ALTENER PROGRAMME

BIOMASS EVENT IN FINLAND

1st - 5th September 1997

Hotel Laajavuori, Jyväskylä, Finland

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BIOMASS EVENT IN FINLAND

1st - 5th September 1997
Hotel Laajavuori, Jyväskylä, Finland

Mr. Ian Higham, ETSU
United Kingdom

AFB-NETT

1
AFB-NETT is an ALTENER funded project lead by ETSU.

2
AFB-NETT began in 1995 with 11 partner nations. There are now 14 of EU nations, represented by the organisations shown. Each of these organisations acts as focus for bringing together industry players within their country, and through the network, across Europe.

The project's initial aim was to bring together the whole biomass supply and use chain, not just within countries, but across Europe. This objective is being met and more than 280 people take part in the network now.

3
Since inception, the project's aims have evolved. It started, as said, with bringing together the whole Biomass chain. The purpose at this stage was to examine why biomass development often seemed so difficult and activities were focused on barriers and solutions. As we progressed the aim moved to implementation of solutions identified and developing action. This now takes the form of working on issues which currently hinder trade, bringing together expertise from across Europe to try and demonstrate that biomass energy does work and developing events which bring together industry players in order to facilitate business opportunities (business fora, study tours etc). Here in Finland, there are several examples of successful biomass projects form which we can all learn. Indeed, we here this week to learn form Finnish experience, exchange ideas and make business contacts and this event is a good example of how the network can facilitate action.

4
All of this embodied in the 4 objectives:

- detection and promotion of business opportunities;
- transfer of knowledge and experience;
- promotion of collaboration and co-ordination;
- implementation of National and European Strategies.

Don't want to spend time on all of these because only some of these elements are directly relevant to this meeting today. I will therefore concentrate on effort in area of business opportunities, transfer of knowledge and strategy.

5
I have mentioned that effort is focused on showing operational biomass systems, and looking at issues blocking trade. Effort in 1997 split in to 4 main activities, 2 based on market sectors and 2 based on improving market conditions. They are :

- Co-Combustion and Gasification - here in Finland
- Small Scale and District Heat - led by Austria with a meeting in 2 weeks time (18-19th September).
- Financial Incentives - led by the Netherlands, who carried out some work last year on demand side, and this year are looking at supply side. The activity should show what incentives available in EU, how opportunities can be developed by mixing incentives, and give policy ideas about what incentives are a success.
- Wood fuel and emissions standards - led by the UK with a workshop here this afternoon.

6

Business Opportunities

There are many examples of things done in the name of this objective. The workshops mentioned above are included because they bring together people like you to see operational plant. This may not result in contracts being signed here in Finland this week but it may happen as a result of your trip here. Series of study tours, equipment demonstrations, personnel exchanges have also been organised. Visit to Elmia Wood, Sweden, earlier this year, by a group from the UK, resulted in orders for new equipment and others may follow.

At last year's 9th EU Biomass Conference, in Copenhagen, evening business fora were held by the Waste and AFB networks. About 75 people attended, some came just for these business fora and gaining any participation after a long day in conference must be considered a success It is hard to quantify actual contracts signed, but we had positive feedback from many delegates. This was effectively a business "dating" meeting. People attended arranged meetings to discuss business opportunities. Similar fora organised alongside this event and will be running this afternoon and tomorrow afternoon.

VTT and CBE have formally agreed to co-operate in:
- the exchange of scientific, technical and technological information and regional data;
- generating and participating in projects of mutual interest.

7

Transfer of Knowledge

This can take several forms. The network has been focus for a series of questions. Participants gather information and circulate it (eg National Biomass Programme information), participants can ask specific questions of other participants or use network to feed queries from industry to other players. The network has been used by ALTENER to gather information on wide range of topics - most recent was likely contribution biomass can make to 2010 targets.

Information has also been circulated on 3rd party finance, use of peat as a fuel, emission legislation etc.

8

Strategy

All nations looked at the market status for biomass in their country and used the national industry to help them define:

- where they wanted the market to be at a given time in the future;
- what was needed to achieve that.

This was defined as the "national strategy". In addition to this work, each country outlined what they felt was needed at European level to help them achieve that. A document was produced outlining 14 national and 14 European strategies for Biomass. This information was submitted to the ALTENER evaluators to help them look to the future needs of the ALTENER programme, and through them to the council of ministers. In addition was used to feedback views on the EU Green Paper.

The strategies were also to be used at national level as part of lobbying national decision makers to help shape national policy. It is important for this information to be available and to be used to help shape local action, national needs and European policy.

9

Through developing the strategy, a series of solutions to overcome barriers to biomass development were identified. Some were fairly obvious, some a bit more "off the wall". examples of these measures are:

- CAP reform;
- fiscal measures
- integration - all policy departments need to act together - Agriculture, Environment etc
- policy to make biomass attractive
- EDF - Provide European Development Fund with money to allow loans to be made to biomass projects at a lower interest rate - immediately bring down risk and make projects feasible. Projects can then be costed and developed at full commercial rates and not as experimental demonstration.

10

Finally, an important part of AFB-NETT is communication. A Web site has been set up for this purpose.

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Ms. Olivia Matos,
Biomass Centre for Energy-CBE
Portugal

ALTENER PROGRAMME

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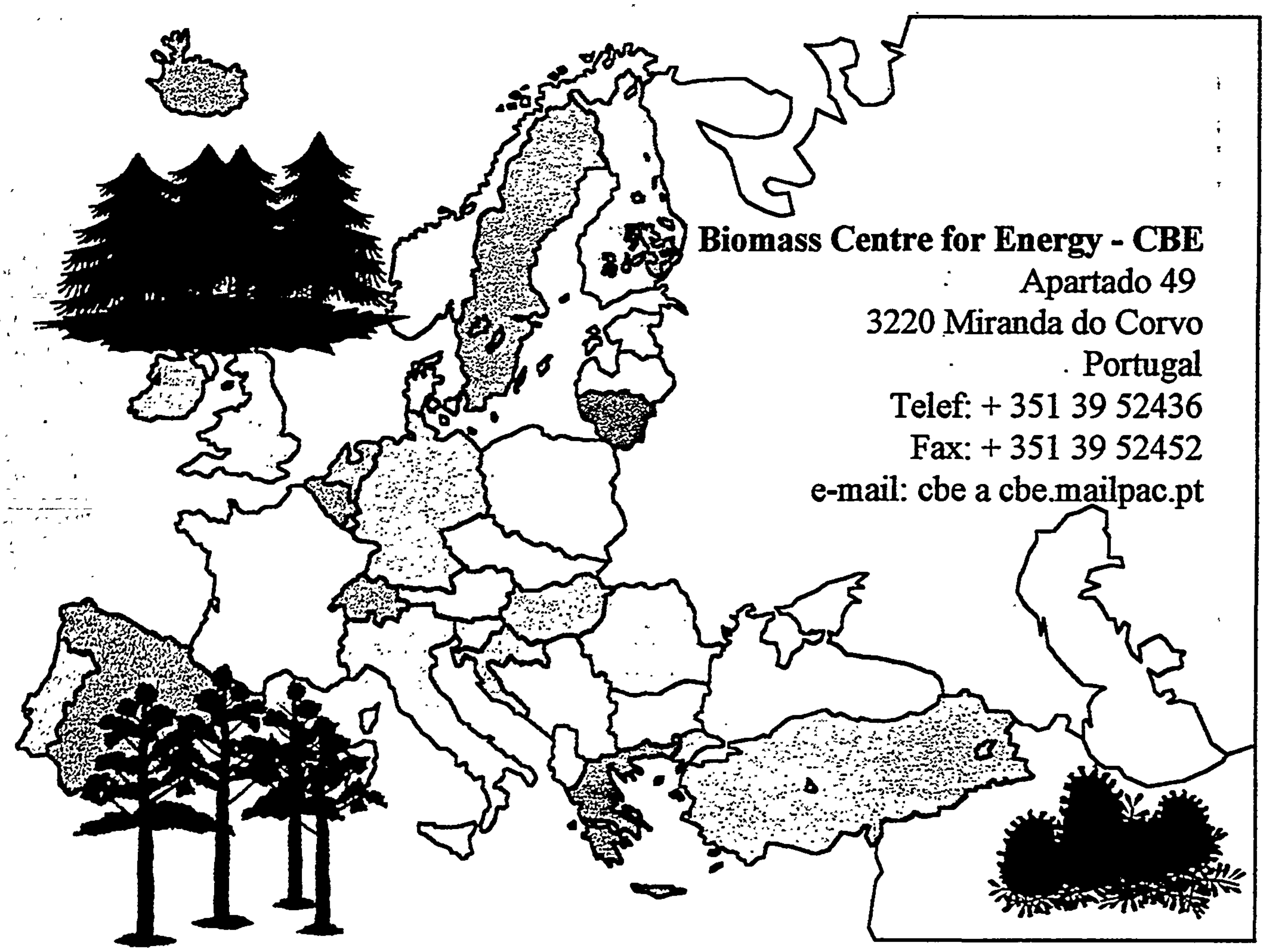
WOOD WASTE IN EUROPE

Olívia Matos, Rui Ribeiro

Workshop
FUEL PRODUCTION AND HANDLING SESSION
2nd September, 1997



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WOOD WASTE IN EUROPE

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1 ABSTRACT

The energy policy of the EC, as well as most of member states points to a sizeable increase of energy production based on renewable resources, namely biomass -wood, wood residues, agricultural residues, energy crops including SRF, organic sludges, solid residues, etc.-. Most recent goals indicate a desirable duplication of today's percentage by 2010.

The reasons for this interest, besides diversification of sources, less dependence on imported fuels, use of endogenous resources, expected decrease of fossil fuel reserves, use of available land, additional employment and income for rural communities, etc., are related to important environmental benefits namely in terms of emissions of hot house gases.

Wood waste, resulting from forest operations -cleaning, cultural and final cuts-, and from wood based industries, constitute a special important resource by reason of quantity and availability. In addition to this they do not require additional land use and the removal is beneficial.

In the run-up to the coming December's 1997 "Climate Change Summit" in Kioto, there is mounting pressure on companies to plan on carbon cuts.

2 ACTUAL SCENARIO

2.1 EMISSIONS

The European Round Table of Industrialists (ERT) has suggested 12 measures to reduce greenhouse gas (GHG) emissions, and says that the measures could cut EU GHG emissions by 29 percent by 2010.

1. Encourage government and industry co-operation through voluntary action
2. *Offer incentives for renewable energy technologies*
3. *Promote energy-efficient technologies such as cogeneration.*
4. Use Joint Implementation (trading emission quotas)
5. Encourage technology co-operation with developing countries
6. Develop tradable permits to facilitate use of superior technologies
7. Research safe treatment of nuclear waste, to allow use of nuclear power
8. Educate the public about energy use and climate change
9. Promote management of energy efficiency and provide incentives
10. *Develop carbon dioxide sinks such as sustainable forestry*

11.Include other gases that may contribute to Global Warming.

In spite of all this, world wide carbon emissions from the burning of fossil fuels climbed to 6.5 billion tons in 1996, reaching a new high for the second year in a row. This increase of just over 2.8% reflects a steady rise in emissions in the developing world, a slowing of growth in industrial countries and a flattening of steep declines in the former Eastern block. The most significant rise is taking place in China, with double digit , coal driven economic growth, has boosted emissions more than 27 percent since 1990 [1].
At the same time dependence on fossil fuels has reached new highs, close to 8 billion TOE in 1996 providing over 80 percent of total worlds commercial energy. Use of oil reached about 3.3 billion tons and will probably rise from 20 to 30% before reaching the maximum between 2005 and 2015 (according to Worldwatch Institute).

2.2 STEPS

One of the most important steps to take, is to rationalise use of energy and increase use of clean forms of energy.
According to the TOMORROW issue of July-August 1997 [1], Professor Friedrich Schmidt-Bleek, Vice President of the Wupertal Institute and President of the Factor 10 Club, says that "Within one generation, nations can achieve a ten-fold increase in the efficiency with which they use energy, *natural resources* and materials" and that is "technically feasible, it's environmentally and ecologically feasible, it's absolutely necessary". This belief rests on the emerging of a more efficient and more sustainable new economy, where the share of manufacturing is dwindling.
According to Professor Schmidt-Bleek *"Pricing of goods and services should fully reflect the environmental impact and scarcity of resources. Subsidies that are detrimental to sustainable development must gradually be reduced and abolished. Taxation on resource and energy consumption must gradually increase".*
These orientations are in line with the conclusions of the strategy document presented at the end of Phase II of the "Waste for Energy Nett" [2], and we do believe that use of waste for energy and, specifically, wood waste for energy deserves strong support.

2.3 NEEDS

The need for an increased use of wood waste, resulting from the objective of use duplication by 2010, will open new business opportunities for land owners and forest operators, equipment manufacturers and power producers and will be beneficial to the people.
The increase of demand, initially helped by effective incentives, will lead to better opportunities, help the development of more efficient equipment, and open a new and economically attractive market of renewable energy solutions.
In the case we are more familiar with, the Portuguese situation, and according to recent statements by the Secretary of State for Energy, our present share of 6% shall be increased at least to 12% by 2010 and one of the supporting incentives will be a special tariff for biomass based electricity sold to the national grid by independent producers.

Also according with the Secretary of State we have possibilities to reach that goal even before 2010.
One 10 MW power station to burn forest waste and industrial wood wastes is going to be built in the Center Area of the country, and the two MSW incinerators to be built in Lisbon and Oporto will help the increased participation of renewables as energy sources.

3. FOREST RESOURCES

The European countries have committed themselves to the sustainable management and conservation of forest resources. The need for protection of forests was recognised at ministerial level at the Strasbourg Conference in December 1990, that decided on a follow up programme of six Resolutions including one on the "Decentralised European Data Bank on Forest Fires".
Since the Helsinki conference, most countries have formulated national forest policies that include strong interest on afforestation.

According to the Progress Report of the Ministerial Conference on the Protection of Forests in Europe, of 1996 [3], following data are available:

- Total forest area increased from 145.0 million hectares in 1960/1970 to 149.3 million hectares in 1990
- The area of other wooded land, during the same period, increased from 31.1 million hectares to 45.5 million hectares.
- Data for 1990 shows Sweden, Finland and France with over 28 million , 23 million and 16 million hectares of forest and other wooded land, the countries with biggest forest area

3.1 FIRES

Forest damage by fire, most important in southern climates has affected particularly Portugal, 137,000 ha in 1990, the only country with a negative balance between annual total growth and removals for the same year [3].
The removal of wastes is an important way to protect forests.

4. LAWS, PROGRAMMES, INCENTIVES

All the countries that participate on the Network, as other European Countries, promote, by diversified ways, the use of renewable energies and, specifically, biomass.
These incentives are of different nature and reflect special local conditions and government policies.
The recently presented Green Paper - "Energy for the Future: Renewable Sources of Energy" [4] tries to define a comprehensive police strategy to boost the contribution of renewable energy sources in the Community's energy balance, increasing it from 6 to 12%.

In order to achieve this objective the Commission suggests the following strategy:

- to strengthen the co-operation between member states on renewables, given mainly the variation of use between them
- to reinforce the policies to promote development of renewables, namely by the internalisation of external costs
- to reinforce monitoring procedures allowing progress towards meeting the target..

5 PRESENT SITUATION

5.1 COMMUNITY POLICY FOR RENEWABLES. ENERGY 2010

According to the Green Paper - "Energy for the Future: Renewable Sources of Energy" [4], it is recognised that today, renewable energy sources are unequally and insufficiently exploited, with the exploitation level reflecting different weather and geographic conditions as well as differences on politics in the different countries.
At the present economic conditions the cost of exploitation of some renewable energies constitutes a serious obstacle to use, namely due to the fact that the costs of fossil fuels do not reflect all the costs, and namely the costs to society caused by environmental damage.

It is generally accepted that the present state of the energetic sector is responsible for most of the climatic changes and damage to environment, and this situation (we have to remember, for instances, the consequences of an increase of the ocean level), should be of the greatest concern.

On the other hand the Community is dependent, to a large extent, on outside sources to supply it's energy needs, and renewable energies constitute a safe source of dependable endogenous supply and are environmentally friendlier.
In the case of biomass, the incineration of MSW with energy recovery; not denying the priority to reuse and recycling, can help solve the problems of final destination and energy.

For all these reasons the increased use of renewables has been an important Commission concern and has been object of different programmes, namely the ALTENER.

Data for 1994 shows that at Community level (15 States) renewables account for 5.4% of total energy against 5.0% for 1990. This represents 60 million toe or about 16% of the technical available potential of 400 million toe.

As said before, the costs, although showing a continuous decrease, are still a strong barrier to increased use and it's reduction is an essential action to be taken by technical development of harvesting and converting processes.

Several studies have been made to determine the participation of renewables in the total energy use namely the "Europe of Energy in 2000" with four scenarios that have resulted in percentages of renewables changing from 7.4% to 9%, showing that the assumed goals imposes drastic measures of promotion and support.

Based on the FORUM scenario, three supplementary scenarios were studied, with one of them, the "Best Practice Policies" resulting in 12.5% in 2010.

The interest on renewables is connected with many advantages of use, namely:

- environmental
- security of supply
- expected competitively
- regional development

During previous phases of the Waste for Energy project [5] we have identified the different barriers to development and proposed a strategy to overcome these barriers.

The goal set for 2010 requires a firm determination to develop these strategies, mainly in relation with:

- ♦ liberalisation of the electricity market
- ♦ internalisation of external costs
- ♦ support to R&D and pilot projects in the most promising areas-gasification, combined cycles, co-combustion, pyrolisis
- ♦ information interchange and collaboration.

Once that the hydro electricity takes an appreciable share and has a limited potential to increase, most efforts have to be developed in the other forms.
We are particularly interested in biomass, specially forest based biomass-resulting from forest operations or from activities of wood working or processing industries-.
In the analysis of the market we have however to have in mind that, most of the technical conditions related with conversion of these biomass residues to energy are common to other lignocelulosic biomass materials, namely wood from SRF, and agricultural residues. On the other hand wood residues from forest operations or from wood based industries can be used in co-combustion with other woody residues, coal or peat, MSW, and to substitute part of other fuels in cement kilns, etc.
Gas from gasification of wood residues can be burnt in existing boilers alone or in co-combustion with other fuels, used in gas turbines alone or enriched with natural gas, in internal combustion engines, etc..

5.2 PRESENT USE OF RENEWABLES

According to data given in the Green Paper [4], renewable energy contribution for 1994 and for 15 European countries is given on the following chart:

Table 1 - Renewable Energy in Europe - 1994 [ktoe]

Country	Total renewables	% of total	Total biomass	MSW	Other (1)	Forest Biomass
Germany	6254.1	1.9	4374.4	1065.6	354.6	2954.2
Greece	1727.1	7.2	1397.7	0	0.7	1397.0
Belgium	411.6	0.8	372.1	126.8	17.3	226.0
Denmark	1306.5	7.0	1200.4	455.2	31.7	713.5
France	16564.0	7.2	9534.5	804.2	129.6	8600.7
Spain	6015.6	6.2	3876.1	115.8	22.5	3737.8
Ireland	237.3	2.2	162.4	0	2.5	159.9
Italy	9827.4	6.4	3666.9	265.1	135.9	3265.9
Luxembourg	47.9	1.3	40,5	24.3	0	16.2
Netherlands	965.3	1.4	933.2	472.6	107.2	353.4
Austria	6179.0	24.1	3108.5	0	0	3108.5
Portugal	3171.2	17.5	2229.4	0	2.7	2226.7
Finland	5554.0	19.3	4536.3	0	0	4536.3 (2)
Sweden	11668.8	24.6	6586.5	0	0	6586.5
United Kingdom	1430.4	0.6	957.8	244.2	340.0	273.6

Source: Green Paper [4]
(1) - Other includes: biofuels, biogas, sludges, agricultural residues, food industries
(2) - Peat included (?)

Renewables are very important in Austria (biomass and hydro), Sweden (hydro and biomass), Finland (biomass) and Portugal (biomass and hydro).
For the above countries, total renewables correspond to about 71,000 k toe, with total biomass accounting for 43,000 k toe, with 2,160 k toe of MSW and 37,000 k toe of forest based biomass.

Part of the increased use for 2010 can come from additional incineration of MSW and other equivalent industrial wastes Some countries, like Portugal, have recently decided on using incineration as a good alternative for waste treatment.

Biomass offers also a very good potential for growth, not only by a more efficient use of existing resources but from increased efforts of afforestation and use of available land (such as set aside) for energy crops like SRF.

6 2010 GOALS

Taking data for 1994 as a base, total renewables in 2010 would reach about 140,000 k toe, still away from the technical potential of 400,000 k toe.

For the purposes of this paper we will only consider the part related with forest based residues that include residues resulting from forest operations -cleaning, cultural cuts, final cuts, and residues from wood based industries including pulp and board industries.
According with data recently collected increase of these could reach close to 16,000 k toe, about 44% of duplication of present, but this could eventually reach close to the objective when missing information is available.
The analysis of different answers show that additional woody biomass could be produced by SRF.

In any case the announced policy opens a wide market for biomass for energy projects and involves forest owners and operators, the whole range of forest management equipment manufacturers (plantation, harvesting, preparation, transportation), conversion equipment industries, etc.
The increase of market opportunities and a progressive increased acceptance of biomass to energy solutions, will lead. We believe, to conditions that will make attractive the use of biomass as a combustible independently of subsidies.

The additional availability of forest resides -about 16,000 ktoe will correspond to an additional installed capacity of 2700 MW_e.
In terms of volume of biomass an additional amount of 89 million m^3 will have to be harvested, prepared, transformed and converted.

7 MEASURES TO REACH 2010 GOAL

This ambitious but possible goal needs considerable reinforcement of present policies and support measures and specifically the following.

7.1 STRATEGIES FOR DEVELOPMENT

It is considered of importance:
- to set an ambitious goal that permits the focusing of decision makers at all levels
- to reinforce co-operation between member states
- to strengthen policies connected with increased use of renewable sources of energy (internalisation of externalities, for example)
- follow up development of strategy.

Some of the measures have to do with:
- ♦ deregulation of electricity market
- ♦ special tariffs for energy produced with renewable sources with preference to longer periods
- ♦ support R&D or most promising technologies
- ♦ support information interchange and dissemination
- ♦ use forest cleaning as fire reduction strategy (in southern countries)

We have dealt, with these matters during the previous phases of the project, and what is expressed in the Green Paper is a clear indication that the Community is definitely decided to give an ample support to renewables assuming a set of actions of undeniable interest.

7.2 HOW TO FINANCE

The consideration of externalities will translate into taxation of energy and emissions with exemption for renewables, and further help can come from higher taxes on landfilling of combustible materials, sale of green electricity at higher prices (with fiscal benefits to green electricity users), etc.

These measures will also contribute to a more rational energy sector where large economies can be made at all levels and, by decreasing total energy input per unit of GDP, will make more important the part of renewables.

7.3 SPECIAL AREAS OF SUPPORT

The need to reduce costs of biomass, a necessary measure for competitivity with conventional fuels, requires special efforts and support to the development of most promising areas.
- gasification and use in gas turbine (combined cycles)
- co-generation
- co-combustion with other woody residues and MSW
- forest residues harvesting and fuel preparation

In order to improve efficiency and costs, solutions that lead to substantial savings and improved reliability should be particularly supported: co-combustion, cogeneration, association of biomass producers with power companies, etc.

Miranda do Corvo, 8 August 1997
Olívia Matos
Rui Ribeiro

SOURCES:

[1] TOMORROW, number 4, volume VII, July-August 1997

[2] MATOS, O., RIBEIRO, R., Final Report, WfE-NETT II, A Concerted Action for European Co-ordination and Information Exchange on the Industrial Exploitation of Waste for Energy, January 1997

[3] Progress Report of the Ministerial Conference on the Protection of Forest Fires in Europe, 1996

[4] GREEN PAPER, Energy for the Future: Renewable Sources of Energy, January 1997

[5] MATOS, O., RIBEIRO, R., Interim Report, WfE-NETT III, A Concerted Action for European Co-ordination and Information Exchange on the Industrial Exploitation of Waste for Energy, July 1997

[6] MATOS, O., RIBEIRO, R., Final Report, WfE-NETT I, A Concerted Action for European Co-ordination and Information Exchange on the Industrial Exploitation of Waste for Energy, January 1996

Altener

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WOOD FUEL PRODUCTION TECHNOLOGIES IN EU COUNTRIES

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Abstract

The paper reviews the major technologies used for the production of fuel chips for heating plants in Europe. Three primary options are considered: production of whole-tree chips from young trees for fuel; integrated harvesting of fiber and energy from thinnings based on the tree-section system; and production of fuel chips from logging residue in clear-cut areas after fully mechanized logging. The characteristics of the available biomass reserve and proven technology for its recovery are discussed. The employment effects of fuel chip production and the cost of wood fuels are also briefly discussed.

1 INTRODUCTION

A half of the world's annual wood harvest is used for energy purposes. The contribution of wood-based fuels to the total consumption of energy is as high as 20 % in the developing countries, but in the industrialized countries the figure is only 1 %. However, the role of wood as a source of energy varies among industrialized countries. In the EU it is highest in Finland and Sweden, which are forerunners in the development and introduction of modern fuelwood production technologies. It follows that this review is based primarily on Nordic experiences.

2 WOOD FUELS AT PRESENT

Heating rural houses and farms with firewood is a common practice in all parts of Europe. France is the largest user of firewood, followed by Germany, Austria, Spain, Portugal, Italy, Sweden and Finland.

Firewood is still cut to short lengths (30—50 cm) and split for drying. Production is commonly based on the use of light handtools such as chainsaw and ax, as well as farm tractors. However, during the last 15 years there has been a rapid development of equipment for small-scale processing, handling and burning of firewood.

A large variety of farm tractor-driven equipment, often manufactured by local workshops, is in use in different countries. The technical solutions applied in these machines include circular saws and chainsaws for cross-cutting and hydraulic or mechanical pressure bars, guillotine knives, wedges and screws for splitting. Although large amounts of firewood are processed by these machines, they are not discussed further here, since the emphasis of the Altener workshop is in larger scale operations.

The second category of wood fuels is the *process waste from forest industries*: bark, sawdust, waste liquor from chemical pulping etc. In forest industry countries such as Sweden, Finland and Austria, industrial wood residue is a particularly important source of energy in view of the quantities and their economic importance. Since this waste accumulates passively as a byproduct of industrial processes, it is outside of the topic of the present paper, which deals with the production technologies of wood fuels.

The third major category of wood fuels is chips reduced from unmerchantable trees and logging waste for *combustion in heating and power plants.* In most EU countries, the production of fuel chips from forest residue is still of marginal importance. In Sweden, however, the energy content of wood fuels burned by heating plants corresponded in 1994 to 8 TWh; more than in the other EU countries altogether for this purpose. Finland is also a country with a large number of chip-fired heating plants (Figure 1). Nonetheless, the table below shows that even in Sweden and Finland the use of wood fuels as an energy source of heating plants is still modest compared with the total use of wood fuels.

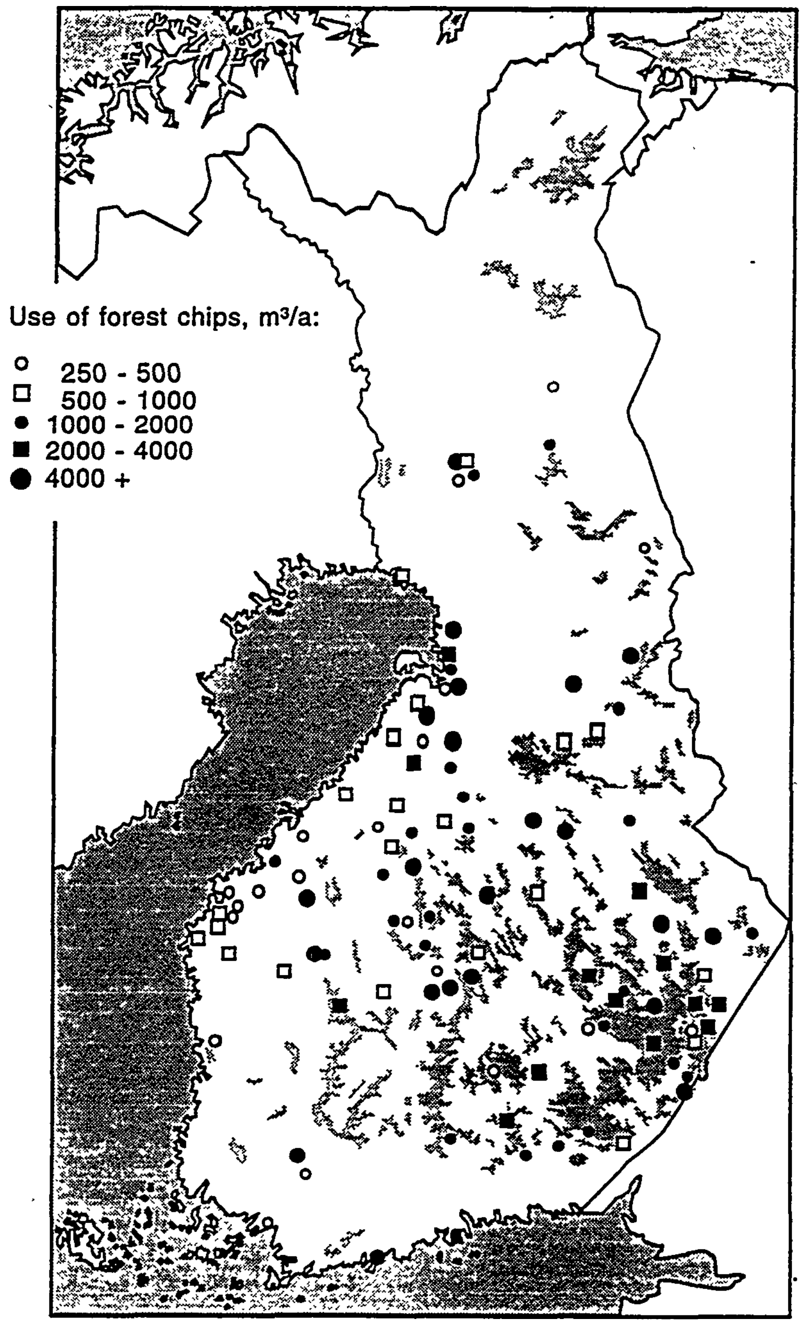

Figure 1. Forest chip-fired heating plants in Finland in 1995.

	Finland	Sweden
	Use of wood fuels in 1994, TWh	
Process waste in the forest industry:		
Bark, sawdust, etc.	13	15
Waste liquor	31	30
Firewood in small houses etc.	11	11
Chips at heating plants	2	8
Wood-based fuels, total	57	64

Due to the large reserve of unmerchantable small-sized trees and logging residue left unutilized in the European forests, this renewable source of energy has a great development potential. The utilization of this untapped reserve is therefore an essential goal in a large number of European national and international research, development and demonstration programs in the field of renewable energy.

3 UNUTILIZED RESERVES OF WOODY BIOMASS

The structure of the unmerchantable biomass reserve of the forests varies from country to country. It is affected by the species composition, age structure and management practice of the forests, and the raw material demand by the forest industries.

Only wood which is not acceptable in industrial processes should be used for fuel. The situation varies from country to country, but in general the unmerchantable biomass reserve is composed of unwanted species, under-sized trees (diameter less than 10—12 at the breast height), under-sized tops of larger trees, and defective stems or stem sections. In addition, crown mass from live and dead branches, including foliage, forms an even larger reserve of renewable energy (Figure 2).

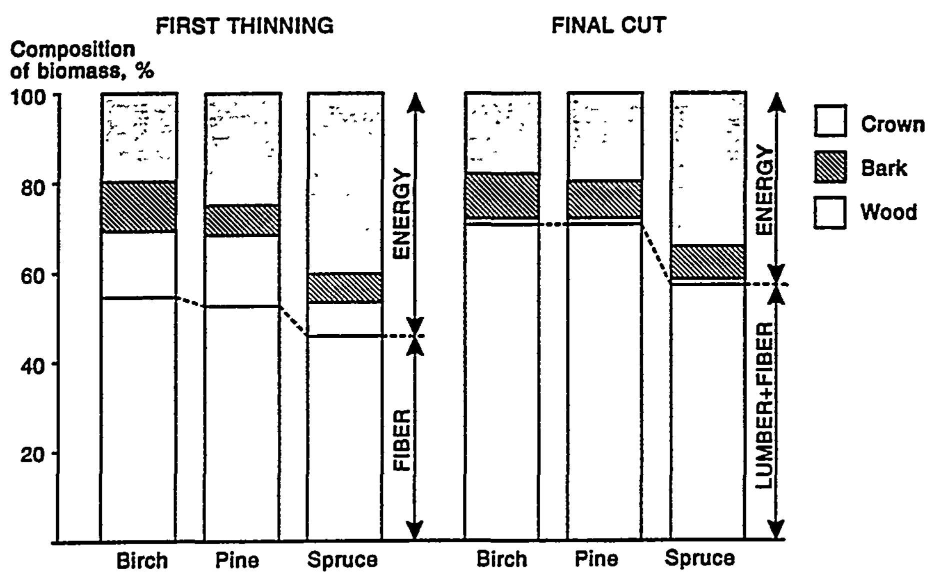

Figure 2. Distribution of woody biomass into industrial raw material (wood only) and fuel (crown, bark, unmerchantable wood) in early thinnings and final cuttings.

4 TECHNOLOGY FOR SMALL TREES

Chip production for heating purposes was started in the Nordic countries already in the 1950s. Chips were reduced from small-sized trees and low-quality hardwoods.. Initially trees were carefully delimbed in order to facilitate the feeding of transportable chippers and to improve the particle size distribution of the chips so as to ensure reliable operation of the chip handling systems at the heating plants. However, due to delimbing, biomass recovery was decreased while the cost of production greatly increased.

With decrease in the cost of fossil fuels, the competitiveness of chips suffered. It therefore became necessary to reduce the cost of production by abandoning the delimbing of small trees and adopting *the method of whole-tree chipping*. This permitted the introduction of more advanced technology, resulting in:

- an increase in chip yield (20—35 %)
- a decrease in chip cost (25—40 %)
- the need for heavier production equipment
- the need for stricter chip quality control and more efficient chip handling systems
- an increase in ash residue in combustion (30—60 %)
- a decrease in job opportunities in chip production (30—40 %)
- an increase in nutrient loss from forest soil (50—100 % unless logging methods are adjusted)

Whole-tree chipping is presently a common practice in North America and North Europe. In other parts of Europe it is used on a much smaller scale. Depending on local conditions and the scale of operation, many alternative production schedules are used. The three basic options are as follows:

- Option 1: *Chipping in the terrain*
  - Felling by chainsaw + some manual bunching
  - Size reduction with self-powered terrain chipper, and use of the same unit for chip transport to roadside and loading of chip containers
  - Transport of chips to the heating plant with a truck equipped with exchangeable chip containers
- Option 2: *Chipping at the road side*
  - Felling as above
  - Transport of whole trees or tree sections to the roadside with a load-carrying forwarder
  - Size reduction using a heavy whole-tree chipper and blowing the chips directly into a truck
  - Transport of chips to the heating plant with a large (100—130 m^3 loose) truck equipped with a trailer

— Option 3: *Chipping at the terminal or heating plant*
  — Felling and off-road transport as in option 2
  — Transport of whole trees or tree sections with a truck and trailer
  — Centralized size reduction with stationary chipping equipment in controlled conditions

Proven, reliable technology is available for all these options. A majority of the equipment used for the production of whole-tree chips in Europe is made by Swedish, Finnish and Danish manufacturers. Key aspects in the development programs for improved efficiency are the mechanization of felling and bunching, combination machines for felling and forwarding, load compaction accessories for whole-tree trucks, improvement of the particle size distribution of chips, and planning and organization of the entire production schedule.

5 TECHNOLOGY FOR INTEGRATED HARVESTING OF FIBER AND ENERGY FROM THINNINGS

The integration of the harvesting of all products, whether used for raw material or fuel, offers significant advantages in forest management planning, the purchasing of wood, and the organization and employment of forest machines and trucks. Simultaneous recovery of fiber and energy for chemical pulp industries from thinning cuttings has become an attractive operation model in Sweden and Finland.

Trees are felled and cross-cut into 5—6 m sections by chainsaw or by felling machines and left undelimbed in order to recover crown mass for energy. To prevent excessive loss of nutrients from the site and increase the bulk density of tractor and truck loads of undelimbed tree sections, trees may be topped and the thin tops rich in foliage left in the forest. Tree-sections, branches included but thin tops excluded, are transported to the road side and unloaded into 5—6 m roadside piles.

The critical phase of the integrated tree-section system is the separation and *segregation of the fiber component from the fuel component.* It is essential that the fiber component is clean from bark and foliage (maximum content of bark 1 %), and that high-quality fiber is not lost with process residue into the fuel component. Fiber losses of less than 2—3 % are possible when using the latest technology in small-tree debarking.

Two alternatives are available: *separation before size reduction or separation after size reduction.* In most cases, especially in Sweden, the separation is carried out before size reduction in a pulp mill's ordinary debarking drum where up to 10—15 % undelimbed tree sections can be mixed with conventional pulpwood logs and treated simultaneously. Another possibility is the use of chain flail technology, in which tree sections are delimbed and debarked by impacting steel chains using either portable truck-mounted equipment at the roadside or stationary equipment at the pulp mill. Although chain flail technology is in common use in the United States and Canada, Finland is probably the only European country where it is presently applied. Finland has also developed and built an upgrading plant for separation of impurities from whole-tree material after size reduction. The upgrading of chips is based on a series of subsequent grinding, screening, and pneumatic and optical sorting actions.

Integrated harvesting seems to lower the cost of fiber and energy, to slightly increase the yield of fiber due to a lower top diameter requirement of pulpwood, and to more than double the yield of fuel due to the partial recovery of branches. However, the technology is still under development. To reduce the cost of harvesting of small trees, further mechanization of cutting is of the utmost importance. The most promising technology is based on multi-tree handling with accumulating felling or harvester heads, which are being developed in Denmark, Finland, Norway and Sweden. Another promising option is a combination machine, a harvester-forwarder for small trees.

6 TECHNOLOGY FOR HARVESTING LOGGING RESIDUE FOR FUEL FROM CLEAR-CUT AREAS

Foresters tend to consider small-sized trees as the most important source of forest chips, since they see here an opportunity to promote silvicultural management of young forests. However, from the business economy standpoint, the recent adoption of fully mechanized logging technology has made logging residue in clear-cut areas an attractive and considerably cheaper source of energy.

This logging residue or slash is defined as all above-ground residue left on the ground after harvesting of commercial timber, i.e. unmerchantable tree species, under-sized trees, under-sized tops, culls, defective stem sections, breakages, and live and dead crown mass. In managed forests, crown mass is typically the primary component of logging slash in clear-cut areas.

When slash is salvaged for energy in conjunction with stemwood harvesting, even foliage will be recovered. If the slash is left at the site to season for couple of months, branches will shed their needles. The yield of crown mass will then decrease by 20—30 %, the moisture content of the dry mass salvaged will decrease from about 55 % to 35—45 % on the green mass basis, and the loss of nutrients from forest soil will decrease radically by at least 50 %.

When cutting was carried out by chainsaw, slash was left evenly scattered at the logging site. Recovery required special bunching, which was a costly operation and tended to result in excessive impurities and difficulties in subsequent chipping with sharp knives. Now that practically all clear-cutting in the Nordic countries is carried out with one-grip harvesters, the *felling and delimbing pattern can be adopted to accumulate the slash* in larger heaps. This raises the percentage of recovery to 65—75 % of the quantity of crown mass, improves the productivity of subsequent collection and transport to road side by 15—30 %, and results in cleaner chips.

Logging *slash is reduced to chips at the stump*, at the road side or at the heating plants. If chipping takes place at the stump with a mobile terrain chipper, the same unit is normally responsible for the off-road transport of chips to road side as well. The system is only competitive over short distances (less than 300 m) and in easy terrain.

It is more common to perform the *size reduction at the road side*. This makes it possible to use more efficient and robust chippers or, in order to avoid problems caused by stones and grit, crushers applying blunt impacting tools instead of sharp shearing knives. In this system slash is collected, hauled and unloaded into road side piles with conventional forwarders equipped with a special grapple and enlargened load space. If *size reduction takes place at the plant*, slash is transported with special trucks equipped with side panels and a compression device to increase the bulk density of the load. A new method is based on baling of slash which is being developed especially in Sweden and UK.

All systems of producing wood fuels from logging residue are fully mechanized. This means higher productivity and lower costs but less job opportunities compared with wood fuels produced from small-sized trees with or without branches.

7 EMPLOYMENT EFFECTS OF WOOD FUEL PRODUCTION

One of the goals of wood fuel production is creation of new job opportunities in rural areas. Unfortunately, to be economically competitive, wood fuel production must also be based on efficient, mechanized operation systems. This means that the input of labor is lower than sometimes expected.

According to calculations made at the Swedish University of Agricultural Sciences, the employment effect of fuelwood harvesting depends greatly on the source of biomass, forest conditions, and machinery and methods applied. The current average labor requirement of harvesting and transport under northern European conditions is about 425 man-years/million m^3 solid or 200 man-years/TWh. It is higher for small-tree materials and lower for logging slash. When indirect jobs are also taken into account, the total employment effect of wood fuel production is at least doubled, 400—500 man-years/TWh.

8 THE COST OF FUEL CHIPS

Very little reliable information on the cost of wood fuels is available, since the range of variation is wide in all countries.

A recent questionnaire revealed the average fuel wood prices of 50 plants using forest chips in Finland. Industrial wood residues are a less expensive fuel than forest chips. The least expensive are bark and sawdust. The cost of chips from small-sized trees is considerably higher, especially chips from delimbed stems (Figure 3).

NUTEK's quarter-annual price statistics show that the average price (not including VAT) of forest chips paid by Swedish heating plants in 1995 was 24 % higher than the average price of forest chips in Finland. Heating plants paid slightly more for wood fuel than industrial plants:

	Sweden 1995	
	Heating plants	Industrial plants
	Price of fuel, FIM/MWh	
Chips from industrial residue	64	55
Chips from forest residue	76	72
Pellets and briquettes	102	..

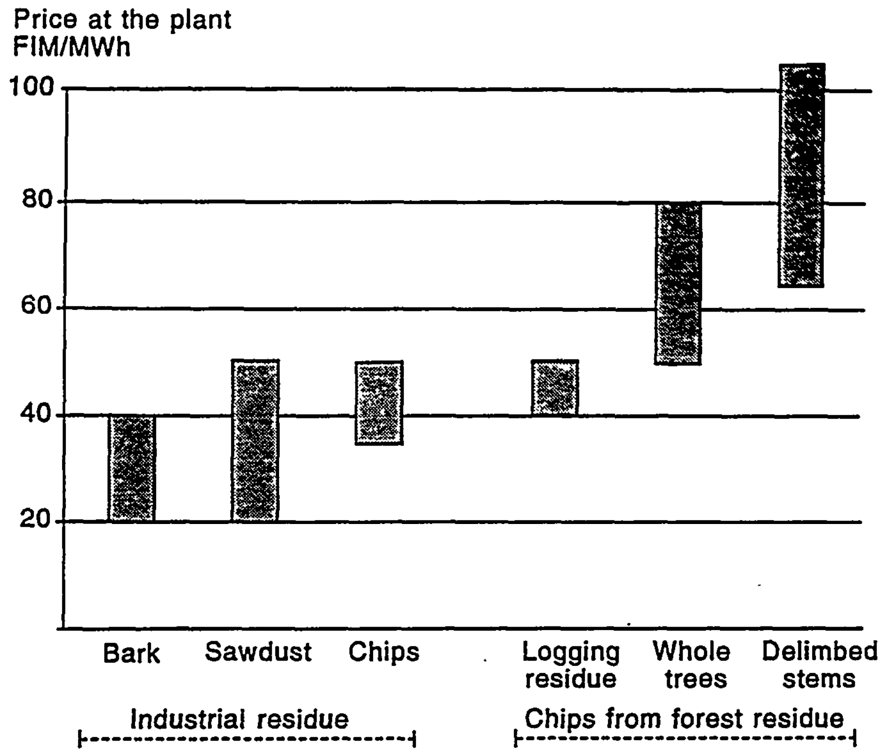

Figure 3. The price of wood fuels (excluding VAT) paid by heating plants in Finland in 1995.

In Finland, the cost of forest chips has decreased during the past 10—15 years. This has been partly due to the development of machinery and methods, but also due to developments in the organization and logistics of procurement. Competitive bidding has resulted in the general decrease of forest machinery rates, and this has an effect on the procurement costs of energy wood, even though logging equipment is underemployed. Only the cost of chips from delimbed small-sized stems has slightly increased, since it has not been possible to mechanize the work. As new efficient technologies is introduced and the scale of operations expands, fuel chip prices are expected to decrease and the competitiveness of forest energy improve.

SOURCES:

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BIOMASS EVENT IN FINLAND

1st - 5th September 1997
Hotel Laajavuori, Jyväskylä, Finland

Mr. Seppo Hulkkonen,
Imatran Voima
Finland

Bed Mixing Dryer for High Moisture Content Fuels

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Bed Mixing Dryer is a new type of fuel drying technology to be utilized with fluidized bed combustion. The idea is to extract hot bed material from the fluidized bed and use it directly as heat source for drying the fuel. The drying takes place at steam atmosphere which makes it possible to recover the latent heat of evaporation to process. This improves the thermal efficiency of the power plant process considerably especially in combined heat and power (CHP) applications.

Imatran Voima Oy (IVO) in Finland has been developing the Bed Mixing Drying technology since early 1990's. The first pilot plant was built in 1994 to IVO's Kuusamo peat and wood fired power plant. The capacity of the plant is 6 MW of electricity and 20 MW of district heat. In Kuusamo the dryer is connected to a bubbling fluidized bed. Since it's commissioning in 1994, the pilot dryer has been used successfully for about 3000 hours during the heating seasons in winter time.

The next application of the Bed Mixing Dryer will be a demonstration project in Örebro in Sweden. IVO Power Engineering Ltd. (a subsidiary of IVO) will supply in 1997 a dryer to Örebro Energi's peat and wood and coal fired CHP -plant equipped with circulating fluidized bed boiler. The fuel to be dried in that case is saw dust with fuel input of about 60 MW. In Kuusamo the dryer produces 3 MW of district heat and in Örebro the additional district heat output is 6 MW.

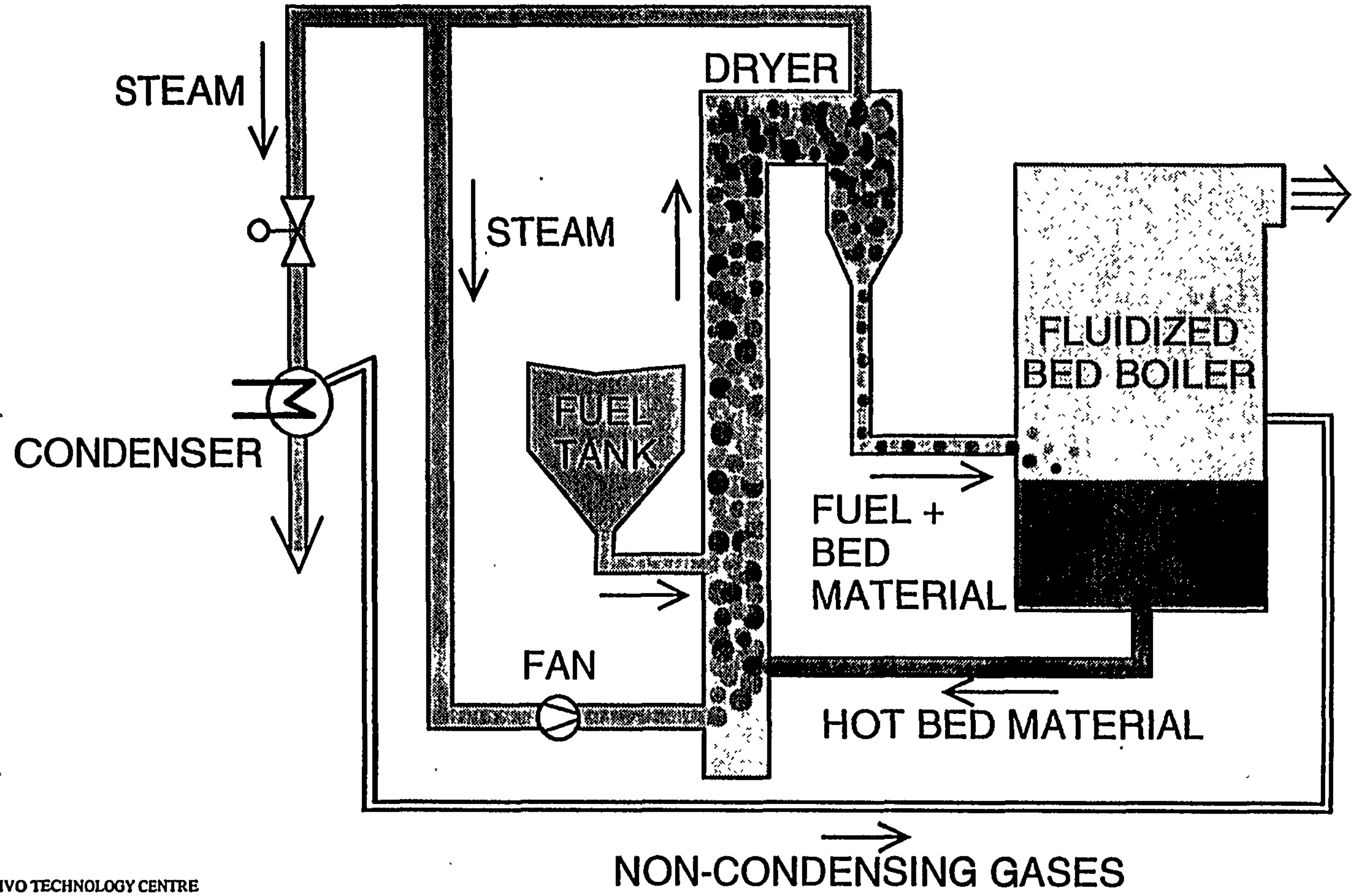
The Bed Mixing Dryer in Kuusamo functions well and is in commercial use producing district heat to the town of Kuusamo. The fuels there are peat, saw dust and bark. Örebro dryer is going use mainly saw dust, and will be double the size of the Kuusamo dryer. In addition to the municipal heat production, this type of drying technology has its benefits in pulp and paper industry processes. Disposal of paper mill sludges is becoming more difficult and costly which has resulted in need of alternative treatment. Drying of the sludge before combustion in a boiler for power production is an attractive option in many cases. At the moment IVO is carrying out several studies to apply the Bed Mixing Dryer in pulp and paper industry processes. The economy of drying the sludge and looks promising.

NEW DRYING METHOD FOR MOIST FUELS

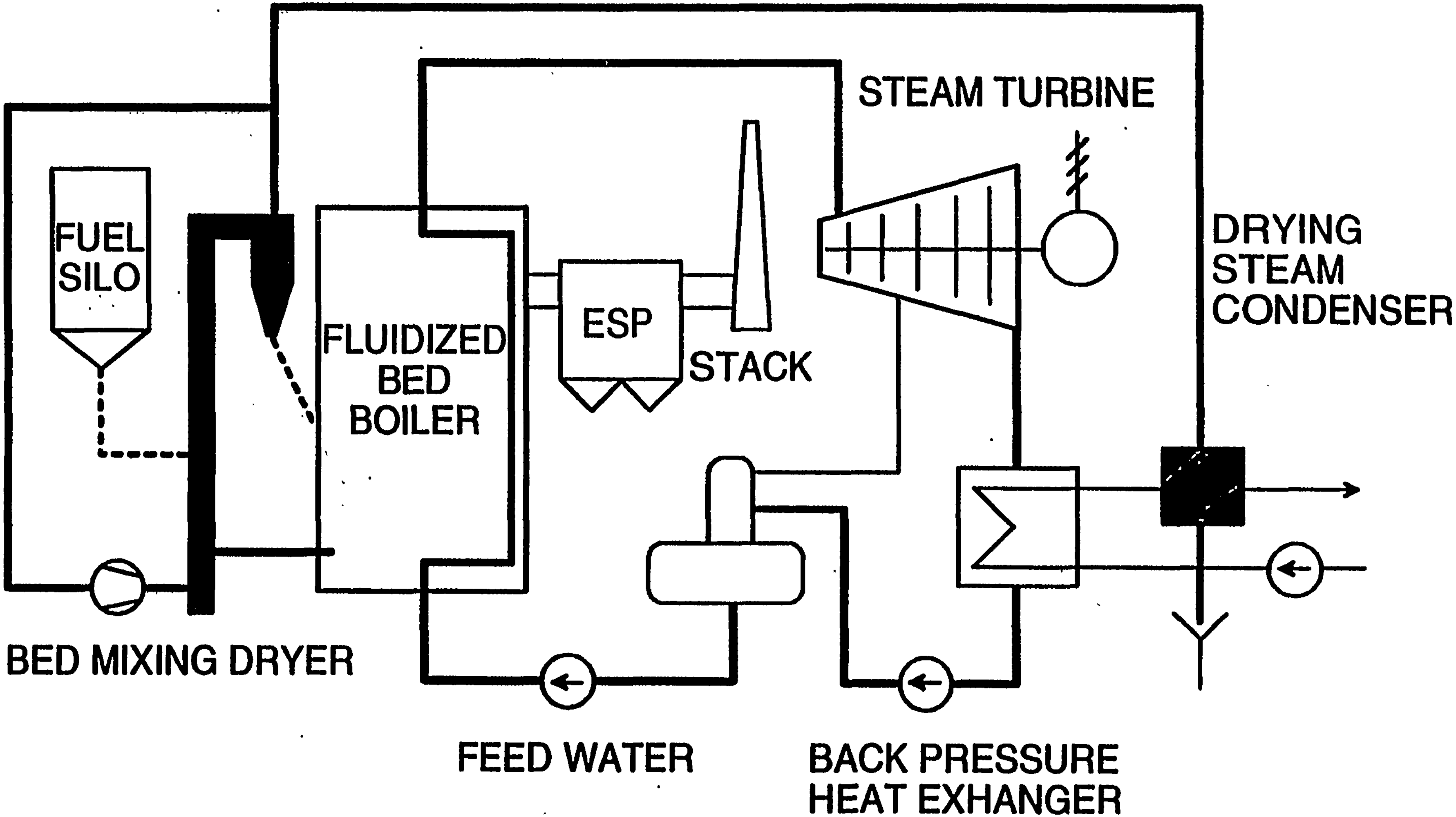
Seppo Hulkkonen
Imatran Voima Oy

- TECHNOLOGY DESCRIPTION
- BENEFITS
- TECHNOLOGY STATUS

PRINCIPLE OF THE BED MIXING DRYER



DISTRICT HEATING POWER PLANT WITH BED MIXING DRYER



IVO GROUP

IVO TECH

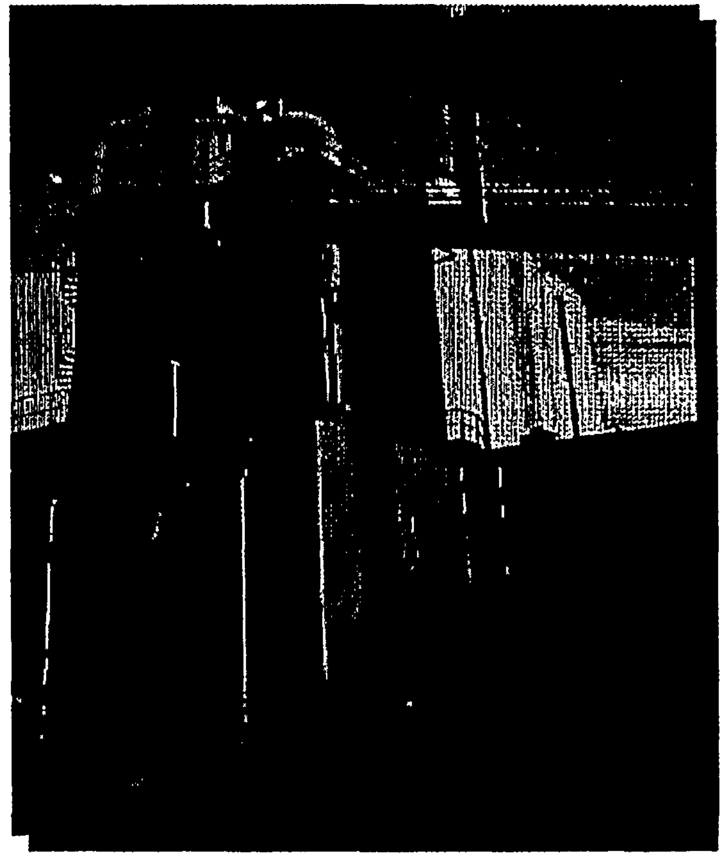
ADVANTAGES OF THE BED MIXING DRYER

- High thermal efficiency
  - Recovery of latent heat back to process
  - Decreased fuel consumption and emissions
- Decreased flue gas flow
  - Moisture doesn't go through boiler
  - Smaller boiler size in a new plant
  - Increased capacity in an old plant
- Simple dryer
  - No heat exchangers
- Safe operation
  - Steam atmosphere, no risk of fire
- No odour emissions
- Less visible smoke
- Cooling of boiler in shut downs

Toranki Heat and Power Plant at Kuusamo
Demonstration of the bed mixing dryer

A plant with bubbling fluidized bed boiler (BFB) for peat and wood chips

	No drying	With dryer
Fuel power	26.3 MW	26.0 MW
Moisture	50%	15%
Electricity	6.1 MW	6.1 MW
District heat	17.6 MW	21.2 MW
Efficiency		
* lower h.v.	90%	105%
* higher h.v.	73%	84%



IVO GROUP

IVO TECH

Bed Mixing Dryer at Örebro

- Circulating fluidized bed boiler
- Fuel input 165 MW
- Fuels Wood waste, Saw dust, Coal
- Plant retrofitted with Bed Mixing Dryer
- Fuel to the dryer Saw dust
- Moisture Content 50->20%
- Fuel input to the dryer 60 MW
- District heating output from dryer 6 MW
- Support from EU-Thermie - program
- Commissioning planned for 1998

BIOMASS EVENT IN FINLAND

1st - 5th September 1997
Hotel Laajavuori, Jyväskylä, Finland

Mr. Fred Dumbleton,
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OVERVIEW OF CO-COMBUSTION TECHNOLOGY IN EUROPE

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Abstract: There have been a number of tests and trials co-combusting biomass and waste with fossil fuels, often with promising results. A wide variety of combustor types have been tested at scales from laboratory test units to full scale utility boilers. Some commercially operating plant is in service, often designed for multi-fuel capability. However further R&D is needed in the areas of corrosion, fuel preparation, ash utilisation, plant operability and emissions, before co-combustion options can be fully defined and considered fully commercial for both new plant and retrofit projects.

1 INTRODUCTION

Historically, environmental standards concerned with air quality have been associated mainly with the emissions of SO_2, NO_x, CO and particulates. However, discussion of the greenhouse effect has introduced an awareness that CO_2 will have to be reduced in the long term. Since there is no practical control technology available, the remaining possibilities are increased process cycle efficiencies and fossil fuel substitution. Co-combustion is one method of achieving such substitution.

2 COMBUSTION SYSTEMS

Most coal combustion technologies have some ability to co-fire other solid fuels. However, the maximum amount of supplementary fuel will depend on the chemical and physical properties of that fuel and so will the performance obtained. For co-combustion, the technologies of major interest are fluidised bed combustion (FBC), grate combustion, pulverised fuel (pf) combustion and cyclone combustion.

2.1 FLUIDISED BED COMBUSTORS

Fuels with a wide range of chemical compositions and physical characteristics can be burned using FBC technology. FBC technology is already in commercial operation burning agricultural based fuels and residues such as bark, wood chips, saw-dust, energy crops, straw, sludges from paper mills and de-inking plants, and other wastes such as municipal sludge, waste paper, packaging waste and RDF. The advantages of fluidised bed combustion which directly affect their co-combustion capabilities are fuel flexibility, ability to burn low grade fuels, in situ sulphur capture and low NO_x emissions. There are a number of types of FBC which all share the above advantages. In all cases combustion is regulated to take place at temperatures of 800-900C in a suspended bed of inert material. These low combustion temperatures are close to the optimum for sulphur capture when sorbents are used. They also reduce the generation of thermal NO_x and the risk of ash softening and fusion. The large bed inventory of inert material has significant thermal inertia which stabilises combustion conditions even for low grade fuels with variable properties, so that proper combustion control can be maintained.

2.2 GRATE COMBUSTION

Grate combustion systems in various forms have a long history of use with solid fuels. Grates are still used in many small and medium sized boilers for steam and hot water production. They have been able to compete with more modern technologies and more convenient fuels due to continuous improvements and the use of modern control systems. However, grates are less flexible than fluidised beds with regard to fuel quality and are less suited to variable fuel mixtures and variable fuel quality. The common feature of all grate systems is that the solid, non volatile, portion of the fuel is mixed with air and burned on the grate itself. The grate is usually arranged to move so that fuel travels towards the ash discharge during combustion. Fuel may fed on top of the grate or firebed or from underneath the grate. Fuel may also be fed into the combustion volume above the firebed where the volatile matter is burned, with mostly char falling onto the grate itself. Overfeed technologies seem to be more suited to co-combustion operation.

When designed for low volatile fuels, such as coal, grates are often equipped with rear arches to direct combustion gases toward the fuel inlet area to assist in ignition. The volatile components of the fuel are also burned in this volume. Such grates may have insufficient combustion volume to cope with the high volatile matter content of biomass and waste fuels and this will limit the proportion of these fuels which can be burned in co-combustion mode. Higher proportions of alternate fuels will produce unacceptable emissions of volatile gases.

2.3 TRAVELLING GRATES

Fuel is normally fed from a hopper at the front end of the grate, where the thickness of the layer is controlled by means of an adjustable gate. Over fire or secondary air can be added to create a recirculation zone to complete the combustion of volatiles above the incandescent and ignition zones. The incandescent and ignition zone surface areas and fuel bed thickness range are fixed during grate design to suit the type of fuel or fuel mix being specified. The low calorific value of most alternative fuels limits the proportion of these fuels that can be used, whilst maintaining an adequate fire bed, on a unit originally designed only for coal. There is also lack of any mixing action by the grate which can lead to uneven mixing of alternative fuels and coal which could give rise to combustion problems.

2.3.1 Vibrating grates

Vibrating grates are used in combination with spreader stokers or mass feeding hoppers. The grate consists of tuyère blocks assembled in a frame, which is either air or water cooled, to form a rigid construction supported by flexible joints. The whole structure is driven by a vibrator whose action causes the fuel to move along the grate and which generates a well distributed and uniform fuel bed. This, in turn, minimises the risk of blow holes, poor combustion and overheating of the grate. These characteristics are of particular interest when considering co-combustion. Vibrating grates are capable of burning a variety of coals and other fuels at high specific heat release rates particularly when water cooling is employed.

2.3.2 Reciprocating grates

Most reciprocating grates are designed for mass feed systems. Combustion air is admitted through slots alongside and between each grate element. Fuel feed is usually from a chute or hopper using a pusher and a gate to control the fuel feed. This arrangement is not ideal for co-firing as the fuels would have to be pre-mixed and the fuel flow rate would have to be increased due to the low calorific value of the alternative fuels.

2.3.4 Underfeed stokers

Underfeed stokers have a long history of successfully burning solid fuels. Fuel is normally fed from hoppers under the grate by means of screw conveyers (small units) or reciprocating rams. Fuel is forced upwards through a retort into the combustion zone. Too many fines and/or a low ash fusion temperature may create problems with clinker. This makes them less suitable for co-firing biomass and wastes which have constituents which increase problems with clinkering. Underfeed stokers are generally not suitable for wet materials making them less suitable for wet biomass/waste fuels.

2.3.5 Experience with Co-combustion with Grates

Co-firing has been trialled for varying lengths of time at a number of stoker installations often to investigate whether co-firing can be introduced with little or no investment cost. Whilst the results have often been promising it is clear that modifications would be needed in some cases and that these are untried over extended operating periods. Therefore, most of these trials have ended without a firm commitment to conversion to co-combustion being achieved. The preferred route for burning biomass and waste materials, where the economics are favourable, has been to replace the existing coal combustor with a dedicated biomass or waste unit.

If the use of biomass/waste fuels for co-combustion has been largely abandoned, the use of tyre chips has reached commercial status, being fired on a continuous basis in several units. A spreader stoker at Linköping Tekniska Verken AB has a capacity of $83MW_{th}$, producing steam at 67 bar/475C, and is equipped with a travelling grate. The tyre fuel arrives ready chipped and it is blended with the coal on the conveyer belt at a blend ratio of between 20 - 30 % by energy. Operation is essentially trouble-free.

2.4 PULVERISED FUEL CO-COMBUSTION

In large scale coal firing, pulverised fuel (pf) combustion has been the standard system for many years because of its high efficiency and because it can burn the fines which are produced as a result of modern mining methods. Pf systems can operate at low excess air levels and still maintain the necessary combustion temperature control throughout the furnace. This is achieved by using accurate diagnostic and computerised control systems. However, to be able to make full use of the potential of these systems it is necessary that the combustion and thermodynamic processes are closely matched to the properties of the fuel to be burned at the design stage, making them less tolerant of other fuels. For coal the primary considerations are grindability, volatile matter, moisture content, ash content and ash-softening temperatures.

For co-combustion, alternative fuels will have to be ground to a particle size that will give compatible combustion characteristics with the coal particles and allow full burn out. This is affected by the volatile content and the reactivity of the fuel. The recommended biomass particle size, which is generally larger than that for coal, must also be compatible with the fuel feeding systems to avoid blockages. Combustion efficiency has been measured by burnout and emissions of CO and C_xH_y. The results of projects to date show generally good results for the co-combustion of biofuels. The effects of particle size and percentage of alternative fuel on combustion efficiency, however, differ in different applications. For example, a decrease in burnout was reported for combustion of straw (10-40mm) within the range of 10-20 % straw input, whereas at higher straw ratios (50-70%) increased burnout occurred. In other experiments, good burnout was reported for straw (0.75-7mm) and Miscanthus (1.5-30mm) at contents up to 40%, whereas when using waste wood (0.2-1.0mm) a decrease in burnout occurred when more than 10 % was used. In full-scale tests with straw, unburned straw knees in the fly ash were sometimes reported, leading to an increase of unburned carbon in the fly ash. In full-scale experiments with wood chips no effect on unburned carbon in the fly ash was found. Overall, the performance of a pf system co-combusting alternative fuels depends on the biomass properties and the precise combustion conditions. This requires optimisation of the co-combustion ratio, fuel preparation and the combustion process for each site and for each alternative fuel to be burned.

In June 1992 tests were conducted at Georgia Power Company's Hammond Unit 1, a 100 MW B& W pulverised coal unit, to evaluate the impact co-firing wood waste on plant performance. Eleven full load performance tests were conducted, five with coal and six with a wood/coal mixture with an average wood content of 11.5% by weight. At medium and high O_2 levels, boiler efficiency with wood co-firing was within 0.2-0.4% of the boiler efficiency with coal alone. Mill fineness was slightly affected and mill power increased with wood co-firing and would eventually become a limiting factor. Opacity was observed to increase with wood co-firing, the cause of which is presently under investigation. NO_x emissions with wood were about the same or slightly less than with coal firing. Sulphur emissions should have been 6-7% lower with wood co-firing but it was not possible to confirm this during the test.

Other fuel characteristics such as moisture and ash content are also important. For pf coal combustion a fuel moisture content of less than 15% (as fired) is recommended. Most biomass and wastes fuels, if not dried, will easily exceed this limit. Exceeding the 15% limit for the fuel mixture may jeopardise flame stability, burn out and boiler control. Total ash content is of little concern with most biofuels and wastes, since they rarely contain more than a few percent total ash. Of greater concern is the possible formation of low melting temperature eutectics when compared to coal alone. Fouling and slagging behaviour is also affected by the ash softening and melting temperatures of the fuel mixture and the furnace temperature. Furnace temperature is controlled by heat absorption by water cooled furnace walls. This reduces the gas temperature prior to the superheater section and the furnace exit. The amount of heat absorbed is controlled by the size and shape of the furnace. When considering co-combustion it is important to confirm that the furnace has sufficient volume to accomplish complete combustion of the fuel mixture, whilst maintaining acceptable gas temperatures. When considering a co-combustion scheme it is necessary to check the blended fuel and ash properties against those for which the boiler was designed.

Long term and successful operation of pf units is reported for RDF and sewage sludge, which is successfully burned in medium to large scale units in Europe and the USA, e.g. Lakeland Electric and Water, Florida, USA and the Weiher II power plant in Germany, respectively. Both units are based on the slagging or wet bottom technique. However, most interest is associated with biomass and waste fuels and major projects aiming at large scale commercial operation are under way in Holland and Denmark. The Dutch EPON project has retrofitted the $600MW_e$ Gelderland unit to burn waste wood up to

14% of thermal input. The Danish project, involving the 150MW$_e$ Vestkraft unit 1 at Studstrup, has generated valuable information related to straw combustion, though it is not yet in continuous operation.

Co-firing experience related to PF combustion in other Scandinavian countries relates mainly to pulverised wood. Tests, though of short duration and involving limited quantities of fuel, have been successfully completed in Uppsala and Stockholm, Sweden. Specific programs related to handling and site grinding of pellets is under way at the Hässelby combined heat and power plant in Stockholm.

2.5 CYCLONE COMBUSTION

Cyclone combustors were developed to overcome problems with low grade coals and lignites containing ash of low softening and fusion temperatures. Cyclone combustion provides the benefits of pulverised combustion with the additional advantages of reduced fly ash quantities, savings associated with less costly fuel pulverising equipment and reduction of furnace size. This makes this type of combustor a good prospect for co-combustion of biomass and waste fuels.

3 FUEL PREPARATION AND HANDLING

The handling systems and logistics for alternative fuels must recognise their high volatility and bioactivity which can permit degradation in storage. The preparation of these materials for use as a fuel is governed by the fuel characteristics and by the combustion technology being used and its associated fuel feed mechanisms. Biofuels and wastes can be cut/chopped/crushed (bark, straw, grass etc.), chipped (wood, trimmings, etc.) or ground (wood), again, depending on the combustion technology being used. These techniques are often well proven, but can represent a considerable capital and/or operating cost to the project. Similarly, to be able burn MSW in spreader stokers, BFB or other systems commonly used for coal, it will be necessary to homogenise and comminute the material by sorting and then chipping/shredding.

There are several options for pf coal boiler applications. The existing coal mills and feeding systems can co-pulverize the alternative fuel with coal and fire the mixture into the boiler. This is usually the least expensive option, but limits the amount of biomass or waste that can be handled to about 5 % of the heat input. In general, bituminous coal mills are not suitable for biomass or waste, which require separate milling systems. Straw, wood, miscanthus, and sewage sludge have all been successfully fired in pf boilers, although optimum particle sizes are different for each alternative fuel.

Cyclone and fluidised bed boilers may require some size reduction of the alternate fuel, but not pulverisation. In circulating fluidised bed (CFB) combustion systems the experience with straw firing showed neither the need to mill nor to pre-dry the straw. Pneumatic feeding of straw into the CFB unit functioned very satisfactorily. Also, CFBs can be designed to handle hogged wood and wood chips.

Oversized material in alternate fuel combustion can cause varying degrees of concern depending on the fuel, the non-combustible fraction in the fuel, and manner in which it is fed into the combustor. However, it is possible to screen out oversize material, and this is recommended, either during comminution or at the conversion plant.

Some of the main problems of using MSW as a feedstock have been variability, biological and chemical instability, and poor fuel quality. An improved method for turning MSW into an environmentally safe and economical fuel has been developed. Recyclable metals, glass and some plastics are mechanically and manually separated from the waste. The remaining (combustible) fraction is combined with a calcium hydroxide binding additive, and formed into cylindrical pellets. These pellets are dense and odourless, can be stored for up to three years without significant biological or chemical degradation, and are easily transported. These pellets have been successfully combined with coal in existing spreader-stoker combustors. Pelletisation of other alternative fuels is also possible, although it introduces additional capital and operating costs in the fuel supply chain.

4 EMISSIONS

Co-firing alternate fuels with coal or lignite typically increases the scope of potential flue gas emissions and control requirements. Some alternate fuels (e.g. biomass) can contain lower levels of nitrogen and sulphur than most coals, so co-firing can reduce NO_x and SO_x emissions. In addition, some SO_2 can be captured by the alkaline minerals in the biomass ash. Other alternate fuels may have higher nitrogen and/or sulphur levels which may require NO_x control measures or limestone addition for SO_2 emissions control.

With the exception of biomass, alternate fuels can contain sufficient levels of certain heavy metals to cause environmental concern. They can leave the stack as vapours or solids, and can concentrate in the fly ash, which increases potential for triggering hazardous waste disposal requirements. With the exceptions of mercury which remains as a vapour at stack temperatures, effective particulate control (by fabric filters or ESPs) is considered necessary for controlling stack emissions of most metals.

Because of their high volatiles content, biomass fuels are well suited to use in NO_x reducing procedures such as air staging and re-burning. With coal/biomass blends and the application of air staging in the furnace, lower NO_x emissions can be attained compared to coal alone. For re-burning, biomass is superior to hard coal as a reducing agent, improving both emissions and burnout. This fact can be due to the low N-content of the fuel and, for all biomass types, to the high volatile content. Full-scale tests at Vestkraft power station in which two coal burners were retrofitted for straw injection (up to 25%) confirmed the positive effect of biomass addition on NO_x emissions. At the facilities of RWE, TU Delft and Grenaa, the NO_x emissions with biomass addition remained more or less unchanged at low levels around 200 mg/m^3. ECN, CIEMAT and INETI found decreasing NO_x concentrations, especially with wood co-combustion. Most groups also measured reduced levels of CO with increased biomass input during tests.

Chlorine, which is present in certain types of biomass such as straw or miscanthus, may also affect emissions. Test runs at Vestkraft revealed a rise in HCl emissions equivalent to the higher input of chlorine contained in the fuels. This might have to be controlled if emissions limits were breached. Chlorine-content can also influence the emissions of dioxins. Normally the emissions are low in pf coal furnaces due to high combustion temperatures and rapid gas cooling due to heat transfer into the boiler. At the 130MW$_{el}$ pulverised coal furnace at Esbjerg, no increase of dioxin emissions could be detected despite the level of chlorine in the straw being 6 times higher than in the coal.

Organically-bound chlorine (from plastics, etc.) can contribute to the formation of chlorinated organic compounds such as dioxins and furans. Though effective combustion control (to ensure volatile burnout) is important for minimising dioxin and furan formation for MSW and automobile wastes, wet or dry scrubbing systems are required on some FBCs to provide supplemental control of both HCl and dioxin/furan emissions.

Stadtwerke Saarbrucken in co-operation with Thyssen Still Otto Anlagentechnik verified that a wide range of mixtures of coal, sewage sludge or biomass can be incinerated without problem in comprehensive incineration tests on a 2 MWth fluidised bed installation. The concentrations of the major components in the exhaust gas depend on the composition of the fuel mixtures used. In all tests, the values for both CO and NO_x were below the limit values for long periods, simultaneously. The quality of the bed ash and hot gas cyclone ash was also good. Emissions measurements indicated that the dioxin content of the flue gas will be less than 0.1 ng TE/m^3.

Solid and gaseous emissions have also been measured for eight RDF and PDF co-combustion tests. Results of the tests showed that co-combustion of used packaging seems to be a technically and economically feasible as well as an environmentally friendly solution for packaging waste.

5 ASH AND NON-COMBUSTIBLE IMPURITIES

In some applications temperatures in the combustor will exceed the ash softening and melting temperatures for alternative fuels. Even with low FBC combustion temperatures glass and aluminium from MSW and automobile wastes can become molten. Alkali constituents in some alternative fuels are also conducive to forming low melting temperature compounds. The high concentration of alkali metals in biomass can cause ash deposition problems. Potassium and sodium oxides form eutectics with silica and other constituents which have ash softening temperatures as low as 768C (cf. 1087C for coal). These molten materials can lead to bed agglomeration in FBC's and fouling of combustor walls, air/fuel penetrations and heat transfer surfaces in all types of boiler. This is due to either the carryover of molten or semi-molten ash particles from the combustor or condensation of alkali salts that were vaporised during combustion. These deposits can lead to subsequent corrosion if sulphur or chlorine are present in the deposits, particularly when higher metal temperatures are used (See Section 6). However, at the Vestkraft facility adding straw up to 25 % by energy did not significantly alter the amount of deposition compared to burning Russian and Polish coal alone.

5.1 UTILISATION OF ASH

The composition of fly and bottom ashes from a coal-fired boiler are of great importance when they are used in the production of downstream products. For utilisation of fly ash in concrete and cement applications, the concentrations of alkali, SO_3, Cl and unburned carbon are critical parameters. An increase of alkali and unburned carbon has been observed in ash from some full-scale co-combustion trials. There may be a limit to the permitted proportion of alternative fuel that can be used in some applications for this reason.

6 CORROSION

The clean co-combustion of various RDF and PDF fuels with up to 1 % chlorine together with coal have been demonstrated in three projects in Finland. One project also studied corrosion and fouling during co-combustion of 10 % RDF with peat and coal in a 65 MW CFB plant at 500C steam temperature. 30-40te per day of RDF was combusted for one year in the Kauttua 65MW power plant. Corrosion tests and inspections of the boiler did not reveal abnormal corrosion. However, results from other trials indicate a need for more information about the use of refuse derived fuel (RDF) over extended operating periods.

A one-year test on four seamless composite tubes was carried out in a 65 MWth Ahlstrom PYROFLOW boiler. Two composite tubes of SANDVIK FECRAL/HT8 were installed in the hot end of the final superheater with two different silicon contents; FECRAL0 0.29 w-% and FECRAL1 1.04 w-%. Two reference tubes were also installed in the same superheater. The boiler uses a Circulating Fluidised Bed (CFB) combustor with a mean steam temperature of 470C and pressure of 80 bar. Steam flow varied between 8 and 19 kg/s according to demand. The co-combustion of Refuse Derived Fuel (RDF) started in September 1993 with the main fuels being peat and coal. Approximately 30 tons of RDF was co-combusted daily until June 1994 giving 2000 hours operation on RDF at a fuel energy input of 25-30%. Measurements indicated that corrosion and fouling rates were normal. The test showed that the FeCrAl compounds tubes were more resistant to hot corrosion than the reference tubes.

However, corrosion can occur in fluidised bed systems. A prerequisite is that inorganic alkali ash constituents co-exist with other harmful elements, the most important being sulphur and chlorine. Of particular concern are chlorine containing fuels/wastes, such as MSW with up to about 10 % plastic (mostly polyvinylchloride) and straw and other grasses. For this reason studies concentrating on corrosion mechanisms when co-firing biomass and waste materials have been undertaken in the USA and Scandinavia. Results to date indicate that co-combustion in CFBC with RDF and PDF fuels, at proportions of 10 - 15 % based on thermal energy input, does not cause any significant or abnormal corrosion. However, co-combustion of up to 50 - 60 % of straw in a CFBC steam raising unit in Denmark showed substantial corrosion. The corrosion rate in the convective pass just upstream the final superheater was an order of magnitude higher compared to firing coal alone. Problems of the same order of magnitude were also encountered in the loop seal, again characterised by selective chloride corrosion. The Danes report that corrosion rates can be reduced by longer combustor residence times, higher SO_2 partial pressure, burnout of coke in recycled ash before entrance to the external heat exchangers, reduced steam temperature and reduced temperature in the convective pass. In any project where biomass fuels or wastes, which contain alkali and particularly potassium and sodium, are considered in relation to co-combustion in FBC's, careful examination of the combined fuel ash properties and the bed chemistry is essential. Other measures, of a more fundamental nature, require a re-design of CFBC units. Suppliers are now offering a solution where the superheater is immersed in an external fluidised bed located in the bed material recirculation loop. The advantage is that superheater tubes are no longer in direct contact with the corrosive compounds in the flue gas. They also see more uniform and reduced temperatures. Such designs are now gaining operational experience.

A corrosion test program was conducted by exposing probes on the furnace wall, in the superheater, and at the precipitator inlet of a 65MW pulverised coal boiler during both coal firing and co-firing of RDF. Carbon steel, low alloy steels, and stainless steels were exposed for periods of 1,000, 2,000 and 3,000 hours. The corrosion rates of carbon steel and low alloy steels in the furnace zone were slightly lower during co-firing with RDF than during coal-only operation. There was an increase in corrosion rates of low alloy steels in the superheater during co-firing as a result of attack by sulphur, but there was no evidence of chlorine corrosion. The co-firing of RDF had little effect on the stainless steels. Alloys exposed at the precipitator inlet also showed little effect of RDF.

A 4000 hour controlled-temperature probe evaluation was conducted to determine the long term impact of co-firing coal and refuse derived fuel (RDF) on corrosion of boiler materials in Oak Creek Unit 7 of Wisconsin Electric Power Company (WEPCO). Evaluations included weight loss, penetration, and metallurgical examination as well as chemical examination of selected deposits. While wastage increased with increasing metal temperatures, no significant wastage was attributable to the 10 to 15% replacement of coal by RDF.

7 FUTURE R&D

The results of work completed to date indicate the need for further work in the following areas: corrosion, fuel preparation, ash utilisation, plant operability and emissions.

BIOMASS EVENT IN FINLAND

1st - 5th September 1997
Hotel Laajavuori, Jyväskylä, Finland

Mr. Frank Penninks,
EPON
The Netherlands

COAL AND WOOD FUEL FOR ELECTRICITY PRODUCTION: AN ENVIRONMENTALLY SOUND SOLUTION FOR WASTE AND DEMOLITION WOOD

COAL AND WOOD FUEL FOR ELECTRICITY PRODUCTION:
An environmentally sound solution for waste and demolition wood

F.W.M. Penninks, nv EPON

ABSTRACT

Waste wood from primary wood processing and demolition presents both a problem and a potential. If disposed of in landfills, it consumes large volumes and decays, producing CH_4, CO_2 and other greenhouse gases. As an energy source used in a coal fired power plant it reduces the consumption of fossil fuels reducing the greenhouse effect significantly. Additional advantages are a reduction of the ash volume and the SO_2 and NO_x emissions. The waste wood requires collection, storage, processing and burning. This paper describes a unique project which is carried out in The Netherlands at EPON's Gelderland Power Plant (635 MWe) where 60,000 tonnes of waste and demolition wood will be used yearly. Special emphasis is given to the processing of the powdered wood fuel. Therefore, most waste and demolition wood can be converted from an environmental liability to an environmental and economic asset.

INTRODUCTION

In 1992 approximately 240,000 tonnes of waste and demolition wood was deposited on landfills in The Netherlands. Looking for possibilities to reduce the CO_2 emissions of the 7 EPON power plants (4300 MWe; in total supplying 30% of the Dutch electricity demand) it was decided to start an investigation for the possibility to utilize 25% of this volume for co firing together with coal. A visit was paid to Sweden where 15% of the energy production is based on indigenous fuels, mainly originating from wood.

While products such as wood chips have long been used as industrial fuel, a recent development has been an upgraded wood fuel, known as wood powder or pulverized wood fuel.
Wood powder is a very dry and fine fraction material that is uniform, easy to handle, and with high energy content that can be burned much like oil or gas. These findings were used to start the basic design for a wood powder production plant and burning system with a capacity of 10 tonnes per hour for 6,000 hours per year. The aims of the project are:

- substitution of 45,000 tonnes of coal averaging 4.5% of the total yearly fuel input,
- reduction of the CO_2 emissions with 110,000 tonnes per year,
- using 60,000 tonnes of waste and demolition wood yearly and with that partly solving a landfill problem.

There were several preset conditions under which the project could take place. There should be no risks with respect to the availability of the power plant. Also the 100% use of fly ash as a commercial product to the building industry could not be jeopardized. Finally, all emissions must remain within the limits set by Dutch environmental laws and regulations.

The 635 MWe coal-fired production unit was commissioned in 1981. In 1985 and 1988, a wet flue gas desulphurization system (limestone/gypsum FGD) was put into operation for both 50% of the total flue gas flow respectively. In October 1994 a DeNOx system (SCR - Selective Catalytic Reduction) became operational reducing the NOx emissions with 80%. Furthermore the plant is equipped with electrostatic fly ash filters. The fly ash is used as certified cement and Lytag in the building industry.

GENERAL DESCRIPTION OF THE PROCESS

Waste and demolition wood is collected at three sites in The Netherlands and processed into raw wood chips. In the process large objects of iron, textile or plastic etc. are removed manually. Smaller metallic and non-metallic parts are removed and small plastic and textile parts are separated by wind sifting.

Stones, sand and glass particles are sieved out. The wood chips are transported in containers to the power plant.

The specifications for the wood chips are given in table 1.

TABLE 1: Wood chip characteristics

Density	165 - 185 kg/m3
Particle size	0 - 3 cm
Moisture	< 20% DW
Caloric value	> 16 MJ/kg
Lead	< 1500 µg/g
Zinc	< 1400 µg/g
Chlorine	< 400 µg/g

The containers are stored in an unloading area for a short period and then placed on an automated traverse and dumping system. This system consists of 27 containers which supply the plant with enough material for approximately one day of operation. The wood chips are unloaded into a reception hopper and conveyed to the grinding area.

In this area a cleaning system, magnet and windsifting, is installed as an (extra) system to remove the rest of the dirtying. Then a hamermill (15 ton/hour capacity) reduces the material from its original size to a particle size max. 4 mm. Hereafter the material is

seaved and devided in a material stream that is already fine enough. This stream is transported to a dust collector.

The oversize stream is transported via a chain conveyor to two intermediate storage bins. Each bin contains a maximum of 50 m^3 and feeds two mill units with two variable screw conveyors. In the mill the material is reduced in size and is dried with preheated air.

Material leaving the mill enters a static classifier which removes approximately 10% of the material < 800 µm. Rejects from the classifier fall into a vibrating screen where further separation between product and oversize occurs. Oversize particles are re-entrained into the mill for further reduction. The product from the screen enters the pneumatic conveying line and then merges with the discharge of product from the classifier. The final product is then collected in a dust collector.

The specifications of the woodpowder are given in table 2.

TABLE 2: Specifications of the wood powder

particle size distribution	90% < 800 µm
	99% < 1000 µm
	100% < 1500 µm
moisture	< 8% DW

Each of the mill systems operates independently and produces about 1.8 tonnes per hour of final product with a density between 200 to 240 kg/m^3. Woodpowder from all four systems and the pregrinding is combined in a central collection bin and then pneumatically conveyed over 600 meters to a 1,000 m^3 storage silo adjacent to the boiler. A metering system feeds the powder into four separate burner injection lines, each capable of conveying 1.1 to 3.5 tonnes per hour. Four special wood burners with a capacity of 20 MW_{th} each are mounted in the side walls of the boiler (two on each side) below the lowest rows of the existing 36 coal burners. There are 3 rows of 6 coal burners in the front and back walls.

The coal burners can also be used for burning oil and therefore the combination woodpowder/oil is theoretically possible. The Dual Air Zone (DAZ) Scroll Feed wood burner has two registers in one, with concentric louver zones which divide the combustion air stream into two counter rotating concentric streams. The result is a compact and controllable flame pattern.

The secondary air supply to the burners has to be used as cooling air when the wood burners are not in operation and only coal is used as a fuel.

The control system for burning wood is independent from the coal burning system. By this the availability of the unit is unchanged.

The summarized process is represented in figure 1.

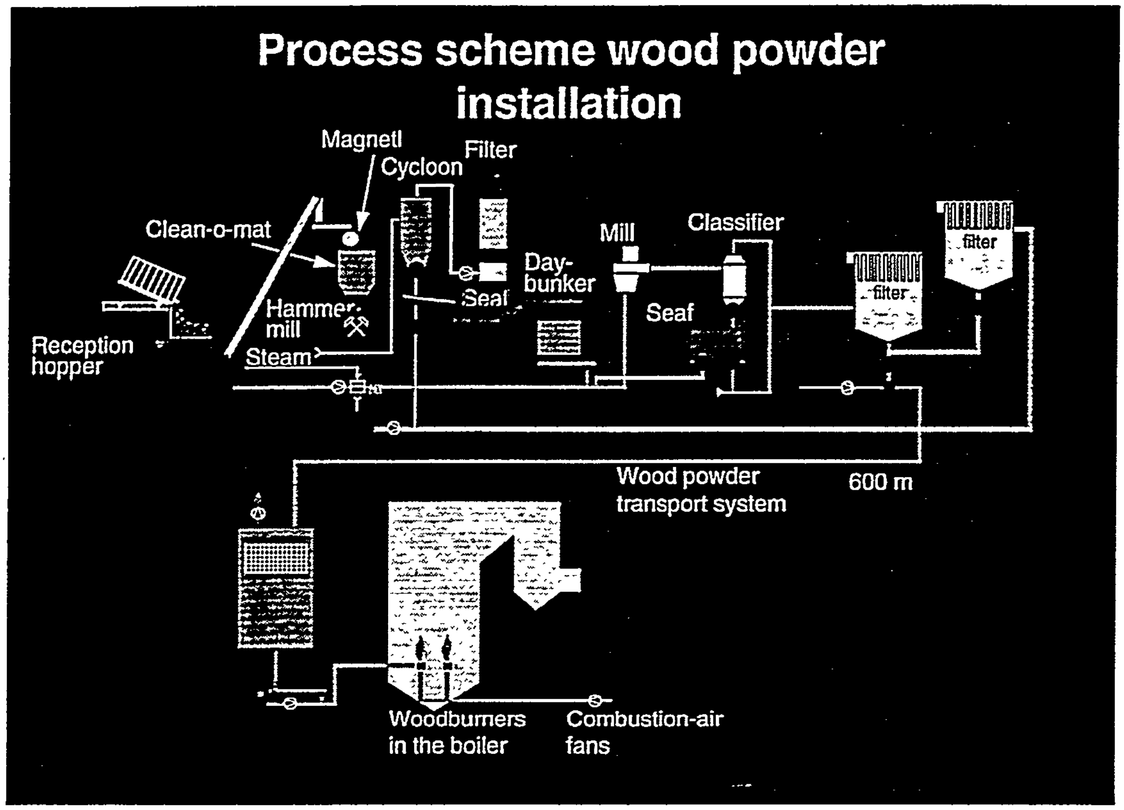
Process scheme wood powder installation
Magnetl
Cycloon
Filter
Clean-o-mat
Mill
Classifier
filter
filter
Day-bunker
Seal
Seaf
Hammer mill
Reception hopper
Steam
Wood powder transport system
600 m
Woodburners in the boiler
Combustion-air fans

FIGURE 1

ENVIRONMENT

On average the electrical output based on woodpowder fuel will be 20 MW, replacing 45,000 tonnes of coal yearly. The CO_2 emissions of this amount of coal equals approximately 110,000 tonnes of CO_2 (1 kg coal burned releases 2.4 kg CO_2). Since there is no nett addition of CO_2 when wood is burned and therefore no contribution to the greenhouse effect, the amount of CO_2 can be seen as a reduction. Except for this reduction there is also a yearly reduction of 4,000 tonnes of fly ash since the ash content of wood is ten times less than that of coal.
The emission limits for the plant set by the provincial government are given in table 4.

TABLE 4: Emission limits for firing wood/coal at the Gelderland Powerplant

NOx	<	200	mg/Nm3
SO2	<	400	mg/Nm3
Dust	<	20	mg/Nm3
CO	<	50	mg/Nm3
Total heavy metals	<	1	mg/Nm3
Cd	<	0.05	mg/Nm3
Hg	<	0.05	mg/Nm3
HCl	<	10	mg/Nm3

GLOBAL ENERGY BALANCE

The overall energy consumption of the process is of significant importance to justify such a project, since a large amount of waste and demolition wood is burned in waste incinerators in The Netherlands. Modern waste incinerators already have an overall electrical efficiency of 21%, whereas the Gelderland Power plant has an efficiency of 38.5%. In table 5 the preliminary global energy balance is given.

TABLE 5: Comparison between a waste incineration plant and the Gelderland Power plant in terms of energy in/output

Input : 10 tons of waste and demolition wood per hour with an average moisture content of 15% DW.
Efficiency: Powerplant 38.5%
Waste Incinerationplant 21%

Gelderland Power plant	kW	kW
Yield		**19,785**
Costs:		
Crushing and grinding to 3 cm	**1,025**	
Transportation over 100 km	**450**	
Production of woodpowder and burning	**1,764**	
	———	
Overall energy costs	**3,239**	**- 3,239**
		———
Overall Yield		**16,546**
Waste incineration plant		
Yield		**9,920**
		———
Difference in yield		**6,626**
Energy recovery gain in%		67%

SAFETY PRECAUTIONS

The micronizing process creates wood dust particles that pose a possible hazard for dust explosions. Therefore safety precautions must be taken. The plant described above will employ the following precautions: grounding of all equipment to prevent electrostatic discharges; explosion panels on the main silo, dust collectors and weigh bin; an explosion suppression system on the feed bins; and isolation systems to contain any possible hazard wherever it may occur; several spark detection systems are installed. All systems are linked into a central control system and will implement an emergency shutdown if engaged.

CONCLUSION

Wood waste is very plentiful and, when pulverized has burning characteristics similar to natural gas and oil with a resulting reduction in CO_2 production.

INFORMATION

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EWAB

Energiewinning uit afval en biomassa

Energy from waste and biomass

Het Novem programma 'Energiewinning uit Afval en Biomassa' (EWAB) bevordert de toepassing van afval en biomassa als energiebron.
The Energy from Waste and Biomass Programme (EWAB) from Novem promotes the use of waste and biomass as biofuels.

EPON POWER GENERATION

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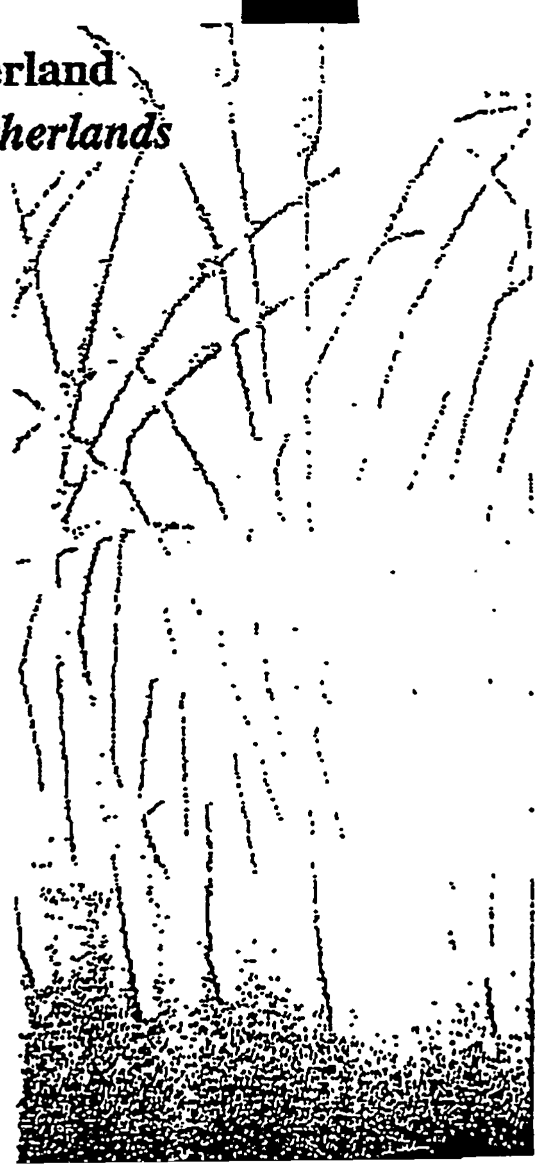
EPON
POWER GENERATION

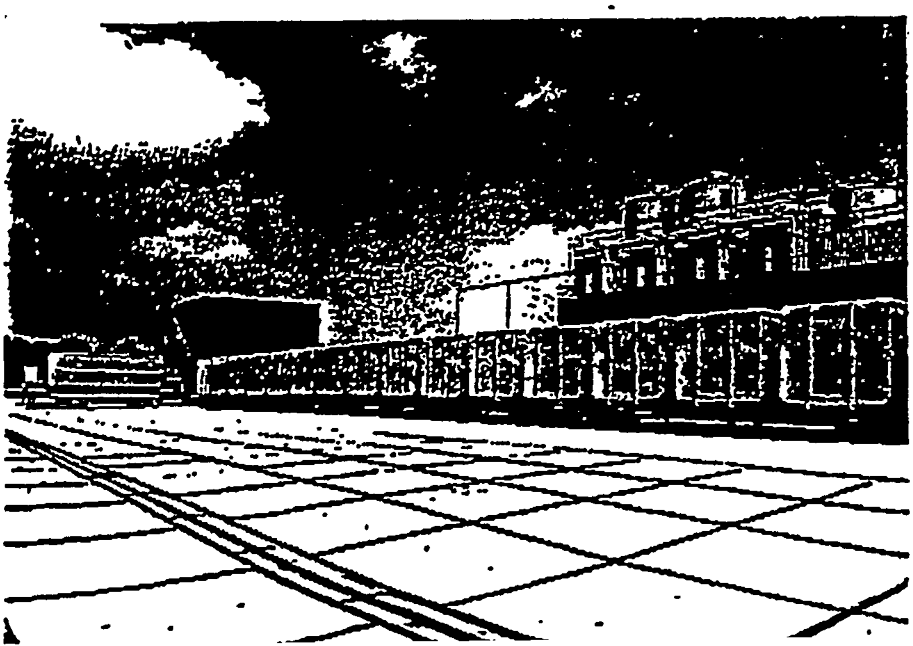
Project:

Co-verbranding van vermalen hout in Nederland

Co-combustion of pulverised wood in the Netherlands

Nederlandse onderneming voor energie en milieu bv
Netherlands agency for energy and the environment
Novem





Co-verbranding van vermalen hout in Nederland

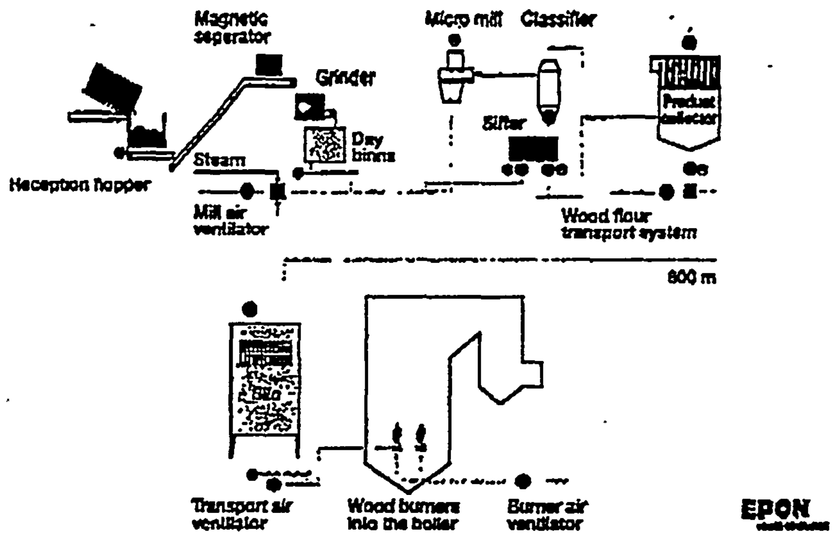
amenvatting
Afvalhout, wat na opwerking als secundaire brandstof wordt gebruikt in een kolencentrale, vermindert het verbruik van fossiele brandstoffen, waardoor het broeikaseffect significant wordt verminderd. Bijkomende voordelen zijn een vermindering van het asvolume en de uitstoot van SO_2 en NO_x. Deze brandstof wordt bij EPON verpoederd en verstookt. Gemiddeld 5% van de verbrandingsenergie wordt door hout geleverd. Dit artikel beschrijft een project dat wordt uitgevoerd door de EPON in de centrale Gelderland (635 MW_e) in Nijmegen, Nederland.

Summary
Waste wood which after processing is used as a secondary fuel in a coal-fired power station cuts down on the consumption of fossil fuels with the result that the greenhouse effect is significantly reduced. Additional advantages are a reduction of the ash volume and of the SO_2 en NO_x emissions. At EPON, this fuel is pulverised and burnt. An average of 5% of the combustion energy is supplied by wood. This article describes a project being carried out by EPON in the Gelderland power station (635 MW_e) at Nijmegen, the Netherlands.

chtergrond
n Nederland komt volgens recente schattingen ca. 250.000 ton afvalhout vrij, waarvan een groot deel op stortplaatsen terechtkomt. De overheid streeft naar een reductie van de CO_2-uitstoot en naar een zo hoogwaardig mogelijke inzet van secundaire brandstoffen. Voor afvalhout zal daarom een stortverbod worden ag rd. De inzet van deze brandstof in kolencentrales onder tr.. milieuhygiënische voorwaarden en met de geldende energetische rendementen draagt in hoge mate bij aan de realisatie van de overheidsdoelstellingen.

Background
In the Netherlands, according to recent estimates, approx. 250,000 tonnes of waste wood is released. A large part of this, however, ends up on the dump. The government is striving for a reduction of the CO_2 emission and for an optimum application of secondary fuels. For waste wood, therefore, a dumping ban will be introduced. With the current energy return, the use of this fuel in coal-fired power stations, in accordance with strict pollution control standards, makes a major contribution to the realisation of the government objectives.

Process scheme wood installation



Technische beschrijving
Afvalhout en sloophout wordt op drie lokaties in Nederland verzameld, gesorteerd en opgewerkt tot ruwe houtspaanders en in containers naar EPON getransporteerd. Twee hamermolens (elk m n capaciteit van 10 ton/h) reduceren het materiaal van de oorspronkelijke grootte (ca. 3 cm) tot deeltjes van 1-8 mm. Vervolgens wordt het materiaal naar de vier molens van de installatie getransporteerd waar het verder wordt verkleind en gedroogd met voorverwarmde lucht. Het eindprodukt wordt verzameld in een stofafscheider. Elk van de maalsystemen werkt onafhankelijk en produceert per uur 2,5 ton eindprodukt met een dichtheid van tussen de 200 en 240 kg/m³. Het houtprodukt dat de installatie verlaat komt in een statische classifier, die ongeveer 15-25% van het materiaal kleiner dan 800 micrometer verwijdert. Terugvoer uit de classifier valt in een vibrerende zeef waar een verdere afscheiding tussen het produkt en te grote deeltjes plaatsvindt. Te grote deeltjes worden weer naar de maalinstallatie gevoerd voor verdere vermaling. Het produkt van de zeef komt samen met het produkt uit de classifier, wordt pneumatisch getransporteerd naar een opslagsilo en vanuit deze silo in een doseersysteem gebracht, die het poeder via brandstofleidingen naar vier afzonderlijke branders transporteert. De speciale houtbranders met een totale capaciteit van 54MWh_{th} zijn in de zijwanden van de ketel gemonteerd (twee aan elke kant).

Technical description
Waste wood and demolition wood will be assembled at three locations in the Netherlands. Here it will be sorted and processed to raw wood chips and transported to EPON in containers. Two hammer pulverisers (each with a capacity of 10 tonnes/hour) will reduce the material from its original size (approx. 3 cm) to particles of 1-8 mm. After that, the material will be transported to the four pulverisers of the installation where it is further reduced and dried with pre-heated air. The end product is collected in a dust collector. Each pulverising system works independently and produces 2.5 tonnes of end product with a density of between 200 and 240 kilogrammes/m³ per hour. The wood product which leaves the installation comes in a static classifier which removes the approx. 15-25% of the particles which are smaller than 800 micrometers. The material returning from the classifier falls into a vibrating sieve in which a further separation of the product from the oversized particles takes place. Oversized particles are retransported to the pulverising installation for a further pulverising. The product from the sieve together with the product from the classifier is pneumatically transported to a storage silo. From this silo it is transferred in a dosage system which conducts the powder via a fuel pipe to four individual burners. The special wood burners with a total capacity of 54 MWh_{th} have been mounted in the side walls of the boiler (two on each side).

Omschrijving bedrijf
EPON Power Generation ontwerpt, bouwt, exploiteert en onderhoudt elektriciteitscentrales en warmtekrachtcentrales. EPON is beschikbaar voor projectontwikkeling, deelneming in het aandelenkapitaal, EPC- en O&M-contracten over de gehele wereld. EPON is dé partner voor alle energieconsumenten en -producenten waarvoor elektriciteit en warmte de belangrijkste produkten vormen.

Description of the company
EPON Power Generation designs, builds, operates and maintains power stations and cogeneration stations. EPON is available for project development, equity participation, EPC and O&M contracts worldwide. EPON is the partner for all power producers/consumers having electricity and heat as their main product.

EWAB-programma
Het EWAB-programma wordt gefinancierd door het Ministerie van Economische Zaken/DGE en heeft een jaarlijks budget van ca. 8 miljoen gulden. Een deel daarvan wordt besteed aan ondersteunende studies en activiteiten op het gebied van kennisoverdracht. Een groot deel van het budget is beschikbaar als subsidie voor bedrijven en instellingen die initiatieven wensen te nemen om afval en/of biomassa te benutten voor energieopwekking.

EWAB Programme
The EWAB Programme is financed by the Ministry of Economic Affairs/DGE and has an annual budget of approx. 8 million guilders. Part of this budget is allotted to the support studies and activities in the area of the transfer of know-how. A large portion of the budget is available as a subsidy to companies and organisations wishing to engage in initiatives in the field of utilizing waste and/or biomass for generating energy.

Ministerie van Economische Zaken
Ministry of Economic Affairs

Novem
Novem, de Nederlandse onderneming voor energie en milieu bv, is een dienstverlenende organisatie, gespecialiseerd in het management van energie- en milieuprogramma's voor de rijksoverheid en de Europese Unie. Belangrijke doelstellingen zijn het bevorderen van energiebesparing en de ontwikkeling van duurzame energie, het stimuleren van de preventie en het hergebruik van afvalstoffen en activiteiten op het gebied van milieutechnologie. Naast kennis en deskundigheid op deze terreinen beschikt Novem voor de uitvoering van haar taken over financiële ondersteuningsmogelijkheden. Novem werkt samen met bedrijven, non-profit organisaties, overheden en onderzoeksinstellingen.

Novem
Novem (the Netherlands agency for energy and the environment) specialises in the management of energy and environmental programmes for European Union governments. Major objectives are the promotion of energy saving and the development of sustainable energy, the stimulation of the prevention of waste and the re-use of waste, and activities in the field of environmental technology. In addition to know-how and expertise in these fields, Novem has the possibility to grant subsidies for the implementation of its activities. Novem cooperates with industry, non-profit organisations, government agencies, and research institutes.

Informatie
Voor meer informatie over het EWAB-programma kunt u contact opnemen met: (030) 239 34 88 (Novem).

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Co-combustion of pulverised wood in the Netherlands

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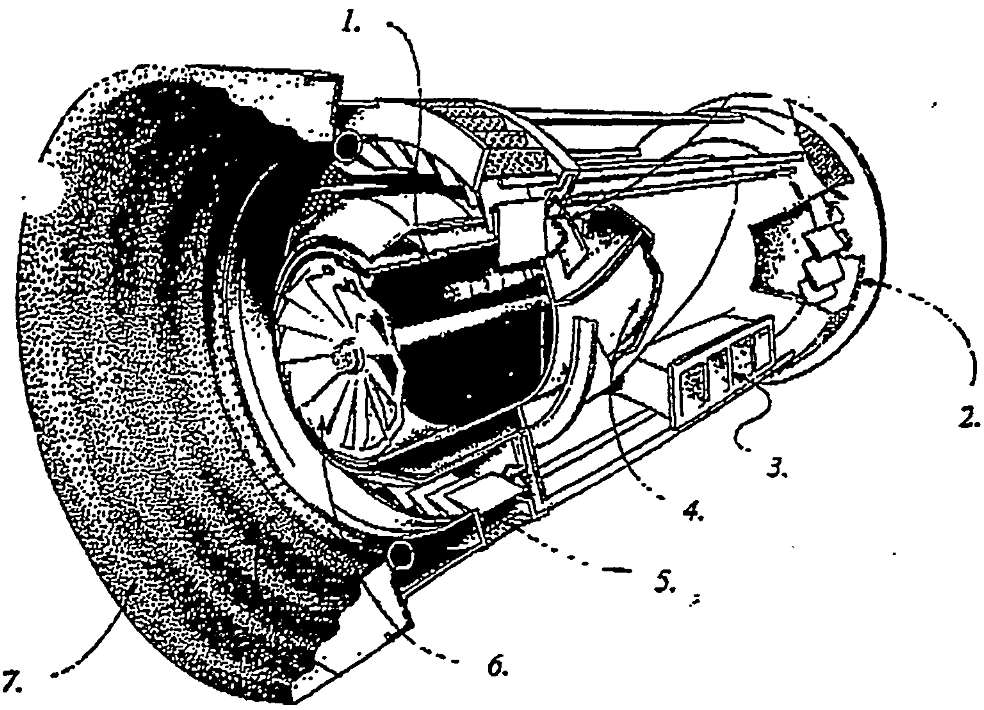
Resultaat

Gemiddeld zal de elektriciteitsproduktie op basis van houtpoederbrandstof 20 MW_e bedragen, hetgeen per jaar 45.000 ton kolen vervangt. Jaarlijks wordt 60.000 ton afvalhout als brandstof ingezet, daarmee wordt een CO_2-uitstoot van 110.000 ton vermeden. Bij een aantal draaiuren van 7.000 wordt een besparing gerealiseerd van 1,25 PJ.

Result

On average, the amount of electricity generated based on pulverised wood will be 20 MW_e which will replace 45,000 tonnes of coal per annum. Annually, 60,000 tonnes of waste wood will be used as fuel, thus reducing the CO_2 emission by 110,000 tonnes. For every 7,000 operating hours, a saving of 1.25 PJ will be achieved.



1. Starter burner
2. Register valve secondary air
3. Pulverised wood + primary air
4. Screw-shaped fuel feed
5. Register valve tertiary air
6. Impeller
7. Burner opening

Economie
De energie die nodig is voor het verpoederen en drogen van het hout is ongeveer 10% van de totale energieproduktie. De totale inv ring bedraagt ca. 30 miljoen.

Economy
The energy required for pulverising and drying the wood is approx. 10% of the total energy production. The total investment amounts to approx. 30 million guilders.

Overheidssteun
De subsidie vanuit het EWAB-programma bedraagt 1 miljoen gulden. Bijdrage Thermie 3.7 miljoen gulden (=1.8 miljoen ECU).

Government subsidy
The subsidy from the EWAB-Programme amounts to 1 million guilders. The contribution of Thermie is 3.7 million guilders (= 1.8 million ECU).

Startdatum
Start van de bouw september 1994. Start proeffase najaar 1995. Vanaf 1 januari 1996 is de installatie in produktie.

Starting date
Start of construction work: September 1994. Start of trial phase: Autumn 1995. Installation in production: as of 1 January 1996.

Informatie
Voor meer informatie over het project kunt u contact opnemen met:
Ing. F.W.M. Penninks
N.V. EPON Power Generation
Postbus 10087
8000 GB ZWOLLE
Telefoon: (038) 427 29 00
Telefax: (038) 427 29 06

Information
More information on this project may be obtained from:
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N.V. EPON Power Generation
P.O. Box 10087
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Fax: +31 38 427 29 06

BIOMASS EVENT IN FINLAND

1st - 5th September 1997
Hotel Laajavuori, Jyväskylä, Finland

Mr.Henrik Lundberg,
TPS Termiska Processer AB
Sweden

PRESENTED AT THE ALTENER -PROGRAMME BIOMASS EVENT
1-5 September 1997. Jyväskylä, Finland

BIOMASS GASIFICATION FOR ENERGY PRODUCTION

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ABSTRACT

Biomass and waste are becoming increasingly interesting as fuels for efficient and environmentally sound power generation. Circulating fluidised bed (CFB) gasification for biomass and waste has been developed and applied to kilns both in the pulp industry and the cement industry. A demonstration plant in Grève-in-Chianti, Italy includes two 15 MWth RDF-fuelled CFB gasifiers of TPS design, the product gas from which is used in a cement kiln or in a steam boiler for power generation.

For CFB gasification of biomass and waste to reach a wider market, the product gas has to be cleaned effectively so that higher fuel to power efficiencies can be achieved by utilising power cycles based on engines or gas turbines.

TPS has developed both CFB gasification technology and effective secondary stage tar cracking technology. The integrated gasification - gas-cleaning technology is demonstrated today at pilot plant scale. To commercialise the technology, the TPS' strategy is to first demonstrate the process for relatively clean fuels such as woody biomass and then extend the application to residues from waste recycling.

Several demonstration projects are underway to commercialise TPS's gasification and gas cleaning technology. In U.K. the ARBRE project developed by ARBRE Energy will construct a gasification plant at Eggborough, North Yorkshire, England, which will provide gas to a gas turbine and steam turbine generation system, producing 10MW and exporting 8MW of electricity. It has been included in the 1993 tranche of the UK's Non Fossil Fuel Obligation (NFFO) and has gained financial support from the European Commission's THERMIE programme as a targeted BIGCC project.

1. ATMOSPHERIC-PRESSURE GASIFICATION

In 1984, TPS began work on developing atmospheric-pressure gasification technology for application to wood fuels, peat, RDF and other reactive solid fuels. The impetus for this work was the use of the product gas in lime kilns.

The gasification concept selected by TPS was an air-blown circulating fluidised bed (CFB) type that operated at 850-900°C and produced a hot tarry gas (typical tar content of 0.5-2 per cent of dry gas) with a heating value of 4-7 MJ/Nm3. CFB technology is favourable for gasifiers with fuel capacities greater than 10 MWth for the following reasons:

* good fuel flexibility
* compact gasifier even at atmospheric pressure means cost-effective large-scale construction
* good controllability and good low load operation characteristics
* uniform process temperature due to highly turbulent movement of solids
* optimum gas quality (high carbon conversion)

In addition to the general CFB gasifier qualities, the TPS CFBG design has the following specific features:

* no extensive fuel treatment required, fuels with a considerable fraction of coarse particles can be utilised
* increased carbon conversion is achieved by partially recycling the fines from a secondary solids separator

1.1. TPS Pilot Plant

In 1986, a 2 MWth CFB gasification pilot plant was erected at TPS (Figure 1). During tests in late 1986 and early 1987 using bark, several hundred operational hours were accumulated and both the stability of the process and the high carbon conversion within the gasifier were proven. In spring 1987, pilot plant gasification tests on both wood/PVC mixtures and RDF were performed.

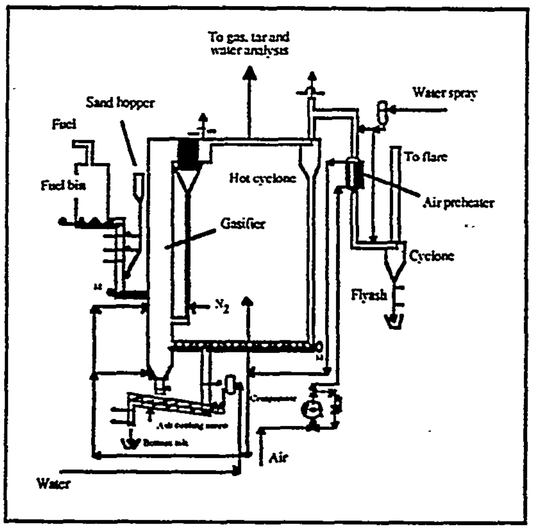

Figure 1. CFB Gasifier Pilot Plant (1986)

To achieve a high carbon conversion of the fuel and a low tar content in the resultant product gas a high operating temperature in the gasifier is preferred. However, there are several other factors that limit this operating temperature, such as the likelihood of sintering in the gasifier (which is especially relevant when utilising agrofuels as feedstock) and the lowering of the chemical heating value of the product gas.

1.2 GRÈVE-IN-CHIANTI WASTE GASIFICATION PLANT

In 1989, TPS sold a licence for its CFB gasification technology to Ansaldo Aerimpianti SpA for the construction of a waste-fuelled gasification plant in Grève-in-Chianti, Italy (Barducci et al, 1995 and Figure 4). As part of this project, TPS conducted test work in its pilot plant using refuse-derived fuel (RDF) pellets as feedstock.

Figure 2. Waste-fuelled Gasification Plant in Grève-in-Chianti, Italy

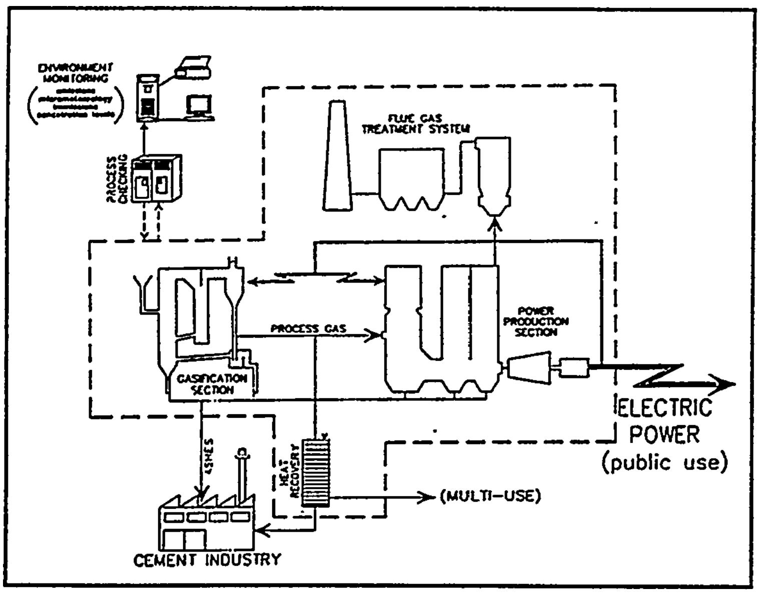

Figure 3. Grève-in-Chianti Plant Process Scheme

The raw gas from each gasifier passes through two stages of solids separation before being fed to a furnace/boiler (Figure 3). Alternatively, part of this raw gas stream can be led to a nearby cement factory to be used as fuel in the cement kilns. Ash and lime are fed to the cement factory as ballast material. The flue gas exiting the boiler is cleaned in a three-stage dry scrubber system (Teller technology from Research-Cottrell) before being exhausted through the stack. Steam produced in the boiler drives a 6.7 MWe steam condensing turbine.

2. ADVANCED POWER CYCLES

Employing a gasifier in a power cycle opens the way to increase the process-energy efficiency substantially by utilising the energy-rich gas in an engine or a gas turbine .

2.1 PRODUCT GAS CLEANING

When biomass is gasified, relatively large quantities of tar are produced. The amount and composition of the tars are dependent on the fuel, the pyrolysis conditions and the secondary gas phase reactions. If the tar is allowed to condense when the gas is cooled down (condensation temperature of tar from woody biomass is 200-500°C) considerable problems with equipment contamination (such as filter clogging) can result. In 1985, TPS started work on developing a hot gas cleaning process for application to the CFB gasifier.

In this TPS-patented process the tars are cracked catalytically to simpler compounds at about 900°C in a dolomite-containing vessel located immediately downstream of the gasifier. By converting the tar in the gas in this way the gas can be cleansed of particulates and alkalis in conventional gas-cleaning equipment. This tar conversion process does not result in any significant reduction in the gas's chemical heating value.

In 1987, the laboratory-scale development of the catalytic tar cracking process had progressed to a level where pilot plant testing was deemed worthwhile. An engineering study showed that a secondary CFB cracker was preferred for implementation in the pilot plant. Intimate mixing between gas and solids, good control of temperature and no risk of plugging from soot were decisive factors in the choice of a CFB.

2.2 DUAL-FUEL DIESEL ENGINE

The cogeneration possibility and the high electric efficiency of a large dual-fuel diesel engine plant fired on product gas from biomass attracted such attention that in late 1987 the pilot plant was extended by the installation of a dolomite-containing CFB tar cracker, a cold gas filter, a wet scrubber (Figure 4) and a modified 500 kW-shaft-power turbo-charged eight-cylinder dual-fuel diesel engine.

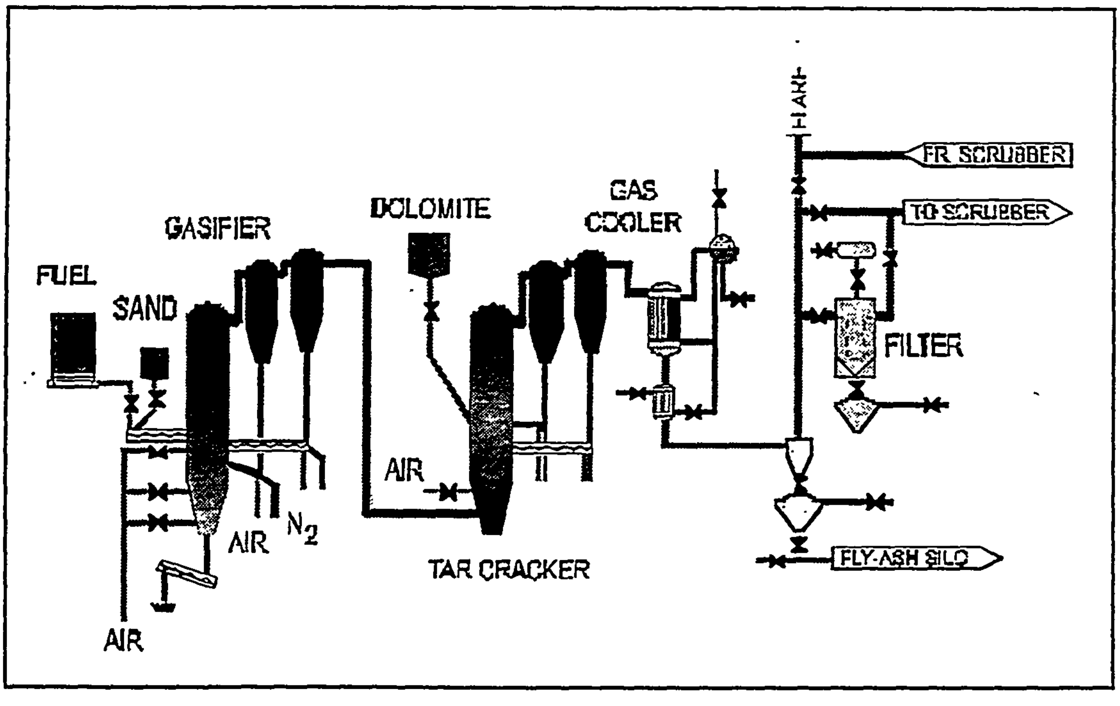

Figure 4. CFB Gasification and Hot Gas Cleaning Pilot Plant (1997)

Following modification of the pilot plant, long-term test work using wood chips as feedstock was performed. The plant was operated for 1300 hours, of which 750 hours also included operation of the motor.

In 1990 and 1991, test work in the pilot plant was conducted utilising several waste materials as feedstock. Domestic and industrial wastes in pelletised and briquetted form were each tested separately.

Figure 5 shows values of the tar content in the product gas, measured upstream of the scrubber, as a function of the operating temperature of the gasifier.

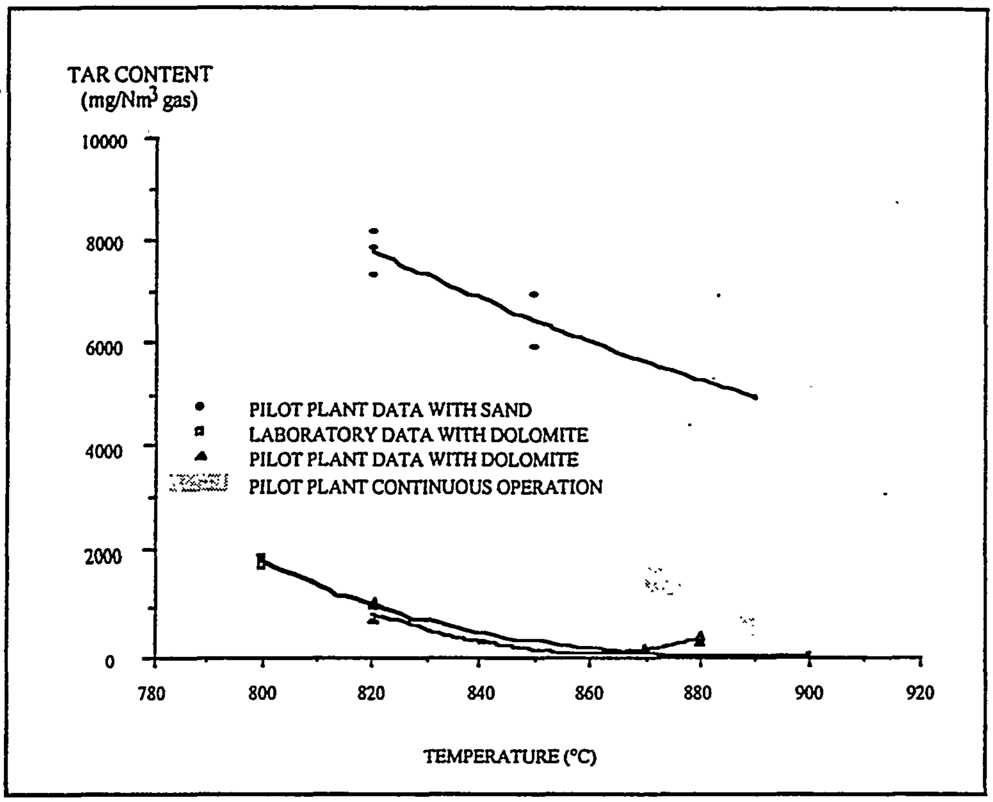

Figure 5. Measured Tar Content in Product Gas

Figure 6 shows the temperature profile of both the gasifier and the tar cracker during a typical pilot plant test.

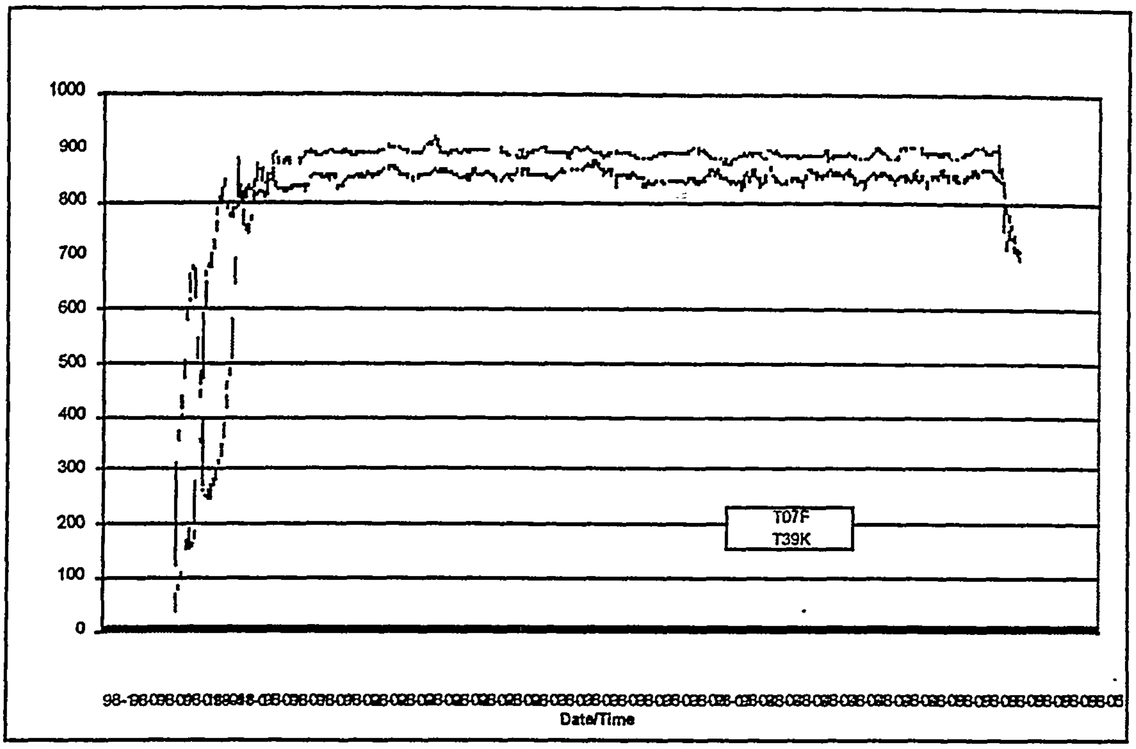

Figure 6. Gasifier and Tar Cracker Temperature Profiles from a Typical Pilot-Plant Test

The total number of operational hours of the 2 MW pilot plant to July 1996 was about 3000. Table 4 is a summary of the pilot plant tests performed at TPS between 1993 and 1997.

Table 1. Pilot Plant Testwork at TPS between 1993 and 1997

Project	Number of tests	Feedstock
BIG-GT Brazil	10	Eucalyptus wood
Fabel	2	Forestry residues
APAS	2	Wood residues/lignite
THERMIE	2	Short Rotation Coppice (SRC)
THERMIE	1*	Short Rotation Coppice (SRC) and forestry residue

* Long term test (600 hours).
In total: 20 weeks with 1900-2000 hours logged time of operation

2.3 COMBINED-CYCLE TECHNOLOGY

In 1990, TPS evaluated the atmospheric-pressure gasification process for application to combined-cycle operation for small- to medium-scale plants (Figure 7). Following a positive outcome of this evaluation, it was decided to promote the commercialisation of biomass-fuelled integrated gasification combined-cycle (BIG-CC) technology.

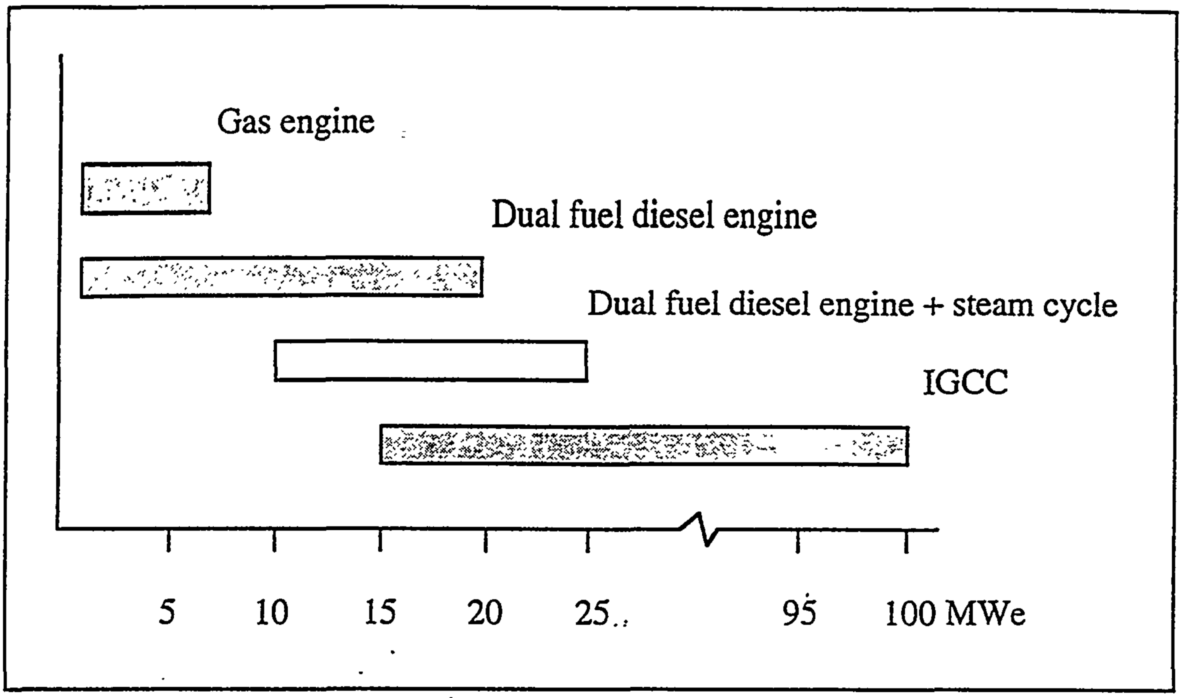

Figure 7. Output Capacity of Different Biomass Gasification System Arrangements

Advantages of the atmospheric-pressure BIG-CC technology over pressurised technology include:

* less development required - reliable operation
* simpler fuel and ash handling systems
* more reliable gas purification - use of gas scrubber ensures that the product gas is of sufficient quality for gas turbine operation
* higher heating value of the product gas
* supplementary firing of the heat recovery steam generator allows plant output to be boosted
* weak process coupling between gasifier and gas turbine
* greater possibilities to use difficult feedstocks (e.g. waste)

The atmospheric-pressure BIG-CC technology (Figure 8) is comprised of the following:

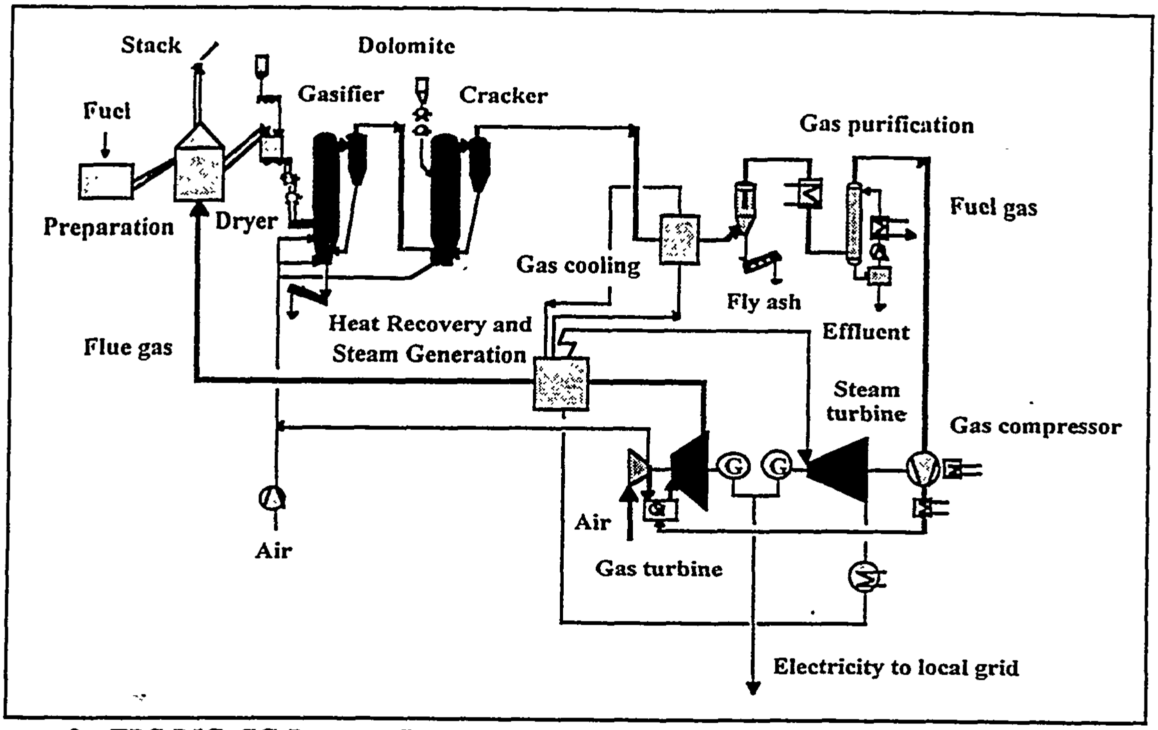

Figure 8. TPS BIG-CC Process System

* Fuel preparation and drying (if required)
* Air-blown gasification in an atmospheric-pressure CFB reactor
* Tar cracking using a dolomite catalyst in a secondary CFB reactor
* Product gas cooling and cleaning in a conventional filter/scrubber unit (to remove particulates, chloride (as $CaCl_2$), tar, alkali, ammonia, moisture and so on from the fuel gas, as required)
* Fuel gas compression in a multiple-stage compressor
* Fuel gas combustion and expansion in a gas turbine-generator, and
* Gas turbine exhaust gas heat recovery by employing a steam turbine generator

The plant is designed to generate low heating value fuel gas. By virtue of the tar-cracking process, no fouling is expected on gas coolers, and a filter combined with a wet scrubbing system can be used for final gas cleaning, thereby avoiding costly hot gas filtration. As the gas is essentially free from tars, the scrubber water will contain only minor quantities of contaminants. Water scrubbing will be very effective against alkalis, and will also dissolve ammonia, so reducing overall NOx formation.

3 BRAZILIAN DEMONSTRATION PLANT

In 1992, TPS received an order to perform the experimental work, engineering studies and basic engineering of a BIG-CC plant as part of phase two of a gasification project sponsored by the United Nations Global Environment Facility (Elliott and Booth, 1993). The goal of this project is to confirm the commercial viability of producing electricity from wood through the use of BIG-CC technology. To fulfil this goal, it is envisaged that a 30 MWe demonstration power plant, fuelled with eucalyptus wood, will be built in Brazil. The gas turbine proposed for the plant is a General Electric LM 2500.

Test work in the CFBG pilot plant using eucalyptus wood as feedstock started towards the end of 1993 and was completed in 1994. In the same period, several other biomass-fuelled tests were conducted in the pilot plant as part of biomass-fuelled projects in Sweden. During these two years more than 1200 hours of pilot plant operation were achieved.

The first stage of phase two of the project also included the evaluation of a pressurised gasification process by the group of companies planning to build the plant. On completion of this stage of the project, the atmospheric-pressure gasification process was chosen in preference to the pressurised process for application in the Brazilian plant. By mid-1996, the full basic engineering of the plant was completed. A go/no-go decision on the construction of the plant is expected in 1997.

4. NETHERLAND'S CHOICE

TPS has taken part in an evaluation by a potential customer in the Netherlands of atmospheric-pressure and pressurised gasification technologies. The customer has selected the atmospheric route as the preferred process, and expects to award the contract for construction of a 30 MWe plant later this year (Figure 9). The plant shall be fuelled by park wood and demolition wood. Start-up is scheduled for 1999.

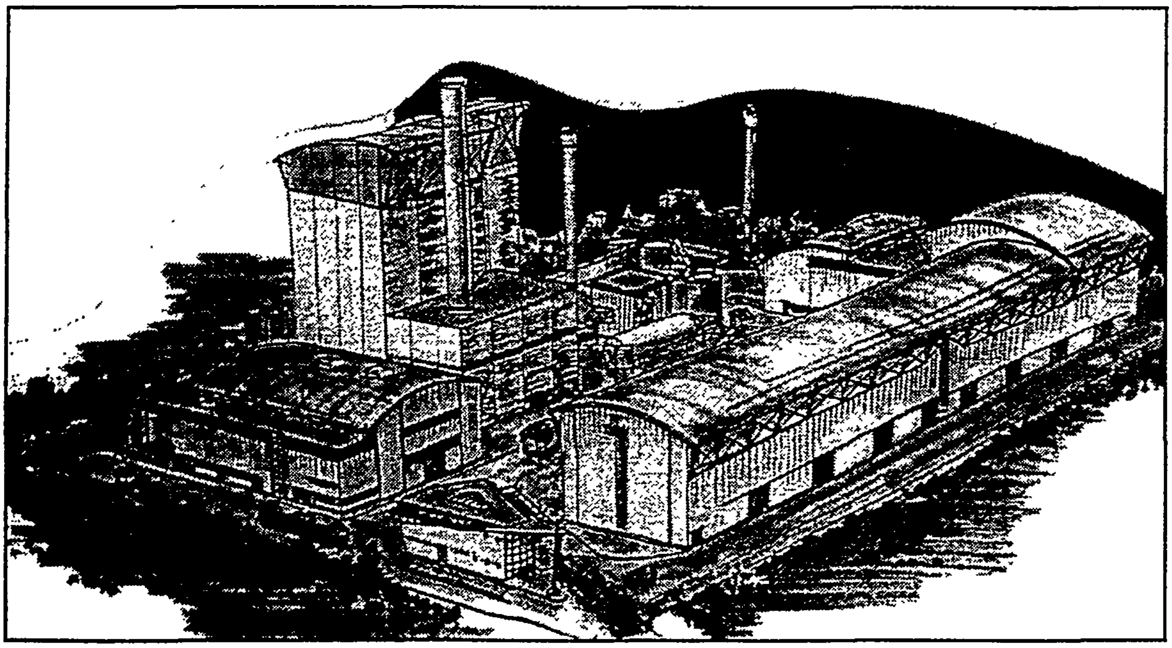

Figure 9. Artist's Impression of the Plant in the Netherlands
(as proposed by Royal Schelde, NBM and TPS in tender for project)

5. EUROPEAN UNION POLICIES

The 1987 report of the World Commission on Environment and Development (Anon, 1996c) stated that the principal rationale for supporting renewables is the concept of sustainable development and, in particular, the recognition that renewable sources of energy are inherently more environmentally benign than fossil fuel sources. Renewable energy sources can displace fossil fuels, which currently are responsible for polluting emissions which lead to increased acidity of rain, in particular SO_2 and NO_x. The report indicated that every effort should be made to develop the potential for renewable energy which could form the foundation of the global energy structure during the 21st century. This tenet has been endorsed by the UK and other Governments at the 1988 Toronto and 1992 Rio de Janeiro summits.

The European Commission's TERES report (Anon, 1996b) estimated the overall potential for biomass energy to be 180 Million tonnes of oil equivalent (Mtoe) of final energy consumption for the 12 member states of the Commission, by far the largest potential. If the significant biomass resources that the three new member States possess is included, the overall potential of the sector is estimated to be over 200 Mtoe.

The European Commission requested biomass gasification proposals to be submitted to its 1994 DGXVII Energy THERMIE Programme. The Commission recognised that although these technologies were well advanced at research and development stages and had the potential to enable higher conversion efficiencies to be achieved, they could not compete with electricity prices currently being paid in the open electricity markets. Three projects were selected for development, based in Italy, in Denmark and in the UK (the ARBRE project). Each are in the range 10-15 MWe and will demonstrate the efficient use of biomass to produce electricity and heat from atmospheric and pressurised gasification processes. As it was a targeted call, it specifically identified a market area ready for technical demonstration. The development of ARBRE will realise policy objectives at European and national level as it will:

"Demonstrate heat and power production from biomass (short rotation coppice) via gasification on a significant scale for development on a fully commercial basis, having due regard for all environmental and conservation issues. The project will make data available on clean, efficient energy production, in combination with treated sewage sludge application, to enable its replication in member states and elsewhere." (Anon, 1993)

On 4 July 1996, the European Parliament adopted a report (Anon, 1996d) on a European Union action plan for developing renewable energy sources. The report stated that an increased share of renewables in the community's energy balance would make a contribution to both its security of supply and environmental protection. In the long term renewables will constitute the Union's main sustainable energy source. The report called for the proportion of renewable energy sources used in the European Union to be increased from a current 5% to 15% of all primary energy use by the year 2010.

6. UNITED KINGDOM POLICIES

The UK Government's renewables policy is to stimulate the development of renewable energy sources, wherever they have prospects of being economically attractive and environmentally acceptable, in order to contribute to:

- Diverse, secure and sustainable energy supplies;
- Reduction in the emission of pollutants including greenhouse gases, carbon dioxide and methane;
- Encouragement of internationally competitive renewable industries.

UK Energy Paper 62 (Anon, 1994) demonstrates that energy crops and forestry residues have the potential to supply over 60% of the 1992 UK electricity requirement. Realistic targets are currently considered to be 20% of the total figure. The UK plan is to develop 1500MW of new generating capacity from renewable energy sources. Renewable energies have been developed via orders in its Non Fossil Fuel Obligation (NFFO). Four NFFO tranches have already been developed. ARBRE was included in the third tranche (the first time the biomass band had been included) with a 15 year contract to sell electricity into the local electricity grid.

7. ARBRE ENERGY BIG-CC PLANT

The gasification and hot gas cleaning technology will be demonstrated at close to commercial scale in an EU-Thermie-sponsored project (Pitcher and Lundberg, 1995). As part of this project, an 8 MWe IGCC plant using short-rotation forestry (SRF) as feedstock will be built in the UK (Figure 10), with start-up scheduled for 1999. TPS is part of the joint venture company, ARBRE Energy Limited, formed to build, own and operate the plant. The company is the recipient of a 15-year NFFO (Non Fossil Fuel Obligation) contract, which provides a guaranteed preferential price for the electricity generated. As part of the project, tests were conducted in 1995 and 1996 at the pilot plant using willow as feedstock.

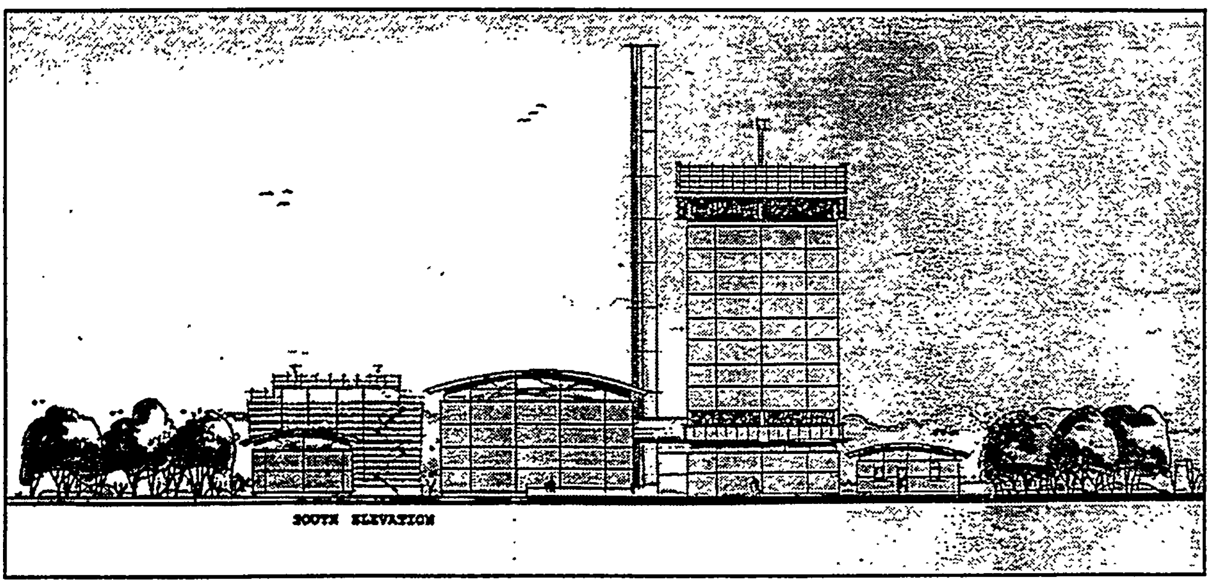

Figure 10. Artist's Impression of the ARBRE Energy Plant

8. ECONOMICS OF BIOMASS

The atmospheric-pressure BIG-CC technology is considered to be potentially competitive in the long term, with pressurised BIG-CC systems up to a size of 60-80 MWe (Blackadder et al, 1992).

The capital cost of a 'green field' 30 MWe atmospheric-pressure BIG-CC demonstration plant is expected to be up to US$ 2700/kWe (Table 2). As no atmospheric-pressure BIG-CC plants are in commercial operation today, there is no effective database for predicting the long-term future cost of electricity produced by such plants. However, a technical-economic study by

TPS of the economics of such plants for combined heat and power generation in Sweden suggests that when reasonable assumptions are applied to reducing the capital cost of the plant, by virtue of moving from demonstration to fully commercial units, and taking into account likely advances in gas turbine technology over the next 10 years, the typical capital cost of a complete 55 MWe BIG-CC plant should be as low as US$ 1400/kWe. With a net electric efficiency of 47% (based on the lower heating value of the fuel), the cost of electricity produced by such plants is expected to be competitive with that produced from alternative fuel sources.

Table 2 First Demonstration and 'Nth' BIG-GT Plant Cost

	First plant	'Nth' plant
Plant size (MWe)	30	55
Wood preparation	4000	4000
Gasification	24000	16000
Combined-cycle	28000	33000
Sire-preparation and buildings	3000	3000
Indirect costs	20000	15000
Contingencies	5000	4000
Plant total cost ($)	85000	75000
Specific cost ($/kWe)	2700	1400

9. BUSINESS OPPORTUNITIES FOR BIOMASS GASIFICATION

The immediate business strategy of TPS is to demonstrate its hot gas cleaning technology through the operation of commercial-sized biomass-fuelled IGCC plants in Sweden, Brazil, the UK and the Netherlands, or in at least one of these countries. TPS continues to develop the same process for application to waste fuels with the intention that it be demonstrated at commercial scale within a decade.

If the technology meets expectations, the global implications could be significant, with biomass possibly contributing to power supplies on a scale similar to nuclear and hydro by the mid-twenty-first century. It could provide a basis for rural development and employment in developing countries, and utilisation of excess croplands in the industrial world.

From the environmental standpoint, the technology has much to commend it. Sustainable-grown biomass used for power generation is essentially 'carbon neutral' to the atmosphere; energy plantations can be designed for bio-diversity with multiple tree species; and extensive afforestation offers the opportunity to rehabilitate deforested or otherwise degraded lands.

The future for biomass-fuelled power generation will depend not only on a reduction in capital cost of plants but also on external factors such as how the greenhouse effect influences energy taxes, CO_2 fees, and so on. Initiatives from major companies in the pulp-and-paper industry, the forestry industry and the power industry will also affect implementation of the technology.

In many countries there are factors that favour the construction of biomass-fuelled power generation plants such as preferential electricity prices and loans with low interest repayments for 'green' power plants. When the technology is mature it will have the potential to compete without subsidies.

The use of low cost feedstock will mean that atmospheric-pressure combined-cycle technology will be in a position to compete economically with fossil-fuelled power plants within the next 10 years.

10. PRIVATELY-OWNED R&D

TPS Termiska Processer AB (formerly a part of Studsvik AB) is a privately-owned research and development company based in Sweden. The company has 50 employees and works in the field of energy and environmental process research and technology development. The heart of the company's operation is basic and applied research, process and product development and process design within the heat and power generation sector, with special emphasis on the environment. Commercialisation of the technologies developed by TPS is normally through licensing to, or by joint ventures with, experienced engineering companies.

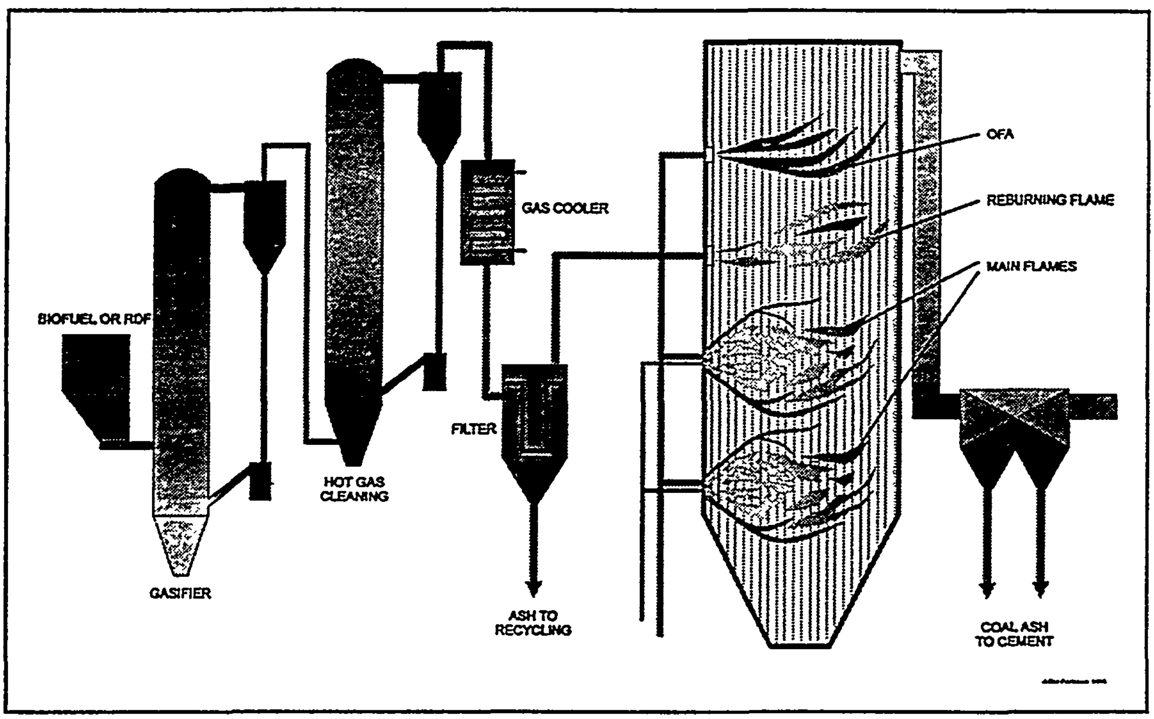

Figure 10. Proposed Waste Gasification Plant

One of the main activities of the company is the development and commercialisation of environmentally sound gasification technology for the efficient production of heat and/or electricity from biomass or waste.

11. FUTURE

The immediate business strategy of TPS is to demonstrate its CFB gasification - gas-cleaning technology for relatively clean fuels such as woody biomass through the operation of commercial-sized combined-cycle plants and then extend the application to residues from waste recycling, including RDF.

Gasification of waste fuels rather than conventional waste incineration/energy recovery technology provides the key to higher overall plant efficiencies. This advantage combined with competitive investment costs will mean that waste gasification technology will play an ever increasing and important role in the field of waste treatment.

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BIOMASS EVENT IN FINLAND 2nd- 3rd Sep 1997

BUSINESS FORUM/COMPANY PROFILE
Companies:

Agrobränsle AB
Aston University
BMH Wood Technology Oy
Biowatti
CARBONA Inc.
Condens Oy
COWI
Factorias Vulcano, S.A.
Finnish Technologydata Ltd.
Foster Wheeler Energia Oy
Foundation Erudia
Geco-Gabinete Tecnico E Controlo De Moldes Em Fabricacão, LD
HoSt vof
IVO Power Engineering
JEDbiosol
KIC International
Koba
Kvaerner Pulping Oy
OY LOGSET AB
Ministry for the Environment, Physical Planning and Public Works, Greece
Netherlands Energy Research Foundation (ECN)
Nordist
Osmo·Kaulamo Engineering Ltd.
Public Power Corporation
Sermet Oy
Tecnitermo
TPS Termiska Processer AB
Vapo Oy Energy