated electricity demand. Rather than minimize the cost only of capacity expansion, LCUP examines options to reduce load growth and purchase options as well.

Option: Support demonstration projects to increase the familiarity of utilities and PUCs with LCUP

Option: Provide regulatory and financial incentives to adopt LCUP

Policy: Increase the Capital Turnover Rate in Generating Capacity

Increasing the capital turnover rate in generating capacity would accelerate the introduction of new, more efficient technologies. Options to encourage turnover include tax incentives, regulatory revisions, and the introduction of equipment performance standards that encourage earlier retirement of existing equipment.

Option: Allow accelerated depreciation in the corporate income tax for investments in new generating equipment

Option: Revise rate-of-return regulation and the ratemaking system to change the distribution of risks for investing in generating capacity

Option: Develop and implement a system of expedited siting, permitting, and certification for new generating capacity

Option: Set performance standards for heat rates or emissions limits that force equipment replacement but do not dictate a specific technology for replacement

Option: Demonstrate new technologies to reduce uncertainties about their benefits and costs which otherwise may delay investment decisions

Policy: Promote the Choice of Generating Technologies and Fuel Combinations With Low or No Greenhouse Gas Emissions When Investing in Additional or Replacement Capacity

This policy focuses explicitly on encouraging the choice of low- or non-greenhouse gas emitting technologies when replacements are made. Options for promoting these choices include a range of emissions taxes and restrictions, positive incentives such as tax credits and purchase guarantees, and regulatory revisions.

Option: Impose greenhouse gas emission fees on utilities using fossil fuels

Option: Impose carbon-based fuel user fees on utilities using fossil fuels

Option: Allocate tradable emission permits for greenhouse gases to utilities

Option: Allocate tradeable coal- (or fossil-fuel) use permits to utilities

Option: Establish a deposit-refund system for the carbon in fossil fuels used by utilities

Option: Tax credits for investments in selected, low- or non-emitting technologies

Option: Technology standards or emission limits for new investments in generating capacity

Option: Rate-of-return discrimination favoring low- or non-emitting technologies

Option: Government cost-sharing for fuel switching

Option: Subsidies to manufacturers for investments in selected, low- or non-emitting technologies

Option: Purchase guarantees for investments in selected, low- or non-emitting technologies

Option: Resolve the problems of nuclear waste repositories to facilitate substitution of nuclear for fossil-fuel generating capacity

Option: Revise the current permitting and licensing process by standardizing design of nuclear plants to facilitate substitution of nuclear for fossil-fuel generating capacity

Option: Encourage research and development of low greenhouse gas emitting technologies, particularly those suitable for small-scale capacity additions that IPPs could utilize

Policy: Promote High-Efficiency Cogeneration

Permitting greater utility use of electricity cogenerated from industrial, commercial, and large-residential waste heat could reduce greenhouse gas emissions. Regulatory reform is necessary to permit this, and investment tax credits for cogeneration equipment would offer additional encouragement for potential cogenerators.

Option: Reform regulations to allow utilities to operate cogeneration business entities serving their own service territories

Option: Investment tax credit for investors in cogeneration

Policy: Encourage Anticipation of Possible Effects of Climate Change on Utility Systems

While most policies are directed at preventing or mitigating climatic change, attention must be paid also to the possibility that climate will indeed change. Options to encourage anticipation of this possibility involve revising regulatory procedures for power plant siting and encouraging information exchange among utilities.

Option: Require FERC and public utility commissions to consider vulnerability to climate change when issuing certificates of convenience and necessity for new power plants or site licenses

Option: Promote workshops and networks for information sharing about anticipated hydrological impacts of climate change on utility generations at regional levels

Use, Maintenance, and Upgrade of Existing Equipment (Section 7.4.2)

Existing plants can be repowered to produce more electricity for the same amount of fuel burned. Small reductions in CO_2 emissions from existing power plants can be achieved if plant heat rates are reduced, or if plants with low emissions are given preference in utility operations over those with high emissions. Reducing the amount of electricity lost in transmission and distribution also could reduce the amount of fuel consumed to supply consumer demand.

Policy: Promote Repowering Over Life Extension to Improve Plant Efficiency

Repowering increases the efficiency of electricity generation at an existing coal plant as well as adding generating capacity, effectively choosing a lower-emitting technology to add capacity. Options to implement this policy are the same as the first eight in the list of those to promote the choice of low- or non-emitting technologies (above).

Policy: Promote Efficiency Through Operating and Maintenance Improvements

Improved operating and maintenance (O&M) procedures can raise fuel efficiency and modestly reduce greenhouse gas emissions. Options to encourage O&M improvements are performance standards for heat rates and regulatory revision to modify fuel-adjustment clauses.

Option: Impose performance standards on heat rates

Option: Modify fuel-adjustment clauses in rate-of-return regulations

Policy: Promote Emission Reductions Through Changes in Dispatching Practices

In a large grid with a variety of generation types it may be possible to incorporate emissions as well as fuel costs as a criterion in computing merit order for dispatch. Additional information is needed to determine the potential effectiveness of this policy. Therefore no specific options have been identified to implement it, although emission charges and education programs might be effective.

Policy: Encourage Investments in New Transmission and Distribution Technologies

Reduction of losses in transmission and distribution (T&D) systems could be reduced with new technology. Standards for T&D equipment could accelerate introduction of new technology. Research and development on superconducting applications and on power systems automation also could reduce losses. U.S. grids operate close to the technical limits of existing technology. Without major technical innovations, such as superconductivity, overall greenhouse gas emission reductions would be small.

Option: R&D for superconducting and power system automation

Option: Establish standards for replacement of transmission and distribution equipment

Emissions Abatement (Section 7.4.3)

No commercially proven technology exists to control CO_2 emissions from power plant stacks, although some have been proposed. During the short and medium term, CO_2 emitted by power plants can be captured by biological systems such as forests, and R&D may develop effective emission controls for plants.

Policy: Promote Biological Offsets

Trees collect and fix carbon from the atmosphere. Large-scale afforestation efforts could partially offset utility emissions. Numerous afforestation schemes could be explored, and allowances for bio-offsets could be included in tradeable emission-permit systems.

Option: Investigate feasibility of utilities' use of transmission-line and highway corridors to plant biomass offsets for CO_2 emissions, and/or investigate potential for utility-sponsored urban tree planting or rural afforestation to offset CO_2 emissions. Positive results to be communicated through government sponsored demonstration programs

Option: Integrate allowances for bio-offsets in a tradeable emission permit plan

Policy: Promote Emission Control Technologies

Currently, emission control technologies for CO2 are expensive. Further R&D to bring costs down could be undertaken. When control technologies are closer to commercialization, emission limits and design standards on control technology could be established.

Option: Research, develop, and demonstrate commercially available CO_2 emission control technology

Option: Impose emission limits on generating equipment to require reductions in greenhouse gas emissions

Option: Impose design standards requiring the use of the best available or best practical technology for efficient use of fuel in new generating capacity

Utility Demand-Side Management Programs (Section 7.4.4)

Demand-side management improves the match between planned supply resources and future demand, often at lower cost than building a new generating plant. Much of this effort seeks to reduce the rate of growth in demand, and by doing so it would reduce future CO_2 emissions. Promoting demand-side management could strengthen this trend.

Policy: Improve the Efficiency With Which Electricity is Used by All Customer Classes

The policies so far have focused on producers, but consumers could conserve electricity with minimal sacrifices in services. Customer-education programs, combined with a tax on electricity production could reduce electricity consumption and greenhouse gas emissions. Regulatory revisions to emphasize conservation programs would be crucial.

Option: Require the Federal Energy Regulatory Commission to incorporate greenhouse gas reduction considerations in their review of all utility wholesale contracts

Option: Require the Federal Energy Regulatory Commission to issue an order on competitive bidding that explicitly considers CO_2 reduction and that encourages bidding for demand-side resources

Option: Require the Federal Power Marketing Agencies and the Tennessee Valley Authority to expand their conservation programs and to set rates for their member distributors based on their achievement of energy-efficiency goals

Option: Impose a tax on electricity sales to improve end-use efficiency

Option: Provide federal grants to utilities for implementation of cost-effective energy conservation programs. Couple these grants with requirements that utilities achieve certain energy-efficiency improvement goals for each of their customer classes

Option: Expand the technology transfer activities of DOE with electric and gas utilities

Option: Require DOE to assess alternatives to traditional rate-of-return regulation that would reward utility shareholders for implementation of successful conservation programs

Table E.7.1 summarizes the foregoing list of policies by activity and type of instrument that could be employed.

E.7.3 Conclusions

The opportunities and constraints that currently operate on the electric utility sector shape its ability to respond to the greenhouse gas issue. The wide variety of policy options listed above may offer varying degrees of success in reducing greenhouse gas emissions. Even if a national consensus develops that the effects of greenhouse gas emissions are so adverse that a strong set of policies is required to reduce them, it will take several decades before the utility industry can reduce substantially the present level of emissions it generates.

Several important reasons form the basis of this conclusion. First, the electric utility industry is overwhelmingly dependent upon fossil fuels and particularly coal for its generating capacity. Advanced clean-coal technologies that are being developed and demonstrated will bring some intermediate benefits if used to replace existing coal capacity, but in the long term this will not eliminate emissions outright.

Nuclear power is an attractive option in regard to CO_2 emissions. Presently, 110 nuclear reactors generate 20 percent of the electricity used in the USA without emitting any CO_2. DOE currently sponsors work on light water reactors that will be simplified, incorporate passive safety features, and have improved economics. The Department expects these to be ready for commercialization in the 1990s. DOE also sponsors work to develop safe, economic nuclear powerplants for the 21st century. These include the modular high temperature gas-cooled reactor and the liquid metal reactor. However, all nuclear technologies face significant barriers of market and public acceptance that may limit their role in CO_2 reduction.

Other technologies that produce no greenhouse gas emissions, primarily nuclear fusion, geothermal, and solar, eventually could become available and help reduce such emissions, but these technologies are either too expensive, or inadequately developed to reduce greenhouse gas emissions in the near or medium term. Thus, unless cost and public-acceptance barriers to

Table E.7.1. Policies for the electric utility sector

Activity/Policy	Addition/Replacement of Generating Capacity	Maintenance/Use of Existing Equipment	Emissions Abatement	Demand-Side Management
REGULATION				
Controls	Increase capital turnover rate by more favorable risk-spreading. Promote high-efficiency cogeneration. Institute favorable rate-of-return regulation for low-emissions technologies. Promote use of least-cost utility planning	Promote repowering over life extension and promote operating and maintenance improvements by allowing expenditures in rate bases	Promote biological offsets with flexible emissions standards and promote new control technologies with tighter emissions limits	Revise FERC requirements for utility wholesale contracts to promote end-use efficiency
Standards	Set performance standards to increase capital turnover rate in generating capacity	Promote repowering over life extension by tightening standards for heat rates. Tighten performance standards to promote operating and maintenance improvements Tighten equipment and performance standards to encourage investment in new transmission and distribution technology	Promote new emission-control technologies with performance standards	Promote end-use efficiency through tightened equipment standards
Licensing/Certification	Impose technology standards or emission limits for licensing new facilities. Encourage anticipation of climate change in utility-siting decisions			
FISCAL INCENTIVES				
Price	Use emission fees, carbon-based user fees, tradeable coal use permits, deposit/refund systems to promote technologies and fuel with low or no emissions	Use emissions and user fees to promote repowering over life extension and change dispatching practices	Promote biological offsets with allowances for bio-offsets in tradeable emission permit systems	Introduce FERC requirements for CO_2 considerations in competitive bidding
Taxation	Increase capital turnover rate by accelerated depreciation allowances. Promote low CO_2 technologies and fuels with tax credits. Promote high-efficiency cogeneration with investment tax credits	Promote repowering over life extension with investment tax credits		Introduce excise taxes on electricity production to promote end-use efficiency
Subsidies	Promote low CO_2 technologies and fuels combinations with subsidies to manufacturers	Use subsidies to promote repowering over life extension and change dispatching practices		Subsidize utility conservation programs.

Table E.7.1. Continued

Activity/Policy	Addition/Replacement of Generating Capacity	Maintenance/Use of Existing Equipment	Emissions Abatement	Demand-Side Management
Direct Expenditures	Promote low CO_2 technologies and fuels with government cost-sharing and purchase guarantees	Government cost-sharing to promote repowering over life extension R&D on superconductivity applications and on power system automation	R&D to lower costs of new emissions control technologies	Make grants to utilities for conservation programs
INFORMATION				
Advertising			Promote biological offsets with mass information programs	Advertise end-use efficiency
Education	Encourage anticipation of possible effects of climate change of utility siting decisions with workshops and information networks	Education programs to change dispatching practices	Promote biological offsets with educational programs	Promote efficiency through consumer education programs
Moral Suasion				
Signalling	Promote low CO_2 technologies and fuels by revising the permitting and licensing procedures. Require FERC and PUCs to consider vulnerability to climate change when issuing site licenses	Rate-of-return regulation discrimination in favor of repowered plants		
RESEARCH, DEVELOPMENT, AND DEMONSTRATION				
Public Invention-Support Programs				
Commercialization Education				Assist formation of energy service companies.
Provision of Specialized Information				
Demonstration	Encourage anticipation of climate change on utility siting decisions by demonstrating new, adaptive technology R&D on low greenhouse gas emitting technologies	Demonstrations to change dispatching practices R&D superconductivity applications and on power system automation	Promote biological offsets with demonstrations. Promote new emission control technologies with demonstrations	Demonstrate efficient technologies to utilities and consumers

nuclear fission are rapidly resolved, technological solutions are unlikely to be available before the long- to extended-term.

The second major hurdle is the long-lived nature of the industry's capital equipment. With a minimum life expectancy of 30 years and a maximum of 40 years or more, the industry's generating capacity–the source of almost all its greenhouse gases–takes a long time to replace. This long life, coupled with the 10 years or more required to construct a baseload plant, means that it will take several decades to replace most of the generating stock by non-greenhouse gas emitting plants once they become available. This constraint may be partially offset by the availability of small-scale and cogeneration facilities to the extent that they can displace baseload capacity.

The third hurdle to reducing substantially the electric utility industry's greenhouse gas emissions is the immense capital outlay required. Almost three-fourths of the industry's summer generating capability is fossil fired, and the expense of replacing this investment under normal conditions will be huge in its own right; speeding up the replacement rate to remove greenhouse gas emissions could be financially intolerable for the industry.

The final major difficulty in implementing quick solutions to the greenhouse gas issue is the adverse impact that any effective policy would likely have on society. The utility industry would have to obtain its huge capital requirements from somewhere--the financial community, ratepayers, federal government, or foreign investors--and each has its price for American society. Some expensive tradeoffs are required, and when these tradeoffs become better known as they occur, the cost may be higher than seemed warranted by the original problem. Plausible costs could include: a financially stressed electric utility industry; angry ratepayers facing much higher utility bills; companies that relocate or close because higher utility rates made them uncompetitive; higher federal taxes; increased indebtedness to foreign countries; increased inflation; an economically depressed coal-mining industry, towns, and railroads; and other investments that are foregone in order to pay for the non-greenhouse gas technologies.

The adverse impacts need not occur, and the hurdles discussed above can be overcome if the nation adopts a long-term, carefully constructed policy designed to replace greenhouse gas emitting plants with low and non-emitting technologies as they reach their normal life expectancies. At the same time, the country could adopt a strong energy efficiency policy in energy production, distribution, and use.

An integrated research program designed to accelerate development of low and non-greenhouse gas emitting technologies and improved energy conservation policies should be initiated by the federal government and the industry. Once these technologies are sufficiently developed, the utility industry could begin factoring them into its planning through use of the least-cost utility planning process so that the technologies can begin making their appropriate contribution to reducing emissions. Indeed, one of the earliest measures that the industry can take is to use the most recent data to identify technologies, costs, and industrial factors that play a part in the decision that ultimately must be made.

E.8 THE MANUFACTURING SECTOR

E.8.1 Overview of Constraints and Opportunities

The manufacturing sector contributes substantially to greenhouse gas emissions, comprising 20% of total U.S. CO_2 emissions in 1985 and serves as the source of all CFC-based products. The principal relevant manufacturing activities are energy-intensive, heavy-industrial processes which consume fossil fuels for process heat, electricity for process heat, and electricity for motive force. In addition, some of these industries generate greenhouse gases (primarily CO_2 and CFCs) in non-combustion processes, either directly as a product or as a by-product of their manufacturing processes. The sector's potential for assisting with prevention and mitigation of the greenhouse effect is relatively large, although most of its possibilities lie in the medium and long terms.

Within the manufacturing sector, eight industries account for 65% of all purchased fuel use and a concomitantly large share of CO_2 emissions. In order of total energy use (in 1985) they are petroleum refining, chemicals, paper, steel, glass and stone, cement, transportation equipment, and aluminum. For the most part, the manufacturing processes in these eight industries are uniform across firms, further easing the design of preventive strategies. The major exception to this rule is the chemical industry, which employs highly diverse manufacturing processes to produce over 2000 products.

A primary opportunity for preventing the release of greenhouse gases in the manufacturing sector involves energy conservation. Industry uses energy in the forms of process heat, mechanical power and electric drive, instrumentation and control, and space heat. Process heat is by far the largest user of energy, with electric drive and mechanical power being of secondary importance. A host of technological (process and equipment) options exists that could reduce the manufacturing sector's energy use and thereby reduce greenhouse gas emissions. These options include waste heat recovery; process flow optimization; improvements in combustion technologies; and basic process R&D.

Materials recycling provides another opportunity for reduced energy use, particularly the recycling of steel and aluminum which would save 50-95% over the use of virgin ores. Another opportunity for reduced energy use lies in consumer substitution away from energy-intensive manufactured products. Beyond energy conservation, there are further opportunities for climate change prevention in the manufacturing sector through fuel switching away from fossil or carbon-intensive fuels.

Manufacturing methods which directly release greenhouse gases in non-combustion processes, including CO_2 from cement manufacture and primary aluminum smelting, may be altered or the product discouraged. Since the manufacturing industry is both the primary producer and user of CFCs, there are opportunities to limit the release of these materials.

The availability of promising energy conservation technologies raises the question of why they are not being used. The answers range from the experimental nature of the technology (for some advanced combustion methods) to the simple fact that a proven, well known, and readily available technology may be uneconomic at current and projected fuel prices. Within this range are: technologies that work but are not demonstrated and fully evaluated at a commercial scale (e.g. catalytic chemical separation processes); emerging technologies that require added development and demonstration (e.g. biomass gasifiers); technologies not commonly known and requiring a concerted effort by private investors to understand and evaluate them; mature technologies that must be customized and proven for each particular industry (such as energy management by improved instrumentation and control, or waste heat recovery); and technologies that require large front-end investments and possibly the scrapping of useful existing equipment (like cogeneration or fluidized bed combustion). Other constraints on technology adoption include short industry planning horizons and rigid planning and operating procedures.

The number and strength of firms in each manufacturing industry influences the effectiveness of potential greenhouse prevention policies. Some industries are highly concentrated. For example the four largest firms in the automotive, (flat) glass, and aluminum industries account for over two-thirds of total output of their respective products. Fewer major firms may mean that firm behavior (such as fuel use and CO_2 emissions) is more easily monitored, conservation techniques may be more easily communicated, and control policies may be more easily enforced.

Despite the high concentration of these industries and the ability of some to dominate local markets (e.g., cement), these firms do not necessarily possess the market power to garner excessive profits from which they might find it easy to pay emission fees or a fossil fuel tax. A number of market constraints exist on firms in these industries to prevent acquisition of excess profits, including: intense foreign competition; high capital costs with slow capital turnover, and aging productive plant; product uniformity (e.g. for basic materials) limiting profits from product differentiation; and the consumers of manufactured basic materials often are also large firms, with market power.

It generally is true that negative incentives may decrease greenhouse gas emissions, but they also reduce international competitiveness. Creating a disadvantage for U.S. industry could shift production overseas, resulting in U.S. economic losses with no net reduction in global emissions. To avoid this problem, positive incentives for emissions reduction and energy conservation can be used. However, they also may lower product price and increase product demand, and these concerns must be balanced.

A political constraint is that if negative fiscal incentives or restrictive regulatory policies are established, the prospect for political conflict is heightened for those industries which are regionally concentrated. For example, 65% of the pulping and 50% of paper making capacity exists in the southeastern U.S., with many communities entirely dependent on large mills.

The low rate of R&D in certain basic manufacturing industries, (notably pulp and paper, cement and glass), and old capital stock (notably paper and pulp) are other constraints. Without exception, the eight industries that are primary contributors to greenhouse gas emissions are capital intensive with long-lived equipment and slow capital turnover. A boiler, for instance, lasts 40 years. Some paper making machines are 70 to 80 years old. Investment rates and technological change will be slowed further if demand for basic manufactured materials grows only gradually. However, retrofitting equipment can go a long way toward meeting shifts in market or government policy that would require reduced emissions. The low rate of R&D also may present an opportunity for fruitful government-supported research.

An additional factor which may create resistance to new environmental initiatives is the recent history of costly environmental regulation, under the Clean Air Act and Water Pollution Control Act.

E.8.2 Activities, Policies, and Options

Activities, policies, and options are listed below with the relevant policies and various options for their implementation. The principal activities of the manufacturing sector influencing climate change identified in the study are fossil-fuel combustion for process heat, electricity use for process heat or similar process need, electricity use for motors and motive force, use of greenhouse gas inputs, and disposal of greenhouse gas byproducts.

Fossil-Fuel Combustion for the Generation of Process Heat (Section 8.4.1)

The manufacturing sector consumed roughly 20% of all final energy consumed in the United States in 1980. Most of its energy consumption was used for process heat, 80% of which was from fossil fuels. Most industries find substantial substitutability among fuel sources for process heat generation.

Policy: Encourage Energy Conservation Through Industrial R&D, Process Redesign, Improved Energy Management, and Combustion Efficiency Improvements

The largest single component of industrial energy use is for process heat. Conservation is possible through process redesign, improved combustion efficiency, waste-heat recovery, and improved energy management. In some instances, a proven technology is available but major investments are required; in other cases current fuel prices do not yet justify the process change; and in a third set of instances, industry managers could benefit from more information about how some proven cost-effective techniques are practical in their firms.

Option: Use a price-like fiscal measure such as a fossil-fuel use fee, tradeable fossil-fuel use rights, or a carbon deposit-refund scheme to promote fossil-fuel conservation

Option: Alter the corporate tax code to provide incentives for investment in fossil-fuel-efficient production processes, and to speed capital turnover in heavy industry

Option: Conduct or support energy conservation programs, such as informational workshops or energy audits to describe practical waste-heat recovery methods and improved energy management, specific to individual industries

Option: Promote industrial R&D on basic manufacturing process technologies which conserve energy. Use subsidies, advantageous tax treatment, or direct government expenditure.

Policy: Promote Switch from Coal to Fossil Fuels with Diminished Greenhouse Gas Impact (Oil, or Preferably Natural Gas), or from Fossil Fuels to Biomass or Non-Fossil Based Electricity

Substituting natural gas for oil or coal will reduce greenhouse gas emissions. But the manufacturing sector already is using gas for about 50% of its energy, and without added price incentives, the opportunities for further substitution may be limited. Tradeable permits for coal use, or a fuel fee based on carbon content could provide such an incentive.

Alternatively, requiring bio-offsets also will encourage switching while creating new incentives for improved forest resource management.

Option: Impose a fossil-fuel use fee or tradeable coal-use permits on all industry to promote switching away from coal

Option: Require bio-offsets for industrial fossil-fuel combustion to promote switching away from fossil fuels, and compensate for fossil-fuel combustion

Policy: Encourage Substitution from Some Fossil-Fuel Intensive Manufactured Goods, e.g. Substitution of Wood for Cement and Brick, to Reduce Demand for Fossil-Fuel Intensive Products

In some construction applications, wood is a suitable substitute for cement, brick or steel. Lumber offers the dual advantage of being less energy intensive to manufacture and serving to sequester the CO_2 which was absorbed during growth. Fiscal incentives may be required, unless reforestation incentives eventually depress the price of lumber.

Option: Provide fiscal incentives to induce substitution of wood for cement and brick in construction materials

Policy: Encourage Recovery and Recycle of Fossil-Fuel Intensive Manufactured Materials, Particularly Scrap Steel, Aluminum, Paper, and Glass to Reduce Fossil-Fuel Use by Manufacturers

Paper, glass, steel, and aluminum are now actively recycled by manufacturers, with energy savings of about 20 to 95% over the use of raw materials. Policies to promote recycling are consistent with rising municipal waste disposal costs. Scrap material quality will be crucial in determining the full potential for recycling, and a product's original design may be important in determining its ultimate quality as scrap.

Option: Provide federal incentives (e.g. contingent state aid) and model legislation for states and municipalities to implement recycling of fossil-fuel intensive materials (particularly scrap steel, aluminum, glass, and paper). Consider federally imposed deposit-refund systems on all glass and aluminum beverage containers, automobiles, and major appliances

Option: Expand the demand for scrap and recycled materials by promoting investment in scrap processing equipment and supporting RD&D for new equipment

Electricity Use for the Generation of Process Heat and Electrolysis (Section 8.4.2)

Electricity is an essential input to the newer steel mini-mill subindustry and is a favored heat source in the glass industry. The aluminum and chemical industries are also major electricity consumers.

Policy: Promote Electricity Conservation in Process Heat Applications

Electricity is used as a process heat source in instances where freedom from combustion by-products or precise temperature control is imperative (e.g. glass melting, or electric arc steel furnaces). In many instances the options described above to promote improved energy management and waste heat recovery also will be helpful here.

Policy: Promote Switching from Fossil-Fuel-Based Electricity to Biomass-Based or Non-Fossil-Based Electricity

The policy to encourage the use of electricity from one generating source rather than another is only meaningful when industrial electricity consumers have a choice. Discussions on regulatory reform should consider the role of competition in promoting the selection of socially beneficial generating sources. Fossil-fuel use fees or tradeable permits will provide an incentive to switch, when a choice is available.

Option: Impose fossil-fuel use fee or tradeable fossil-fuel use permits on all electric power generators

Electricity Use for Motors and Motive Force (Section 8.4.3)

Electric motors and drives are widely used in manufacturing. The average conversion efficiency of electricity to motive power is 40 to 60%, and 80% of potential electricity savings in manufacturing can be realized in improving electric motive force.

Policy: Promote More Efficient Use of Electricity by Motors

Improved instrumentation and control, and new electric drive technologies offer opportunities for conservation. To the extent that these technologies are mature and effective, policy options may include information programs and investment incentives.

Option: Engage in marketing-oriented advertising programs to help commercialize new electric-drive technology and substitute processes. Couple these efforts with necessary positive financial inducements

Policy: Encourage Self and Cogeneration by Manufacturers

Cogeneration is especially efficient in its use of fuel for the production of both heat and electricity, and is well suited to many manufacturing operations. The Public Utilities Regulatory Policies Act has encouraged electricity cogeneration, by guaranteeing a market for its electricity. Any incentives for fossil-fuel efficiency (such as a fossil-fuel use fee) or for the competitive sale of electricity will further promote this policy.

Option: Provide corporate income tax credits to encourage the necessary capital investment for cogeneration

Option: If the firm is cogenerating, exempt the fuels used and electricity re-marketed from any special fees or restrictions which may be placed on fossil-fuel combustion elsewhere

Manufacture of CFC-Based Products, Use of CFCs in Manufacturing Processes (Section 8.4.4)

CFCs are embedded in closed-cell plastic foams and insulation, which accounted for the bulk of CFC emissions between 1975 and 1980. CFCs are used also as intermediate inputs in manufacturing processes.

Policy: Discourage Incorporation of CFCs in Manufactured Products

CFCs are directly included in products such as closed-cell foams and refrigerators. Reduced CFC use will require further R&D to develop substitutes, the selection of substitutes by manufacturers, and some product redesign to account for the different properties of the substitutes. Broad fiscal disincentives for CFC use will promote all three activities, or the government could provide direct R&D and product redesign assistance.

Option: Encourage further R&D and technology diffusion for benign substitutes for CFCs

Option: Limit CFC use in some products by regulatory control

Option: Provide financial incentives for product redesign and phasing out CFC use by establishing tradeable rights to incorporate CFCs in products

Policy: Allow Incorporation of CFCs in Products, but Restrict or Discourage the Subsequent Release of those CFCs to the Atmosphere

In some manufactured goods, the incorporation of CFCs may be far less expensive or more effective than the available substitutes. If their ultimate release to the atmosphere can be prevented, and they can be destroyed or recycled, then such uses are acceptable. An outright ban on improper disposal of CFC-bearing products is possible, but a deposit-refund system can provide a more flexible incentive and be self-enforcing.

Option: Ban the improper disposal of products containing CFCs, or use a deposit-refund system on those products to encourage proper disposal and CFC reclamation

Option: Use advertising, labeling, or government statements and signals to communicate the hazards of CFC release, and promote consumer demand for substitute products

Policy: Encourage Substitution for CFC Inputs and Process Changes in Industries Which Release CFCs

In some manufacturing processes (such as refrigeration and open-cell foam blowing) CFCs are released by firms. Possible options are phased-in bans on the use of CFCs, emission limits, or emission fees.

Option: Ban or limit CFC emissions for these or all industrial processes

Option: Indirectly promote reduced CFC use or discharge by imposing a fee for CFC emissions

Manufacturing Processes With CO_2 as a Byproduct (Section 8.4.5)

Several industrial processes generate CO_2 as a byproduct apart from combustion of fossil fuel.

Policy: Encourage Process Changes in Industries Which Release CO_2

CO_2 is released from non-combustion processes during the calcination of cement and the electrolysis of aluminum using carbon anodes. Since CO_2 recapture from these processes has been little considered, policies to promote R&D in this area may be productive. The selective imposition of CO_2 emission fees on these industries is unlikely to be deemed fair. Positive tax incentives to take advantage of this special opportunity for reducing greenhouse gas emissions may be widely acceptable.

Option: Encourage R&D on CO_2 capture from non-combustion processes in the cement and aluminum industry

Option: Provide financial incentives for industrial investments which limit CO_2 release, either through emission fees, tax credits, or subsidies

Option: R&D to develop biotechnology for calcium carbonate production

Policy: Explore Foreign Trade Initiatives which Minimize the Competitive Disadvantage U.S. Industries Face Due to Greenhouse Gas Prevention Regulations, Fees, and Restrictions

Many of the policy options suggested impose additional costs (or benefits) on the affected U.S. industries, influencing their international competitiveness. Multilateral agreements with trade partners, imposing equivalent regulations and negative incentives on imported goods, or excluding from regulation those manufacturing operations destined for export may be appropriate.

Table E.8.1 summarizes the foregoing list of policies by activity and type of instrument that could be employed.

E.8.3 Conclusions

There exists a range of technological (process and equipment) options with the potential to reduce greenhouse gas emissions from manufacturing activities. The difficult task for policy makers is to establish which of these changes are justifiable, given concerns about possible climate change, and to determine the appropriate role (if any) for government in promoting these changes.

When the process and equipment are relatively rigid and the opportunities for technological change are small (as may be the case for cement calcination, for example), climate effects may be reduced by encouraging consumer substitution away from the related manufactured products, i.e., by stimulating the private sector to produce a market substitution.

In some instances the changes desired for greenhouse gas reductions currently have little justification within the planning and profit calculus of manufacturing firms: e.g., emission of CO_2 as a by-product of manufacture was heretofore considered benign and certainly imposes no costs on the firm. Similarly CFC emission from refrigerators imposes no private costs. In these instances some new incentives must be provided. Examples include a deposit-refund system for refrigerators, a fossil-fuel or coal-use tax, a CO_2 emissions fee, and a tradeable-emissions or coal-use scheme.

Each of these obstacles to change in the manufacturing sector suggests a somewhat different policy approach. Again, many of the policy measures are familiar. Current relative fuel prices and incentives may be modified by fee or subsidy. High initial capital costs suggest investment tax incentives for such measures as cogeneration equipment, efficient furnaces, and continuous costing mills. Short planning horizons and rigid operation procedures may be modified by practical industry workshops which indicate the merits of efficient processes such as heat cascading. If information about alternative technologies is not readily available to firms, advertising and education are sensible. Finally, if a potentially promising method such as biotechnology-induced formation of calcium carbonate (for the cement industry) is unproven and risky, R&D followed by demonstration is appropriate.

None of the policy options considered is likely to be either simple to design or uniformly appealing to all parties concerned. Some industries within the manufacturing sector are actively interested in global climate change, and how it might alter regulations and markets which concern them. From an optimistic viewpoint, this interest may serve as another opportunity for effective policy formation. However, the national concern of manufacturing firms to protect their own interest, if not properly recognized, may lead to continuing cycles of confrontation and policy destruction.

Table E.8.1. Policies for the manufacturing sector

Policy/Activity	Fossil Fuel Combustion for Process Heat	Electricity Use for Process Heat or Electrolysis	Electricity Use for Motors and Motive Force	Greenhouse Gases as Inputs to Production	Disposing of GHG By-products
REGULATION					
Controls	Provide federal incentives (e.g., contingent state aid) and model legislation for states and municipalities to implement recycling of fossil-fuel intensive materials			Limit CFC use in some products by regulatory control. Ban the improper disposal of products including CFCs Encourage substitution for CFCs. Ban or limit CFC emissions for these or all industrial processes	
Standards	Require bio-offsets for industrial fossil fuel combustion to promote switching away from fossil fuels, and compensate for fossil fuel combustion		Exempt cogeneration fuels and electricity re-marketed from any special fees or restrictions placed on fossil fuel combustion elsewhere		
Licensing and *Certification*					
FISCAL INCENTIVES					
Prices	Use a fossil fuel use fee, tradeable fossil fuel use rights, or a carbon deposit-refund scheme to encourage energy conservation through process redesign, improved energy management and combustion efficiency Impose a fossil fuel-use fee or tradeable coal-use permits on all industry to promote switching away from coal to fuels with lower emissions Encourage recovery and recycling of fossil-fuel-intensive manufactured materials to reduce energy use. Consider deposit-refund systems on all glass and aluminum beverage containers, automobiles, and major appliances Provide fiscal incentives to induce substitution from some fossil fuel-intensive manufactured goods	Promote electricity conservation in process heat applications Consider fossil fuel use fee, tradeable fossil fuel use rights, or deposit-refund to promote switch from fossil fuel-based electricity	Promote more efficient use of electricity by motors	Establish tradeable rights to incorporate CFCs in products to discourage incorporation of CFCs in manufactured products. Impose a fee for CFC emissions Allow incorporation of CFCs in products, but restrict or discourage the subsequent release to atmosphere through a deposit-refund system to encourage proper disposal	Encourage process changes in industries which release CO_2. Provide financial incentives for industrial investments which limit CO_2 release, either through emission fees, through emission fees, tax credits, or subsidies

Table E.8.1. Continued

Policy/Activity	Fossil Fuel Combustion for Process Heat	Electricity Use for Process Heat or Electrolysis	Electricity Use for Motors and Motive Force	Greenhouse Gases as Inputs to Production	Disposing of GHG By-products
Taxation	Alter the corporate tax code to provide incentives for investment in fossil fuel-efficient production processes, and to speed capital turnover in heavy industry		Encourage self- and cogeneration by manufacturers. Provide corporate income tax credits to encourage the necessary capital investment for cogeneration.		Offer tax credits to firms investing in technology to control non-combustion (by-product) CO_2
Subsidies	Support investment in scrap processing equipment				
Direct Expenditures					
INFORMATION/ADVERTISING					
Advertising			Engage in marketing-oriented advertising programs to help commercialize new electric drive technology and substitute processes. Add necessary positive financial inducements.	Use advertising, labeling, or government statements and signals to communicate hazards of CFC release, and promote consumer demand for substitute products.	
Education	Conduct or support informational workshops or energy audits to describe practical waste heat recovery methods and improved energy management, specific to individual industries				
Moral Suasion					Explore foreign trade initiatives which minimize competitive disadvantage to U.S. industries from green-house gas prevention regulations, fees, and restrictions
Signalling					
RESEARCH, DEVELOPMENT, AND DEMONSTRATION					
Public Invention-Support Programs	Promote industrial R&D on basic manufacturing pro-cesses which conserve energy			Encourage further R&D and technology diffusion on benign substitutes for CFCs	Encourage R&D on CO_2 capture from non-combustion processes in the cement and aluminum industry.
Commercialization Education					
Provision of Specialized Information					R&D to develop bio-technology for calcium carbonate production
Demonstrations					

E.9 TRANSPORTATION SECTOR

E.9.1 Overview of Constraints and Opportunities

All individuals, households, firms, and public organizations in the U.S. consume transportation services directly, primarily as a consequence of demand for goods and services that require transportation, but also for recreation. Vehicle operations are the most obvious and by far the most significant source of CO_2 emissions from this sector, but the sector also emits greenhouse gases from the construction of infrastructure (highways, airports), the manufacture of operating equipment (cars, planes), and the production of fuels (the sector runs almost entirely on refined petroleum products). Vehicle operations consumed nearly 28% of the primary energy the nation consumed in 1987. Vehicle operations accounted for 31% of U.S. fossil-fuel consumption, and 63% of its petroleum consumption, while 97% of the energy for vehicle operations was in the form of refined petroleum products. Of the fuel consumed to operate vehicles, automobiles consume 44%, light trucks 13%, other trucks 16%, the remainder being distributed among off-highway heavy equipment, aircraft, waterborne craft, pipelines, and military transport. Conservatively estimated, including energy used to manufacture transportation equipment, produce fuels, and build infrastructure, the sector consumes one third of the nation's primary energy, and a higher proportion of its fossil energy.

The primary greenhouse gases emitted by the sector are carbon dioxide (CO_2) from vehicle operations, from fossil-fuel combustion in making vehicles and the materials for infrastructure, and from the chemical process of making cement; chlorofluorocarbons (CFCs) released from air conditioning systems during operation, maintenance, and vehicle disposal; oxides of nitrogen (NO_x), a possible precursor of nitrous oxide (N_2O), from vehicle operations; and methane (CH_4) leakage from natural gas pipeline systems. The sector also emits significant quantities of carbon monoxide (CO) and volatile organic compounds which contribute to urban air quality problems but only indirectly, if at all, to the greenhouse effect.

The transportation sector has demonstrated the capacity to adapt to large shifts in demand since 1950 and major changes in competition and regulation since 1978. If climate change occurs and causes changes in the economy comparable in scope and pace to those of the past 40 years, the normal decisionmaking practices of the sector appear adequate to enable the sector to adapt. The inland waterway system is the principal exception, and its capacity for adapting depends upon the nature of climate change and on how future investments in its infrastructure are to be financed.

The sector presents a number of opportunities for a prevention strategy. Vehicles now being marketed are more fuel efficient, on average, than those presently in service, so that normal processes of capital turnover will improve fuel efficiency and reduce the rate of CO_2 emissions per trip. Proven technology exists to improve the fuel economy of new vehicles even further in all transportation modes. Some of this technology is likely to be introduced for reasons other than improved fuel economy or reduced greenhouse gas emissions, but government intervention could increase the rate and scope of introduction. Similarly, proven technology would allow vehicles to use alternative fuels, such as alcohols, electricity, natural gas or hydrogen, that emit less CO_2 than petroleum-based fuels. Some fuels with lower greenhouse gas emissions can be used without having to modify vehicle engines. The importance of the US market for foreign automobile manufacturers, and the nation's dominance of commercial aircraft manufacturing, provide opportunities for domestic policies to reduce greenhouse gases from transportation in other countries as well. However, policy options must be tailored carefully to avoid placing domestic vehicle manufacturers at a competitive disadvantage with those overseas.

There are significant differences in the fuel economies of different transportation modes, and therefore some opportunity exists to reduce CO_2 emissions by switching traffic from high-emission modes (e.g., trucks and aircraft) to those with lower emissions (e.g, railroads). Mode switching may be difficult to accomplish on a large scale, however, because people and businesses prefer the convenience, flexibility, speed, and comfort offered by high-emission modes. In addition, present federal policy is to support the provision and expansion of high-emission modes with taxes on users.

Although there are major opportunities for the sector to participate in a prevention strategy, there are significant constraints as well. Decision making is fragmented among five components, most of which involve distinctly different decision makers: infrastructure supply; vehicle supply; fuel supply; use of vehicles to deliver transportation service, and demand for transportation services. This decisionmaking structure permits incremental change but is a barrier to fundamental changes such as switching from petroleum to other fuels (unless the other fuels can be intermixed with petroleum fuels in the pipeline, storage, and distribution system), or developing "smart" highways, where agreement among very different firms is necessary before change will occur.

The inherent mobility of transportation equipment in an integrated, transcontinental economy constrains some kinds of changes. The infrastructure or fuel technologies that support operation of a vehicle must be provided in multiple locations. In addition, emissions (as opposed to fuel use) are difficult to monitor during vehicle use, so that the effectiveness of some policy options can be difficult to assess.

Investments in the sector (infrastructure, vehicle manufacturing plants, fuel supply facilities, and vehicles) are capital intensive and have long lead times and long lifetimes. Quick fixes can be introduced in 3-5 years, but good solutions usually require more time to enter the market and still more time to displace significant shares of existing capital or vehicle stock. For example, half of the highway vehicles sold in one year may still be in use 10-15 years later, and infrastructure can last for decades or centuries.

The greatest obstacle to reducing greenhouse gas emissions from present levels, as opposed to reducing the rate of increase in emissions, is the anticipated increase in demand for transportation services. Highway transportation is projected to double by 2020, and air traffic is projected to increase by 60% by 2000. If projected demand materializes, fuel economy must improve at comparable rates to keep annual emissions from increasing. Major uncertainties exist about how people and businesses make decisions about travel behavior.

There are significant linkages between the transportation sector's emissions of greenhouse gases and other national issues. The sector now consumes more petroleum than the nation produces, and reducing this dependence on imported petroleum either could increase or decrease the sector's emissions, depending upon how the reduction is accomplished. Some alternative fuel systems, such as methanol from coal, could increase emissions, while others, such as compressed natural gas, could reduce them. Biomass-based transportation fuels could reduce emissions to only a fraction of those produced from petroleum fuels. Similarly, urban air quality is another issue linked to the sector's petroleum consumption, as is economic competitiveness. In the latter case, the manufacturing sector is responding to foreign competition by taking measures, such as just-in-time production, that may increase the demand for transportation and create more emissions. On the other hand, a more fuel-efficient transportation system could reduce manufacturing costs and improve competitiveness.

E.9.2 Activities, Policies, and Options

The primary involvement of the transportation sector in national greenhouse gas policies is likely to be in prevention, and most of the policies summarized below deal with prevention. One policy would anticipate possible needs for adaptation in the process of planning investments in transportation infrastructure. The policies are targeted at four major activities in the sector: fuel use, fuel choice, transportation demand, and infrastructure development.

Fuel Use (Section 9.4.1)

Fuel use to operate vehicles is the principal determinant of greenhouse gas emissions from transportation. The efficiency of the vehicles designed and purchased, and the way that people operate vehicles, determine the rate of fuel use per vehicle.

Policy: Promote Design, Production, Marketing, and Purchase of High-Fuel-Economy Vehicles

Improving vehicle fuel economy can reduce growth in petroleum consumption and emissions from vehicle operations. Experience has shown fuel economy standards to be effective in improving fuel economy, and several options can encourage choice of more efficient vehicles once a consumer decides to purchase a vehicle. Higher fuel taxes or prices are unlikely to affect vehicle fuel economy directly, but they would be valuable as a signal and would provide revenue to fund other options.

Option: Raise CAFE standards to require production of more efficient automobiles, and set parallel standards for other types of vehicles

Option: Promote design of high-MPG vehicle designs through tax incentives or direct expenditure on high-MPG prototypes

Option: Use a package of taxes and rebates to increase the rate of replacement of existing vehicles with vehicles that have superior fuel economy

Option: Use a system of taxes and rebates to promote purchase of high-fuel economy vehicles (with minimal effect on capital turnover rates)

Option: Advertising and public information program to improve awareness of differences in fuel economy and promote choice of vehicles with high fuel economy

Option: Direct purchase of high-MPG vehicles to improve fuel economy of government vehicle fleets

Option: Tax petroleum or petroleum fuels to encourage purchase of high-MPG vehicles

Policy: Promote Operation and Maintenance Improvements to Reduce Fuel Emission of Greenhouse Gases

Poor operating and maintenance practices can limit the effectiveness of improvements in vehicle fuel economy. Education and other informational options can reduce fuel consumption, at least in the short term, and requiring more frequent vehicle maintenance also could do so.

Option: Informational incentives to improve operating fuel economy

Option: Require periodic vehicle inspection, maintenance, and certification to reduce emissions

Option: Emission limits to reduce leakage from natural gas transmission and distribution systems

Policy: Promote Vehicle Disposal Practices that Reduce Emissions of Greenhouse Gases

Vehicle disposal releases CFCs from mobile air conditioners, and a deposit-refund system on CFCs could reduce these releases. Setting fuel economy standards for used vehicles could remove vehicles with very low fuel economy from the vehicle fleet, although setting such standards at high levels could make them more costly and less effective.

Option: Introduce a deposit-refund system for CFC refrigerants in mobile air conditioning units

Option: Impose fuel economy standards for used cars to increase scrappage rate of vehicles with very poor fuel economy

Fuel Choice (Section 9.4.2)

Vehicle users regard fuel choice as determined by the vehicles they purchase. With a determined effort, the nation can promote the provision of vehicles that use fuels other than petroleum, and the provision of the alternative fuels to power them. Some alternatives would reduce greenhouse gas emissions, while others would increase them.

Policy: Switch Vehicle Fleets to Fuels with Lower CO_2 Emissions

Several countries have encouraged switching vehicles from petroleum to fuels that yield lower greenhouse gas emissions. Their experiences demonstrate that extensive fuel-switching is possible but that it requires an integrated package of options to alter the pump price of fuels, encourage purchase or retrofitting of vehicles to use alternative fuels, make the alternative fuel available, and ensure high-quality conversion and maintenance. Fuels that can be mixed with current petroleum fuels in pipelines, storage, and distribution would simplify fuel switching, but the technical options for such fuels presently are limited.

Option: Tax petroleum transportation fuels and subsidize alternative fuels (including research and development to reduce alternative fuel costs)

Option: Maintain incentives for alternative-fuel vehicles within CAFE standards

Option: Offer tax credits, lower sales taxes, subsidies, or low-interest loans on vehicle conversions or vehicles that use alternative fuels

Option: Guarantee loans to manufacturers to convert production facilities for alternative-fuel vehicles

Option: Subsidize fuel station construction to improve availability of alternative fuels and thereby encourage their use

Option: Modify regulations facing gas utilities to permit motor vehicle fuel stations in their rate bases

Option: Establish equipment standards and certify mechanics and garages to make conversions to use of the alternative fuel

Policy: Promote Electrification of Railroads to Reduce Emission of Greenhouse Gases

Electrifying railroads would reduce direct emissions of greenhouse gases, but additional information is needed to determine whether the present electricity generating mix would yield a net reduction in emissions. For this reason, options were not considered for this policy. Railroad electrification in other countries has been done with government financial support, and such support would likely be necessary in the U.S. if a policy of railroad electrification were found to be desirable.

Transportation Demand (Section 9.4.3)

Demand for transportation affects greenhouse gas emissions through the choice of available transportation modes, and in the size and anticipated growth of demand. Most of what is understood about transportation demand involves mode choice rather than the decision or need to travel.

Policy: Encourage Substitution of Low-Emission Modes for High-Emission Modes

Present federal policy supports provision and expansion of highway and air transportation modes, which have higher rates of greenhouse gas emissions than competing modes. Efforts to encourage the use of modes with lower emissions have had limited success. Federal support for local mode-switching plans, including standards and expenditures to improve the attractiveness of modes with lower emissions, may be able to improve upon this experience.

Option: Support local efforts to switch travel demand to modes that deliver service with lower emissions

Option: Develop targeted advertising to encourage use of low-emission modes

Option: Direct expenditure or subsidies to develop or improve the performance of low-emission modes

Option: Standards to improve performance of modes with lower emission rates

Policy: Reduce Anticipated Growth in Demand for Transportation (see also Section 11.4.3.2)

Anticipated increases in demand for transportation are likely to offset emission reductions achieved by improving vehicle efficiency or switching to fuels with lower emissions. Before policies can be formulated to reduce demand growth without adversely affecting the economy, research is needed to understand how households and businesses make decisions that affect demand for transportation, and whether new telecommunication technology, other changes in the economy, and anticipated transportation congestion will increase or decrease the rate of growth in demand for transportation services.

Option: Direct expenditures on R&D to understand determinants of demand to allow formulation of policies and options to reduce anticipated rates of growth in demand

Infrastructure Development and Maintenance (Section 9.4.4)

Transportation infrastructure can last for decades, sometimes for centuries, and investments planned today may need to be adapted if the climate changes. Infrastructure also uses large quantities of materials such as steel, asphalt, and cement, whose production releases large amounts CO_2 from chemical processes or energy consumption.

Policy: Anticipate Needs to Adapt to Climate Change in Transportation Infrastructure Planning

Highways, airports, ports, and waterway facilities have long lifetimes and could be affected if climate changes. Planning for new transportation infrastructure in coastal areas, or for inland navigation facilities, can consider the sensitivity of the planned investment to alternative climatic conditions, and modify designs or siting decisions to reduce dependence of the investment upon continuation of present climatic conditions.

Option: Require federal and state agencies to consider vulnerability to climate change when planning major investments in transportation infrastructure

Policy: Promote Infrastructure Designs that Reduce Materials Requirements

Transportation infrastructure uses large quantities of materials whose production requires large amounts of energy or releases large quantities of greenhouse gases. No significant substitutes for these materials appear likely. However, new construction technologies and infrastructure designs may reduce the amount of materials required. Options to promote research, development, and demonstration of innovative approaches could overcome present barriers to innovation in the construction industry.

Option: Direct expenditure on RD&D, or promote limited R&D partnerships in the construction industry, to reduce material use and associated greenhouse gas emissions in infrastructure development

Option: Place a surcharge on construction contracts to support demonstration and certification of innovative designs and methods

Table E.9.1 summarizes the foregoing list of policies by activity and type of instrument that could be employed.

E.9.3 Conclusions

The transportation sector presents substantial challenges to a policy strategy of encouraging the private sector to reduce emissions of greenhouse gases. These challenges arise from the high expectations that individuals and businesses have about the quality of transportation services available to them, the difficulty of coordinating decision making given the fragmented nature of decision making in most of the sector, and the long lead times, long lifetimes, and large capital investments required in the sector. An indicator of the difficulty in changing the transportation sector is the history of public policy to reduce petroleum consumption to improve energy security, an issue that hitherto has had a greater sense of immediacy than climate change. Despite a near doubling of fuel economy for new vehicles since 1974, the sector consumed more petroleum and a greater share of the nation's energy in 1988 than in 1974. The nation's experience with petroleum consumption is useful when considering options to reduce greenhouse gas emissions.

Policy options such as fuel economy and emissions standards, targeted toward the small number of decision makers who make transportation vehicles, have proven much more effective, durable, and politically sustainable than options directed at changing the behavior of the much larger number of highway vehicle users. The long lifetime of transportation vehicles lends durability to the effect of such options (even during the relaxation of standards that has occurred since 1986), but at the same time it prevents rapid reductions in fuel consumption by the entire vehicle fleet. The administration recently announced some tightening of CAFE standards within the limits of current legislation. However, immediate implementation of higher standards would not begin to affect vehicles marketed for 4-5 years, and would not yield significant reductions in fuel consumption and resultant greenhouse gas emissions for another 5-10 years, depending on the level of the standards.

Options to promote carpooling, reduce highway vehicle operating speeds, and promote purchase of higher-fuel-economy vehicles are the most notable examples of policy options directed at changing the behavior of highway-vehicle users. These options can reduce fuel consumption in the short term. However, in so doing they degrade the convenience, flexibility, cost, or speed that people perceive and expect in their transportation services. The effectiveness, durability, and political support of these options have declined since their initial implementation, to the extent that some have been withdrawn entirely. Options requiring periodic inspection of vehicles in some states and urban areas, to improve urban air quality, have proved unpopular for similar reasons.

Energy costs are now a small share of the cost of owning and operating a transportation vehicle in most modes, and the cost of purchasing the vehicle is a much more important consideration in some modes than the cost of fuel. The additional vehicle cost of higher fuel efficiency may outweigh the fuel savings for many commercial and individual purchasers, and increasing the retail price of fuel may have little effect on vehicle choice. A higher fuel tax may have more effect as a signal to other parts of the sector, or as a source of revenue, than as a tool for changing people's behavior. However, the long-term relationship between fuel price and fuel use in the U.S. is not well-understood.

Alternative fuels offer an opportunity for significant reductions in greenhouse gas emissions from the transportation sector. Some of these fuels would require separate distribution networks from presently used petroleum fuels, and substantial vehicle redesign to accommodate differences in the performance of these fuels. These are significant impediments to change. Although the engine technology to use a number of alternative fuels has been introduced commercially abroad, these engine designs may require modification to use the fuel and meet US emission standards for other, non-greenhouse-gas, pollutants. A few alternatives are fungible with present transportation fuels and thus would be much simpler to substitute for petroleum-based fuels, although the ability of several of these to reduce greenhouse gas emissions is technically as well as economically limited at present. A major impediment to the use of all alternative fuels with low greenhouse gas emissions is their high price relative to petroleum fuels. A combination of taxes on petroleum fuels, subsidies to alternative fuels, or research and development to reduce the costs of alternatives over time, will be needed to induce consumers to use alternative fuels even if the fuels and vehicles to use them are otherwise readily available.

A policy strategy of adapting to climate change faces fewer obstacles, because most adaptive measures involve transportation infrastructure which, for most modes, is the responsibility of the public sector. The greatest obstacles to adaptation are likely to be the uncertainty about the rate of climate change and future climate at locations where infrastructure investments are required, and the possible need to change the funding system for the inland waterway transportation system to accommodate large investments during short periods of time.

Table E.9.1. Policies for the transportation sector

Policy/Activity	Fuel Use	Fuel Choice	Transportation Demand	Infrastructure Development
REGULATION				
Controls	Set emission limits on natural gas leakage to promote operation and maintenance improvements	Modify natural gas utility regulations to promote use of natural gas as a transportation fuel	Support local controls on parking and highway lane use to encourage higher vehicle occupancy and lower emissions per trip	Require federal and state agencies to consider vulnerability to climate change when planning transportation
Standards	Raise CAFE standards to promote design, production, marketing, and purchase of high-fuel-economy vehicles Set standards for vehicle maintainability to promote operation and maintenance improvements Impose fuel economy standards for used cars to increase rate of disposal of vehicles that have very low fuel economy	Establish equipment standards for vehicles to promote use of alternative fuels with lower greenhouse gas emissions	Set standards to improve the performance of low-emission modes and, in concert with advertising, make their use more attractive	Develop standards that reduce materials use and associated greenhouse gas emissions in infrastructure development
Licensing and Certification	Require periodic vehicle inspection, maintenance, and certification to promote operation and maintenance improvements	Certify mechanics and garages to service vehicles that use alternative fuels with lower greenhouse gas emissions		Require consideration of vulnerability to climate change in application for permits to develop major infrastructure investments
FISCAL				
Prices	Establish a deposit-refund system for CFC refrigerants in mobile air conditioners			
Taxation	Tax petroleum fuels, establish packages of taxes and rebates or corporate income tax incentives, to promote design, production, marketing, and purchase of high-fuel-economy vehicles	Tax petroleum fuels as part of an integrated package of options to promote use of alternative fuels with lower greenhouse gas emissions	Provide corporate tax incentives for employers to encourage employees to increase vehicle occupancy and reduce emissions	Surcharge on construction contracts to support demonstration and certification of designs and standards that reduce materials use in infrastructure development
Subsidies	Promote design, production, marketing, and purchase of high-fuel-economy vehicles by taxes and rebates	Subsidize a range of sector activities to promote use of alternative fuels with lower greenhouse gas emissions, including R&D	Subsidies to promote development of low-emission modes	
Direct Expenditures	Purchase high-MPG vehicles for government vehicle fleets, and support prototype development to promote design and production of efficient vehicles	R&D to reduce cost of producing alternative fuels with low greenhouse gas emissions	R&D to understand demand for transportation, to permit subsequent formulation of policies to reduce growth in demand	R&D to reduce material use and associated greenhouse gas emissions in infrastructure development

Table E.9.1. Continued

Policy/Activity	Fuel Use	Fuel Choice	Transportation Demand	Infrastructure Development
INFORMATION				
Advertising	Advertising and public information to promote purchase of high-fuel-economy vehicles Promote operation and maintenance improvements		Targeted advertising to promote switching from high- to low-emission modes	
Education	Develop and support courses to promote improvements in vehicle operations that reduce emission of greenhouse gases			Encourage exchange of information on materials reduction through limited R&D partnerships in the construction industry Require federal and state agencies to consider vulnerability to climate change when planning transportation infrastructure
Moral Suasion	Promote operation and maintenance improvements that reduce emission of greenhouse gases		Promote switching from high- to low-emission modes	
Signalling	Require periodic vehicle inspection and maintenance to signal vehicle manufacturers to develop designs that maintain high fuel economy Tax petroleum fuels to signal vehicle manufacturers to design and produce high-fuel-economy vehicles	Promote switching to fuels with lower greenhouse gas emissions, as signal to vehicle manufacturers to produce vehicles that can use such fuels	Increase the tax on petrolem fuels as a signal to local governments to increase efforts to promote use of modes with lower emissions	Require federal and state agencies to consider vulnerability to climate change when planning major investments in transportation infrastructure, as a signal for them to think about the potential need to adapt
RESEARCH, DEVELOPMENT, AND DEMONSTRATION				
Public Invention-Support Programs				
Commercialization Policy				
Provision of Specialized Information				
Demonstrations				Demonstrate designs and methods to reduce use of materials in infrastructure development

E.10 AGRICULTURE AND FORESTRY SECTOR

E.10.1 Overview of Constraints and Opportunities

In no other sector is climate a more determining factor than in agriculture and forestry. The use of energy, production of agricultural inputs, processing of food, natural and anthropogenic oxidation of agricultural products and by-products, and not least the metabolism of all living things, release a variety of greenhouse gases. Of these gases, methane contributes the most to global warming. The sector also includes important sources of carbon dioxide and nitrous oxide as well as of gases that affect atmospheric chemistry, primarily carbon monoxide and nitrogen oxides.

In contrast to the other sectors studied, in which almost all of the carbon dioxide released represents a net addition to the atmosphere, most of the carbon dioxide released by the U.S. agricultural and forestry sector is offset by the amount that agricultural and forest vegetation take up during the growing period. The net releases from the sector are only a small fraction of the annual flux of carbon dioxide through the sector. In contrast to the agricultural and forestry sectors of many developing nations, the entire net release of carbon dioxide by U.S. agriculture derives from the burning of fossil fuels and the production of commercial fertilizers. This is because the standing biomass in the U.S. appears to have been increasing slowly in recent decades and thus now functions as a net carbon sink.

The federal government controls more than 20% of all land in the United States, but the high proportion of land held by private owners suggests that private-sector participation is unavoidable in any greenhouse gas policy that involves the modification of agricultural and silvicultural practices or the conversion of land to different cover types. The primary involvement of the agricultural sector in national greenhouse gas policies is likely to be through mitigation and adaptation. However, many preventive policies that may be targeted at the agricultural and forestry sector are consistent with other important objectives, such as increasing agricultural yields, reducing soil erosion, conserving fossil fuels, and decreasing the demand for land resources. Policies are listed below for the agricultural sector in five major activities: livestock production, cropland management, forestry, agrochemicals and irrigation, and contingency preparedness.

Prevalent agricultural practices have led to an alarming depletion of soil and water resources and to environmental degradation in many areas of the United States. These problems raise concerns about the sustainability of agricultural production, even if climate remains unchanged. In addition, they have reduced the resiliency of the sector to disturbances and diminished the likelihood of successful adaptation to altered climatic conditions.

Current U.S. agricultural and forestry policies have considerable influence on the release of greenhouse gases by the sector. Revision of some of these policies and adoption of new policies could (1) reduce such emissions as part of a strategy to prevent climate change, (2) turn the sector into a major sink for atmospheric carbon as part of a mitigation strategy, and/or (3) prepare the sector for changed climatic conditions as part of an adaptation strategy.

E.10.2 Activities, Policies, and Options

Livestock Production (Section 10.4.1)

Livestock operations are a major source of methane, which is one of the principal greenhouse gases. Livestock production requires more land in the contiguous United States than any other single purpose. Many greenhouse gas policies that have a land-use aspect may be enhanced or counteracted by policies regarding livestock operations.

Policy: Require Better Waste Management Practices to Reduce Methane Emissions From Livestock Production

Proper handling of manure can reduce methane emissions drastically. Improved waste management also reduces water pollution and hence the release of methane from sediment.

Option: Regulate large confined-livestock operations and set waste management standards

Policy: Reduce Livestock Production Entailing High Emissions of Greenhouse Gases

Emissions could be reduced by eliminating overproduction of livestock and feed and by replacing high-emission livestock products with products involving lower emissions.

Option: Revise import controls and agricultural price-support policies to reduce overproduction in the United States

Option: Use advertising and affirmative disclosure to reduce demand for meat from production with high greenhouse gas emissions

Policy: Encourage Increased Reliance on Grazing, Hay, and Silage from Closely Grown Small Grains as an Alternative to Feed from Row Crops

Energy and agrochemicals could be conserved by reducing the proportion of corn in livestock feeds. In addition, land would be freed for bio-fuel production or carbon storage.

Option: Disseminate information, establish demonstration projects, and provide consulting services

Policy: Encourage Livestock Research in Breeding, Hormones, and Vaccines that Will Reduce the Feed Requirements to Produce Meat and Dairy Products

More efficient conversion of feed to milk and meat indirectly diminishes the amount of energy and fertilizer needed to produce feed.

Option: Use R&D incentives and dissemination of information to accelerate the development of feed-conserving livestock

Cropland Management and Agricultural Practices (Section 10.4.2)

Better cropland management and improved practices can increase yields, reduce the need for inputs that cause emissions of greenhouse gases, and make land available for growing biomass crops or for raising trees to store carbon.

Policy: Discourage the Burning of Biomass in Smoldering Fires

The use of fire to clean up after logging and agricultural practices that entail the in-situ burning of crop residues, grasses, or shrubs constitutes an important source of greenhouse gases.

Option: Disseminate information and offer free consulting on alternatives to burning, use moral suasion and signalling to speed adoption of new practices, regulate fire use if necessary

Policy: Promote Crop Production Practices that Require Less Land, Conserve Energy, and Reduce Greenhouse Gas Emissions

Field operations presently are the second largest category of energy use in agriculture. Practices such as conservation tillage and the use of advanced machinery promise substantial savings in energy and agrochemicals.

Option: Offer reduced-interest loans and low-cost crop insurance to farmers who want to switch to conservation tillage

Option: Use fiscal incentives, R&D and technological awareness strategies, and demonstrations to accelerate the development of smart machines

Option: Fund and coordinate research to understand the impact of tillage practices, crop varieties, crop residues, agrochemical use, soil moisture, and other factors on greenhouse gas emissions

Policy: Encourage the Conversion of Unneeded Cropland to Woodland Vegetation

Incentives in the Conservation Reserve Program (CRP) seem inadequate to meet its goals for tree planting. An even larger acreage might be considered for afforestation in a strategy of storing carbon to prevent or limit global warming.

Option: Regulate land use

Option: Increase CRP incentives for tree planting

Option: Encourage more tree planting by local jurisdictions and private land owners to protect or establish carbon stores

Policy: Encourage Production and Consumption of Tree Crops

Fruit and nut trees store carbon and tend to require less fertilizer than field crops. Nuts are rich in proteins and can contribute to a diet that depends less on meat. Woods from these trees could displace demand for tropical hardwoods.

Option: Use the cooperative extension programs to promote the planting of fruit and nut trees and the consumption of their crops and wood products

Policy: Encourage Production of Agricultural Energy Crops

Government programs could help to overcome the commercialization, cost, and acceptance barriers to the production of bio energy from field crops, grasses, and aquatic vegetation.

Option: Use tax incentives, subsidies, and demonstration projects to attract private sector investment and farmer interest

Policy: Encourage Increased Energy Self-Sufficiency of Farms

Farms have a great diversity of potential energy sources. Most of them would be difficult to commercialize, but some could be harnessed fairly easily for the farm's own energy needs.

Option: Use tax incentives, dissemination of information, and demonstration projects to stimulate farmer interest

Policy: Encourage Diversification of Farm Operations

Farms that specialize in one or two products are most susceptible to suffering heavily if climate changes. Greater diversity in species and varieties will increase resiliency to short- and long-term disturbances.

Option: Use technology transfer programs to encourage and support farmers who are willing to diversify

Option: Revise federal programs and tax laws to replace incentives that favor monoculture with incentives that encourage diversification

Forestry (Section 10.4.3)

The expansion and acceleration of tree growing appears to be the only feasible way of removing large amounts of carbon dioxide from the atmosphere. About 60% of the forestland in the contiguous United States is privately owned.

Policy: Encourage Accelerated Tree Growing in the Private and Public Sectors

Fiscal incentives are important because of the long investment time frames in forestry. Parties responsible for anthropogenic greenhouse gas emissions could be urged or required to offset their emissions by planting trees or contributing to silvicultural programs.

Option: Require producers of anthropogenic greenhouse gases to compensate for their emissions through forest offset programs

Option: Use tax incentives, subsidies, moral suasion, and signalling to encourage greater private investment in tree growing

Option: Contract private tree-growing services to reforest and afforest

Option: Educate community groups and local jurisdictions about forest benefits

Option: Revise federal policies that control timber sales on federal land

Policy: Encourage Investment in Energy Production from Fast-Growing Trees as an Alternative Source of Energy

Production of fast-growing trees has high potential for reducing dependence on fossil fuels. Government incentives would stimulate private-investor interest.

Option: Use tax incentives, subsidies, and R&D incentives to lower the costs and risks of woody biomass production for forestry companies and investors

Policy: Promote Investment in Long-Term Forest Production and in Durable Goods Made from Wood

Substantial amounts of carbon can be stored through long-term forestry and use of durable wood products.

Option: Use import restrictions to encourage domestic hardwood production and to reduce tropical deforestation

Option: Use Public Service Announcements and other mass media programs to advertise long-term wood products such as lumber and furniture to extend carbon storage

Policy: Encourage Activities that Will Increase the Resiliency of Forests to Climatic Disturbances

Diversity of species and genetic diversity within species are the best insurance against future calamity and may turn out to be essential for adapting to environmental change in a timely manner.

Option: Preserve diverse forest ecosystems

Option: Provide fiscal incentives for preservation of diverse forests and for the use of more diverse stock for new plantations

Option: Promote research and extension services in mixed-stand forestry

Agrochemicals and Irrigation (Section 10.4.4)

Chemicals and irrigation account for nearly one half of the energy used in agriculture. More effective use of agrochemicals and water could increase yields and thus release land and water for other purposes. ·

Policy: Encourage Conservation of Agrochemicals and Irrigation Water

Information, training, and consulting services combined with accurate monitoring of actual conditions and reliable forecasts of imminent conditions could conserve substantial amounts of agrochemicals and irrigation water.

Option: Disseminate information, provide management assistance, and offer more training opportunities

Option: Review and reduce subsidies and other programs that encourage inefficient use of irrigation water

Option: Assure the quality of soil tests and fertilizer recommendations and encourage their increased use

Option: Establish an agricultural monitoring service to support day-to-day decision making in farm management

Policy: Encourage Conservation of Energy in the Production of Ammonia

Most commercial nitrogen fertilizers are derived from ammonia. The average ammonia plant uses 17,000 Btu of natural gas to produce one pound of ammonia. Best present technology requires only 12,500 Btu.

Option: Use investment tax credits or targeted subsidies to encourage ammonia producers to upgrade or replace energy-inefficient production facilities

Policy: Encourage the Development of Alternative Hydrogen Donors for Ammonia Production

Natural gas is needed in ammonia production primarily as a source of hydrogen. The carbon remaining from the natural gas is emitted directly or indirectly to the atmosphere as carbon dioxide. Research and development is needed to find biological or photochemical hydrogen donors.

Option: Use direct expenditures and technology diffusion incentives to accelerate R&D on biological and photochemical hydrogen donors

Policy: Encourage Increased Use of On-Farm Sources of Nitrogen

Better manure management and the use of nitrogen-fixing plants in crop rotations and pasture can reduce the need for commercial nitrogen fertilizers significantly.

Option: Disseminate better information on the benefits and economics of increased nitrogen self-sufficiency and provide free consulting to interested farmers

Policy: Encourage Development and Adoption of Low-Input Agricultural and Silvicultural Production Methods

More research and special support programs for farmers who are willing to adopt low-input farming practices could eventually lead to a large reduction in the sector's use of energy- and greenhouse-gas-intensive inputs. Low-input agriculture has been shown to be as profitable as conventional agriculture, but a temporary reduction in profitability during switch-over, referred to as the "conversion trough," may occur for several years.

Option: Increase federal support for research on low-input farming

Option: Offer more educational opportunities in sustainable agriculture and forestry

Option: Use fiscal incentives to help farmers through the conversion trough while switching to low-input farming

Policy: Encourage the Development of Crop Varieties that Require Less Agrochemicals and Water

In the future, biotechnology and plant genetics may permit the engineering of plants that produce high yields, yet require less fertilizer, are less susceptible to moisture stress, and/or more tolerant of saline conditions.

Option: Use tax incentives, subsidies, R&D and technology awareness strategies, and demonstrations to stimulate interest and investment by biotechnology and seed companies

Contingency Preparedness (Section 10.4.5)

Adapting plants and animals to changed climatic conditions is very time consuming. If adaptation becomes necessary, its success will depend heavily on the availability of suitable genetic material and prior research and development.

Policy: Preserve Genetic Diversity

Preservation of genetic diversity and the identification of plants and animals specifically adapted to a variety of climate conditions one day may prevent economic hardship and food shortages.

Option: Fund a program of enhanced evaluation and classification of seed in the National Seed Storage Laboratory

Option: Duplicate the National Seed Storage Laboratory

Option: Establish a national repository for genetic material from livestock

Option: Field test varieties of crop species under different climatic conditions

Policy: Promote Activities in Biotechnology, Selection, and Breeding that Will Make Plant and Animal Species More Adaptive to Changing Climate Conditions

A solid base of knowledge and an experienced core of personnel is as important to contingency preparedness as the availability of suitable genetic resources.

Option: Fund programs in basic research and the training of skilled personnel in plant and animal physiology, endocrinology, enzyme science, soil/plant interactions, and agroecology to provide the basis for adaptation technologies

Policy: Encourage Agroforestry

Agroforestry plantations have the potential to store significant amounts of carbon and to produce tree crops and timber or pulp in addition to agricultural crops or forage. Agroforestry systems may be less vulnerable to climatic change than the management systems that presently dominate the sector.

Option: Fund and coordinate research and demonstration projects

Policy: Reduce Water Consumption by Urban Areas

Restructuring water distribution systems for higher efficiency takes much time but may be the only way of building a reserve capacity to maintain agricultural production if the climate gets drier.

Table E.10.1 summarizes the foregoing list of policies by activity and type of instrument that could be employed.

Table E.10.1. Policies for the agricultural sector

Policy/Activity	Livestock Production	Cropland Management	Forestry	Agrochemicals and Irrigation	Contingency Preparedness
REGULATION					
Controls	Regulate large confined-livestock operations to reduce methane emissions. Revise import controls to reduce over-production of livestock and feed	Regulate use of smoldering fires. Institute land-use controls to protect forests, prevent cropping of unsuitable land, and encourage afforestation. Revise CRP rules to encourage more tree planting	Require forest offsets for CO_2 emissions. Import restrictions to encourage domestic hardwood production and reduce tropical deforestation		Restructure urban water distribution systems in arid areas to build a reserve capacity for maintaining agricultural production
Standards	Develop waste management standards for livestock operations to reduce methane emissions			Institute standards for soil testing and fertilizer recommendations	
Licensing and Certification					
FISCAL INCENTIVES					
Prices	Revise price-support policies to reduce over-production of livestock and feed	Revise commodity price-support programs to encourage low-input practices and farm diversification			
Taxation		Incentives for growing and processing agricultural energy crops, on-farm energy generation, and developers/early adopters of smart machines	Incentives for investments in tree growing and for energy production from fast-growing trees	Incentives for ammonia producers to replace energy-inefficient facilities, farmers switching to low-input methods, and developers of crop varieties that require less agrochemicals and water	
Subsidies		Reduced-interest loans for farmers who switch to conservation tillage. Subsidies to stimulate production and conversion of energy crops	Subsidies to simulate private investment in accelerated tree growing and to reduce risks for investors in biomass energy projects	Subsidize energy-efficient equipment for ammonia production, research on low-input farming, conversion to low-input practices, and development of crop varieties that require less agrochemicals and water	
		Low-cost crop insurance for farmers to switch to conservation tillage. Fund research on factors influencing agricultural and silvicultural emissions. Increase CRP incentives for tree planting		Review and reduce subsidies that encourage inefficient use of irrigation water	
Direct Expenditures	Support waste management	Fund R&D into agricultural energy crops	Fund R&D into wood energy crops and mixed-stand forestry	Fund R&D on alternative hydrogen donors for ammonia production	Fund additional evaluation and classification of seed in the National Seed Storage Laboratory and basic research and training in agroforestry and in adapting plants and animals to climate change. Field test varieties of crop species under different climatic conditions

Table E.10.1. Continued

Policy/Activity	Livestock Production	Cropland Management	Forestry	Agrochemicals and Irrigation	Contingency Preparedness
INFORMATION					
Advertising	Use advertising and labeling to reduce demand for meat produced with high greenhouse gas emissions	Convert cropland to woodland, via technology awareness program on smart machines. Promote tree planting by local jurisdictions and private landowners	Promote accelerated tree growing and carbon storage, educate community groups and local jurisdictions about forest benefits	Promote integrated pest management and soil testing. Publicize the benefits and economics of increased use of on-farm nitrogen sources	
Education	Disseminate information about low greenhouse-gas alternatives to feed from row crops	Information about on-farm energy generation and alternatives to burning in agriculture and forestry. Encourage tree planting as an educational activity. Promote planting of crop trees and consumption of fruits and nuts. Provide information and training on low-input practices and farm diversification	Accelerated tree growing: contract with private companies to reforest and afforest. Educate community groups and local jurisdictions about forest benefits. Provide training in the management of uneven-age, mixed forests	Provide information and training opportunities in efficient use of chemicals and irrigation management. Provide instruction in management techniques and practices that maximize on-farm nitrogen production	Species adaptation: Build a core of professionals experienced in the disciplines that are important for adapting plants and animals to climate change
Moral Suasion		To limit burning of biomass, discourage use of burning in agriculture, and urge adoption of alternative practices	Urge timber companies to invest more in reforestation, to accelerate tree growing		
Signalling		Establish guidelines on use of controlled fires in agriculture and forestry, to limit biomass burning	Publicly set goals for reforestation to replace carbon store lost in logging operations		
RESEARCH, DEVELOPMENT, AND DEMONSTRATION					
Public Invention-Support Programs	Accelerate research to develop feed-conserving livestock, and reduce feed requirements	Promote energy efficient farming, support development of smart machines that conserve energy and agrochemicals. Encourage development of biomass-energy systems	Encourage development of biomass-energy systems. Promote use of long-term wood products to extend carbon storage	Stimulate R&D in alternative hydrogen donors for ammonia production, crop varieties that require less agrochemicals and water, and low-input agricultural and silvicultural practices	Encourage initiatives in species adaptation and agroforestry
Commercialization Education		Facilitate commercialization of smart machines	Energy trees: accelerate adoption of biomass-energy technologies. Facilitate marketing of products from mixed-stand forestry Offer consulting on preservation of genetic diversity and mixed-stand forestry	Promote adoption of alternative hydrogen donors for ammonia	Offer programs for agroforestry entrepreneurs

Table E.10.1. Continued

Policy/Activity	Livestock Production	Cropland Management	Forestry	Agrochemicals and Irrigation	Contingency Preparedness
Provision of Specialized Information	Provide consulting services about alternatives to feed from row crops. Information exchange about R&D on feed-conserving livestock	Assist in reducing burning in agriculture and forestry. Coordinate research on the factors that influence agricultural and silvicultural emissions. Offer free consulting on low-input agriculture and farm diversification		Management assistance to improve efficiency of agrochemical use and irrigation. Free consulting on increasing nitrogen self-sufficiency. Establish an agricultural monitoring service to support management decisions in the sector	
Demonstrations	Low greenhouse-gas alternatives to feed from row crops	Show how smart machines can conserve energy and agrochemicals. Demonstration farms and plants for production and conversion of energy crops, energy self-sufficiency, and low-input practices, and high farm diversity	Management of SRIC forestry, conversion plants, and uneven-age, mixed-stand forestry	Demonstrate ammonia manufacturing with alternative hydrogen donors. Field trials of crop varieties that require less agrochemicals and water	Demonstrations of regionally adapted agroforestry

E.10.3 Conclusions

Changes in precipitation patterns and increased frequency of extreme weather conditions may turn out to be more damaging to agriculture and forestry than higher average temperatures. Specialization in agriculture and forestry has led to a dramatic loss of species diversity in our cultural landscapes and to a continent-wide loss of genetic diversity. Both types of diversity are crucial to successful adaptation to any kind of environmental change. Therefore, soil and water conservation, a shift to low-input practices, and diversification of agriculture and forestry are most important elements in any strategy of preparing for the uncertainties of a changed climate. Besides increasing the resiliency of the sector to changing climatic conditions, these activities also increase resiliency to episodic, short-term weather extremes and market disturbances, and not least, they have numerous other economic, environmental, health, and social benefits.

Livestock production is important to the greenhouse gas issue because of its methane emissions. Research and development could reduce feed requirements, and improved waste management practices could reduce methane emissions from current production. Elimination of subsidies that encourage overproduction would be politically difficult and, if accomplished, could stimulate imports, with even worse consequences for greenhouse gas emissions.

Mitigation is best served by transfers of land from annual crop production, pastures, and rangelands to perennial grasses or forests and by active programs to reforest and afforest large land areas. Biomass applications can reduce the dependency on fossil fuels and offer farmers and livestock producers an alternative to current land uses, an important point given the history of national policies to maintain income for this sector. A wide range of policies, spanning regulatory and fiscal incentives, information policies, and RD&D activities, could be used to convert cropland to woodland, encourage agro-energy crops and agroforestry, and improve energy efficiency of farms.

Forests, because they offer a greater carbon-storage capacity than either grassland or cropland, represent an important opportunity for any mitigation strategy. A range of policies could be used to encourage tree growing, but these policies would need to be accompanied by policies to increase the demand for wood products, particularly of long-lived products that sequester the carbon longer.

Chemicals and irrigation account for nearly half the energy used in agriculture, and policies targeted at these inputs could make a significant contribution to reductions in greenhouse gas emissions from agriculture. Fiscal instruments could encourage conservation of both water and chemical fertilizers, but both of these policies would be assisted by educational programs. Encouraging the use of on-farm nitrogen sources could reduce the demand for purchased nitrogen fertilizers.

Adaptation of animal and plant species to manage climatic changes may play an important role in a long-term national response. However, the current state of knowledge in biotechnology, breeding, and selection makes policy formation for this objective speculative at best. Government initiatives could accelerate the rate of scientific discovery, although the practical results for agricultural applications are highly uncertain. R&D efforts could bring new varieties that require less water and agrochemicals, and tax incentives could stimulate more interest in investment by biotechnology and seed companies.

If it is desired to influence the atmospheric concentration of greenhouse gases through policies targeted at the agricultural and forestry sector, review and adaptation of existing policies needs to accompany the adoption of new policies. Traditionally used price supports, target prices, and crop insurance programs have tended to encourage overproduction and cropping on highly erodible soils. As a consequence, energy-intensive, greenhouse gas releasing inputs and practices may have been used to an unnecessary extent. Production controls and quotas, conservation requirements, and set-aside programs are removing some land from crop production, resulting in higher crop prices and possibly delaying adoption of new crops and practices with lower greenhouse gas emissions. Clearly, revisions and coordination of current policies could yield reductions in greenhouse gas emissions from the agricultural sector.

E.11 RESIDENTIAL AND COMMERCIAL SECTOR

E.11.1 Overview of Constraints and Opportunities

The combined residential and commercial sector is a major consumer of energy in the United States. The annual energy consumption of residential buildings is on the order of 8.9 quads, while nonmanufacturing business establishments consume approximately 6.1 quads each year. Factoring in the efficiency of electric generating plants and transmission and distribution losses brings the totals closer to 15.0 quads and 11.4 quads, or 19% and 14% of total U.S. energy consumption in 1985. Constraints and opportunities for greenhouse gas policies arise from the composition of the sector and its likely growth patterns as well as from existing technologies and foreseeable technological improvements.

Because most of the energy consumed by the residential and commercial sector comes from the burning of fossil fuels, the contribution of residential and commercial energy consumption to greenhouse gas emissions is apparent. In addition to its electricity consumption, the direct contribution of the sector to U.S. CO_2 emissions has been estimated at 13%, for a total contribution of 31% when electricity use is included.

If the potential for CO_2 reduction is judged by the amount of energy used, the greatest potential among residential users lies with owner-occupied single family residences: 64.1% of residential units are owner-occupied and use 61% of residential energy. Space heating claims 40% of the energy consumed in the residential sector, water heating 17%, air conditioning 8%, and lighting, appliances and other purposes claiming the remaining 35%. In the commercial sector, food and health care are the most energy-intensive establishments, accounting for 8.9% and 8.5% of sectoral energy use but only 4.4% and 4.0% of total floorspace. Offices account for 20.2% of sectoral energy use and 16.5% of square footage. As in the residential sector, space heating predominates in the commercial sector, but lighting is the next most dominant use, followed by air-conditioning and ventilation.

The most obvious opportunities to reduce greenhouse gas emissions through improvements in end-use efficiency are in space and water heating in the residential sector and in space heating, air conditioning, and lighting in the commercial sector. The best available new HVAC equipment is between 50 and 100 per cent more efficient than existing installations. The efficiencies of commercial and residential lighting can vary substantially, as can the amount of daylight available to reduce the demand for artificial light. Average household energy use lighting could be reduced by 30 to 40 per cent if the most heavily used incandescent lamps were replaced by the new compact fluorescents currently on the market. There may be resistance to such changes in the residential sector due to cost, color rendition, and the fact that these lamps are slow to start. Implementing a combination of cost effective options in commercial buildings could reduce lighting energy requirements there by more than 50 per cent. Additional opportunities may be provided by technologies for space and water heating that result in no or low net CO_2 emissions, e.g., passive solar heating, solar water heaters, and woodstoves using replaceable biomass.

Community design and the weatherproofing of structures also play a role in determining how much energy is consumed to regulate the indoor environment. Structures are weatherproofed by insulating opaque surfaces such as ceilings and walls, by increasing the thermal resistance of windows, and by restricting the infiltration of outside air with caulking and weatherstripping. New buildings can be weatherproofed during construction, and existing buildings can be retrofitted with energy-saving measures. The mix of weatherproofing measures varies substantially among different geographic regions of the United States. Community design also affects the willingness of individuals to substitute mass transit for private vehicle transportation for a wide range of trips.

In addition to its direct and indirect contribution to CO_2 emissions, the commercial and residential sector also accounts for a substantial portion of the CFCs used in the United States for refrigeration, air conditioning (including centrifugal chillers which are used for space conditioning in large commercial buildings), and insulation. Approximately half of all new water heaters use fully halogenated CFC foams in their insulated jackets. While heat pumps result in fewer CO_2 emissions because of their higher efficiencies, they use as a working fluid CFC22, which is only about one-tenth as effective as an ozone depletor as the fully-halogenated CFCs like CFC11 or 12, but is a more potent greenhouse gas than either CO_2 or methane.

Over the next quarter century, it is anticipated that the residential and commercial components of this sector will experience contrasting growth patterns in demand for energy services. Residential building growth is likely to be slow because of a combination of low population growth, reductions in the rate of household formation, and market saturation. Slowed growth in demand may reduce opportunities for rapid penetration of new, energy-efficient technologies because of the depressed rate of capital turnover in the marketplace. Measures to stimulate early retirement of existing HVAC, domestic appliances, and equipment for water heating and lighting may be appropriate. By contrast, the commercial sector is expected to be a major growth sector of the U.S. economy, and its demand for energy is likely to expand accordingly. This expansion need not increase greenhouse gas emissions if energy-efficient technologies are chosen along with low-emitting fuels.

The reduction of energy requirements through efficiency improvements in the residential and commercial sectors offers several opportunities for policies that could be implemented in the near term to reduce the rate of growth in greenhouse gas emissions. Space heating and cooling are significant contributors to energy use in commercial and residential buildings, while lighting is a significant commercial use and water heating a significant residential use. Natural gas, which generates lower carbon emissions per unit of energy than other fossil fuels, is used widely for space heating and water heating. However, the opportunities for gas to displace much existing electrical space and water heating are constrained by a variety of factors, including lack of existing infrastructure, limited domestic supplies and existing or potential demands in other sectors (e.g., use as transportation fuel and fertilizer feedstock). Furthermore, the near-term conversion of end users to gas would require a considerable policy effort that would have to be reversed in a few years as alternative sources of electrical energy become available that are environmentally preferable to natural gas.

E.11.2 Activities, Policies, and Options

Policies and options in three major activity areas for the sector–maintenance and upgrading of existing buildings, design and construction of new buildings, and community design–are listed below.

Maintenance and Upgrade of Existing Residential and Commercial Buildings (Section 11.4.1)

Capital turnover in both building and appliance stocks is slow. Tightening the shells of existing buildings can produce major energy savings and reductions in greenhouse gas emissions, but improving appliance efficiency requires increasing the rate of equipment turnover.

Policy: Improve the Energy Efficiency of the Shells of Existing Residential and Commercial Buildings

Improvements in the energy efficiency of existing residential and commercial building shells can reduce heating and cooling energy requirements substantially, thereby reducing CO_2 emissions from electricity generation and other energy consumption. These improvements could be encouraged with personal and corporate income tax credits, as well as with selective subsidies and information programs.

Option: Establish a personal/corporate income tax credit for major weatherization expenses

Option: Require and/or subsidize energy audits to provide information on the benefits of weatherization and equipment retrofits to residential and commercial decision makers

Option: Use a combination of R&D, rebates and tax credits to increase building conservation activities performed by energy service companies, especially one-stop retrofits

Option: Provide weatherization assistance to low-income citizens

Policy: Promote the Manufacture and Purchase of High-Efficiency Equipment and Appliances

Energy efficiency of equipment and appliances has increased between 5 and 80% since 1973, and room exists for further improvements in some appliances. Further improvements in efficiency and consumer choices of more efficient models could be encouraged with tax credits, appliance labeling, and raising of appliance efficiency standards.

Option: Improve the efficiency of existing equipment by raising or setting appliance efficiency standards

Option: Promote the selection of energy efficient equipment through excise taxes

Option: Improve labeling on appliances and require Home Energy Rating Systems

Policy: Retrieve CFCs from Appliances Prior to Disposal

Collection of CFCs in existing appliances could be facilitated by offering to pay for CFCs returned from retired equipment. CFCs from new appliances could be recovered upon their retirement with a deposit-refund system.

Option: Provide a financial reward for retrieval of CFCs from equipment and appliances upon retirement

Option: Provide a deposit-refund system for new equipment purchases

Design and Construction of New Buildings (Section 11.4.2)

Improvements in unit design and in both construction techniques and materials can yield substantial energy savings and reductions in greenhouse gas emissions.

Policy: Promote Energy Efficiency in the Design and Construction of New Residential and Commercial Buildings

Designing new buildings to be more energy efficient could save considerable energy. Tightening of federal equipment standards and local building codes could encourage this, as could tax incentives and mortgage terms favoring energy-efficient buildings. Educational programs and demonstrations of new design technologies also would be important.

Option: Continue to tighten federal equipment standards and encourage states to tighten building codes for new construction

Option: Promote performance-based hookup fees for new buildings

Option: Support the establishment of a Building Energy Research Institute to conduct RD&D for building energy efficiency and disseminate information to the construction industry

Option: Provide tax incentives or mortgage benefits for small and/or high occupancy units such as townhouses, and for buildings using alternative (solar) or low-energy (earth-sheltered) heating and cooling sources

Option: Encourage design and construction of energy-efficient units, including passive solar/earth-sheltered building design through direct prizes, education, and demonstrations

Policy: Eliminate Insulating Materials Containing CFCs From New Buildings

Reduction of CFCs from this source could be accomplished by a combination of bans on CFC use in new material and R&D on alternative, moisture-resistant foams.

Option: Supplement existing CFC regulation with a ban on CFC foams for wall and roof insulation

Option: Promote research, development, and market penetration of non-CFC moisture-resistant foams

Community Design (Section 11.4.3)

The design of a community's infrastructure can affect energy use in individual buildings as well as in transportation.

Policy: Promote Structure Placement, Street Layout and Setback Requirements, and Landscaping to Improve Energy Efficiency of Communities

Structure placement, street layout, and landscaping all can reduce cooling energy requirements substantially. Efficient designs could be encouraged by modifying zoning requirements, subsidies for urban tree planting, and targeted advertising and educational programs.

Option: Encourage state and local governments to take account of energy efficiency in establishing zoning laws and subdivision regulations affecting layout and setback requirements and landscaping for new residential and commercial development

Option: Use subsidies and moral suasion to encourage tree planting in urban areas for shade and cooling by evapotranspiration

Option: Award prizes to builders, designers, and architects to promote exemplary projects for design of energy-efficient communities

Option: Targeted advertising and education to increase availability of information to architects, planners, and builders on the relationship between greenhouse gases and community development

Policy: Encourage Community Design to Limit Demand for Private Vehicle Use

Presently, community design favors private vehicle use over mass transit for many trip purposes. Combinations of zoning modifications and property taxes could encourage new development to make mass transit more convenient than it is currently.

Option: Modify zoning laws to include facility location requirements

Option: Use property taxes to encourage community developers to site new residential and commercial facilities to minimize demand for transportation

Table E.11.1 summarizes the foregoing list of policies by activity and type of instrument that could be employed.

E.11.3 Conclusions

In determining where to focus efforts in the residential and commercial sector, the obvious course is to concentrate on improving the efficiency of electric end uses. A substantial portion of electric generating capacity is coal fired, and reducing the consumption of electrical energy will lead to greater reductions in greenhouse gases than would reduction in energy used directly for heating purposes. Because of the flexibility that electricity permits, electricity consumption is likely to continue to grow even with improvements in energy efficiency, but without improvements in efficiency, both electricity consumption and greenhouse gas emissions are likely to grow even more rapidly.

There remains a significant potential for reducing energy by tightening existing building shells. Single-family dwellings and commercial buildings are particularly good targets. The mandatory audit programs of the recent past may be redesigned to provide more flexibility and better incentives for utilities to operate them and may be effectively reinstituted.

More importantly, it appears that efficiency standards for new construction and renovation may be particularly effective in reducing energy use. Standards are likely to be more effective than other methods of encouraging builders and contractors to use energy-efficient materials and designs. Experience with the California and Florida buildings standards appears encouraging, while past attempts at informational and fiscal incentives have yielded mixed results, suggesting high levels of decisionmaker sensitivity. Since the residential and commercial sector is characterized by a very large number of dispersed and diverse decision makers, standards, although a relatively crude instrument, would seem to offer the greatest chance of success. However, they may be politically controversial.

Standards also seem to be the most reliable instruments for influencing the end-use efficiency of this sector. Efficiency standards already have been established for some types of residential appliances. These standards can be met with the best of existing technology. Technological improvements to existing appliances are likely to improve efficiencies further by the mid-1990s. While these new designs may be more costly than existing designs, upgrading the national efficiency standards in the 1990s could increase the rate at which these technologies penetrate the market. The imposition and upgrading of lighting standards in the commercial sector are likely to have similar effects. Efficiency standards appear to be among the most effective policy options for encouraging the rapid adoption of efficient technologies.

Design is underemphasized as an energy efficiency resource because technology often is easier to implement. Building design is less tangible than technology and requires more attention to institutions and organizations, yet it appears that policies that encourage the implementation of good lighting design, most likely through standards, could result in energy savings as large as, or larger than, savings from the adoption of new lighting technologies. Community design standards also are likely to be important in encouraging attention to albedo, which can influence cooling energy consumption significantly in urban areas. The widespread introduction of trees and other plantings into the urban landscape through subsidies, tax incentives, educational policies, and moral suasion may reduce energy requirements also.

Zoning and property tax options could encourage people to use mass transit in some situations for which they now prefer private vehicles.

It is not clear that these policies will result in an absolute reduction in the production of greenhouse gases from current levels. However, they may reduce significantly the rate of growth in greenhouse gas production.

Table E.11.1. Policies for the residential and commercial sector

Policy	Maintenance and Upgrade of Existing Buildings	Design and Construction of New Buildings	Community Design
REGULATION			
Controls		Ban CFC foams for wall and roof insulation	
Standards	Promote high efficiency equipment/appliances through efficiency standards	Promote energy-efficient design and construction through equipment standards and building codes	Promote structure placement through zoning laws and subdivision regulations to improve energy efficiency. Raise albedo through standards for materials, landscaping, etc. Reduce private vehicle use by modifying zoning laws to include facility location requirements
FISCAL INCENTIVES			
Prices	Institute deposit-refund scheme for CFCs in New equipment		
Taxation	Improve energy efficiency of existing building shells though tax credits for weatherization measures and for energy service companies especially those providing one-stop retrofits Promote selection of high-efficiency equipment/appliances through excise taxes	Promote energy-efficient design and construction through tax/mortgage incentives for small/high-occupancy units and use of solar/low-energy heating/cooling sources	Use property taxes to encourage siting of residential and commercial facilities to reduce demand for private vehicle use
Subsidies	Improve energy efficiency of existing building shells by subsidizing audits and weatherization assistance to low-income citizens Provide reward for retrieval of CFCs from old equipment	Support establishment of Building Energy Research Institute	Support tree planting in urban areas for shade and evapotranspirative cooling

Table E.11.1. Continued

Policy	Maintenance and Upgrade of Existing Buildings	Design and Construction of New Buildings	Community Design
Direct Expenditures		Offer prizes to promote design and construction of energy-efficient units	Offer prizes to builders, designers, and architects to promote exemplary projects
INFORMATION			
Advertising	Promote selection of energy-efficient appliances through labeling requirements		Use targeted advertising to key decision makers on relationship between climate change and community design
Education		Promote education for designers and builders on energy efficiency	Increase information to architects and planners on relationship between climate change and community design
Moral Suasion			Promote urban afforestation for shade and evapotranspirative cooling
Signalling			
RESEARCH, DEVELOPMENT, AND DEMONSTRATIONS			
Public-Invention-Support Programs		Promote RD&D for non-CFC moisture-resistant foams	
Commercialization Education			
Provision of Specialized Information	Improve energy efficiency of existing building shells through statutory energy audits and assistance to energy service companies	Disseminate information to construction industry through a Building Energy Research Institute	
	Promote selection of high-efficiency equipment through Home Energy Rating Systems		
Demonstrations		Promote demonstration of efficient designs for builders and consumers	

E.12 CONSIDERATIONS FOR ASSEMBLING A POLICY PACKAGE FOR PRIVATE SECTOR RESPONSE TO POSSIBLE GLOBAL WARMING

E.12.1 Introduction

Large reductions of greenhouse gas emissions of the order and timing advocated in the conference statements of several international meetings (Toronto 1988, Villach-Bellagio 1988) and certain bills before the Congress cannot be achieved through the actions of any single sector of the U.S. economy or be met through any single policy aimed at the private sector of the economy as a whole. Combinations of policies, therefore, would be required both within and among sectors if significant reductions are to be achieved in U.S. greenhouse gas emissions. It would be a challenging technical and political task to select an appropriate mix of policies to achieve reduction goals at a cost tolerable to the private sector and consumers without unacceptably constraining other vital policy goals such as international economic competitiveness and, since coal is such an important part of the U.S. energy resource base, national energy security. This chapter addresses some of the major technical issues that would have to be faced in selecting any policy package for greenhouse gas reductions.

The microanalytic approach adopted in this report supports the aim of tailoring policies to specific activities in the economy. However, the sectors interact with each other by using each other's products and by purchasing energy from common energy markets. Policies targeted to one sector, therefore, may affect another, reinforcing or countering their intended effect on the first. There may be interactive effects between policy instruments aimed at the same sector. For example, certain demand-side policy instruments designed to reduce consumption of a good may discourage its manufacturer from increasing capital turnover to install production equipment that would contribute to reduced greenhouse gas emissions.

Not all interactions and linkages are potentially disadvantageous. Many manufacturers of basic materials also own energy resources. A policy package that adversely affects the competitiveness of one part of the firm may be offset by providing benefits to another.

In some cases, policies may be effective only if combined in packages. For example, information programs alone are known to effect only short-term behavioral changes. Fiscal incentives may not be effective if the information costs to potential beneficiaries are too high.

There may be self-limiting effects for policies designed to stimulate demand for fuels or technologies that have lower greenhouse gas emissions than coal. If the demand for the preferred substitute grows faster than the supply, then the market price may rise to the point where coal, once again, becomes the economically preferred fuel, thus defeating the goal of greenhouse gas emissions reduction.

A focus on the sectors misses the economic, political, and cultural milieu in which they operate, and makes it difficult to identify issues common to all sectors. These issues include tradeoffs between stability and flexibility; the timing of policy initiation, given lags in response, if they are desired to produce effects before the extended term; the implications of U.S. policies for international leadership and trade; and the need for additional information about emissions and the technical, economic, and institutional performance of the many policy options identified as being of potential value in the preceding chapters.

As a society we have extensive experience in modeling scenarios for future economic events by changing simultaneously quite large numbers of variables by specific quantities.

Macroeconomic models exist that are capable of predicting the effects of changes in the rates of various taxes, prices of inputs, and rules of exchange. These are used frequently to model the impacts of proposed changes in public policy and are very familiar tools. However, almost invariably it is the case that the changes to be modeled are incremental changes to the existing economy. The policies under consideration frequently are extensions of existing instruments or alternatives to them. The selection of variables to adjust in the models seldom is problematic. Furthermore, such models are not well-suited to include the effects of informational and demonstrational instruments.

The very selection of policy options for quantitative analysis under the conditions of high technical uncertainty and high societal stakes that pertain in the case of global warming appears to be a problem of quite unusual complexity, even before the stage of fixing values for those options is reached. The selection of candidate options from the menu provided in this report for incorporation in quantitative models is likely initially to take us beyond existing experience with such models and their results.

In addition to these technical problems of selecting policy packages and quantifying them for computer analysis, we also need to consider the technical problems of public acceptability of policy options individually and in packages. Even the decision to respond to warnings of global climate change and the strength and timing of that decision may be affected by institutional factors that require some examination.

E.12.2 Policy Strategies and Institutions

Individual policy options may prove controversial, especially when an industry, sector, or consumers are asked to absorb the financial effects of internalizing the costs of environmental harm. While technical analysis can predict the size of these costs and assess their implications for society as a whole, the determination of where they should fall is a complex political choice involving conflicting, often incompatible, conceptions of distributive justice.

As the number of sectors affected by a policy package increases, and as more instruments are employed, the number of parties experiencing negative impacts from the policy is likely to increase. As we move from the expression of goals to means to achieve them, the costs of the solutions will become clear and may provoke widespread societal conflict, almost certainly exceeding that already experienced over nuclear power (even if only because increased use of nuclear power is likely to be only one important option to reduce greenhouse gas emissions). There are important precedents indicating that public willingness to act on problems before a decision is made may change to opposition for the same course of action as the costs of solutions become clear.

It is vital in developing policy packages aimed at global climate change to recognize that there is a persistent conflict in America between advocates of limited growth, steady-state economics, and regulatory preservation of the environment, on the one hand, and those advocating unrestricted economic growth and a laissez-faire approach to the market for determining when the natural environment should be preserved or modified. In the debate over climate change these general philosophies have informed the preventivist and adaptivist approaches respectively. This dichotomy is not a superficial or transitory phenomenon, but a profound component of American culture and political life. Unless real meaning can be given to the notion of sustainable development or there is uncontentious sustained evidence of climate-change impacts, a real possibility exists that the current appearance of societal consensus in favor of urgent action on climate change may fragment as the costs to various sectors of society become clear. Even if the resulting economic disruption and societal conflict can be overcome, such conflict carries its own costs which must be considered part of the true social cost of a policy package, just as emissions impacts must be considered part of the full cost of economic activities.

Sound decision making about climate-change policy may depend as much on the process used for the selection and implementation of policy packages as upon the predicted outcomes of those policies. Success will not be guaranteed, but the probability of achieving desirable outcomes almost certainly will be enhanced by the adoption of a participatory decision process that emphasizes inclusion of many parties in negotiation rather than one that leads to exclusionary conflict over legitimacy.

Scientific and social constraints on decision making may make it difficult to produce a comprehensive climate-change policy package that would be acceptable to all relevant stakeholders. The addition of these constraints to the prospect of coalitions forming in opposition to a comprehensive U.S. climate policy may overwhelm the prospects for such a policy package.

There is an alternative to the formulation of a rational optimizing policy strategy that may prove to be equally rational in circumstances where risks, costs, benefits and distributional effects cannot be predicted reliably. Policies designed to fix a specific problem depend on high levels of predictability. Where predictability is limited, it makes sense to learn from the behavior of ecosystems and orientate policy more towards developing the flexible capacity to deal with surprises as they arise than towards laying specific plans for each imaginable contingency, or investing heavily in measures to prevent consequences that may not have proved unacceptable anyway.

The policy options presented in this report are capable of being combined according to a different principle, specifically, in order to enhance the ability of the private sector to engage in trial and error modifications to its activities, to enhance social learning about the greenhouse gas issue, and develop the capability of various key players to respond flexibly to new information and changing circumstances as they arise. The purpose is to respond to the practical challenges of potential global warming without generating unacceptable costs of conflict over policies.

Such a strategy of modifying institutional capabilities to deal with rapid social and environmental change is not entirely incompatible with aiming at particular technical goals. However, the issue of developing institutional responsiveness currently receives relatively little attention in discussions of the issue and is given prominence here for that reason. If policy approaches prove ineffective, then changing direction is critical, but in the absence of new scientific findings on the significance of the problem, and without demonstrating the ineffectiveness or excessive cost of a policy approach, it would probably be dynamically efficient if policy approaches can maintain sustainability of response.

E.12.3 Additional Criteria for Policy Packages

At least eight general criteria can be identified as having relevance to the selection of policy options for inclusion in any policy package. These are:

- Complementarity of instruments
- Balance between flexibility and consistency
- True social cost effectiveness
- Elapsed time between initiation and effect

- Demonstrability of effectiveness
- Linkage to other goals
- International implications
- Information needs.

E.12.3.1 Complementarity of Instruments

Any policy aimed at a specific sector will change the competitive position of that sector with respect to others that might produce close substitutes for its goods. For example, any increase in the costs of aluminum due to a carbon tax on process heat fuel could reduce the ability of the aluminum industry to compete with suppliers of substitute materials such as plastics. In some cases, there also may be direct implications for greenhouse gas emissions. Increases in utility rates (stimulated by regulation or a carbon tax) could stimulate an increase in household combustion of wood for heating. The creation of winners and losers from targeted policies in the private sector would have to be balanced against the higher effectiveness that is claimed for targeted incentives as opposed to macroeconomic policy. (Here we address only the issue of direct winners and losers from a policy or set of policies; not the more general issue of winners and losers from climate change.) Macroeconomic policies would produce different winners and losers, but these may be even more difficult to identify in advance.

E.12.3.2 Balance Between Flexibility and Consistency

A primary goal of any policy package should be to encourage key sectors of the economy to develop their capacities for flexible responsiveness to changing circumstances and new information. However, institutional flexibility to respond to an unpredictable variable or set of variables, such as climate change, depends largely on the confidence of decision makers that other external variables remain stable. For example, the willingness of a firm to turn over old polluting capital stock may be dampened if there is high uncertainty about how the replacement technology will be regulated.

E.12.3.3 True Social Cost Effectiveness

As is well known, economic efficiency requires that all costs of an activity be incorporated in the price of the activity. Frequently, environmental costs are not incorporated leading to failure to allocate environmental resources efficiently. Similarly, the costs of conflict over policy actions should be considered as part of the true social costs of proposed solutions.

E.12.3.4 Elapsed Time Between Initiation and Effect

The time frames used to screen and evaluate the policies outlined in Chapters 3 through 7 are those within which a policy may achieve effectiveness in meeting its goals. However, many of the policies identified as being of long- to extended-term usefulness may have to be initiated in the very near future. For example, due to the long lead times required to develop some alternative technologies, medium- to long-term R&D needs to be initiated or stepped up without delay. In other cases technologies are well-proven but the long lifetime of existing vehicles and housing capital stocks requires immediate decisions if they are to have significant effect before the extended term.

E.12.3.5 Demonstrability of Effectiveness

Sustainability of support for policy approaches, i.e., packages of policy options, will require some evidence for the public that they are having the intended effect at reasonable costs. Practically, it is difficult to derive indicators of policy effectiveness, especially when multiple policy instruments are pursued simultaneously and their effect is so broadly felt in the economy. It is virtually impossible to demonstrate empirically that the failure of an uncertain anticipated event to occur is actually due to a preventive policy and not to other factors.

E.12.3.6 Linkage to Other Goals

The case is made frequently that measures designed to reduce greenhouse gas emissions make sense on their own merits and ought to be pursued regardless of potential climate change. For example, it is argued that energy efficiency enhances industrial competitiveness, planting trees may help serve various ends such as preserving watersheds or reducing cooling energy needs.

Whatever the merits of particular linkages, it certainly behooves us to think strategically about the issue and not to isolate climate policy goals from other environmental and societal goals. However, calls for strategic thinking usually extend the military metaphor to advocate a comprehensive full-frontal assault on greenhouse gas emissions and deforestation. It is worth considering whether the superior flexibility and sustainability of guerilla warfare does not provide a more appropriate metaphor for thinking about a climate policy package or packages.

E.12.3.7 International Implications

The U.S. has an opportunity to establish world leadership in developing global climate policies through a number of means. First is moral example. A serious policy effort by the United States is bound to receive widespread attention in the industrialized world, leading to popular pressure from the publics of other countries on their own governments and industries.

American leadership also will be felt by foreign manufacturers producing for the large U.S. market. When technological innovations are required for goods to be admitted to American markets, foreign manufacturers tend to add them to models produced for other markets. In this way American standards influence foreign manufactured goods consumed far from U.S. markets.

A third opportunity to influence worldwide standards and practices is through goods and technologies produced domestically to be compatible with the goals of reducing greenhouse gas emissions or adapting to changing climate regimes.

E.12.3.8 Information Needs

Quantitative information about greenhouse gas emissions by industrial sector needs to be assembled so that assessments may be conducted of the economic efficiency of policy alternatives considered here. Existing vulnerability assessments of all sectors, such as those included in the EPA Effects Report, need to be supplemented. In particular there is a pressing need for adequate evaluations of the ability of key institutions to respond to information about the greenhouse effect with all of its inherent uncertainties. Special account needs to be taken of the ability of private sector institutions to adapt to global warming.

E.12.4 The Private Sector Policy Compendium and Other DOE Congressional Reports

The foregoing discussion has identified some of the technical difficulties in assembling policy packages directed at climate change. Several conclusions can be drawn. First, the difficulties with constructing a policy package which will meet certain minimal criteria are more than informational. Technical assessments of policy criteria present methodological difficulties and, therefore, difficulties in quantitatively ranking policy packages. Successful application of policy packages may depend crucially on non-analytical issues. As noted above, policymaking process issues are important.

While quantitative information may not be able to provide precise evaluation of policy packages or perhaps even ranking of combinations, it may nevertheless provide one screening tool for discarding particularly unattractive packages. Model evaluation of policy options can identify some of the linkages to other social goals and interactions between policy options. Such assessment methods can contribute to identifying those options which are complementary in effect.

DOE is conducting a quantitative analysis of policy options as part of the Congressional studies project. One of those studies has a Congressional mandate to evaluate policy options and packages which would achieve large emissions reductions, i.e., 20% in a 5-10 year period and 50% in a 15-20 year period. The purpose of that analysis is to identify the interactions between policies and possible policy packages which might be subjected usefully to more detailed analysis and evaluation in the future. That study will be available in early 1990. It also should provide useful insights into appropriate ways to evaluate policy combinations.

APPENDIX TO EXECUTIVE SUMMARY

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