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Bioenergia Research Programme

1 Background and objectives

1.1 Background

The programme is based on the general justification for increasing the use of biofuels, the abundance of raw materials and the need for more energy, particularly electricity. However, the competitiveness of new bioenergy sources that would allow increased use is a problem.

The general justifications for increasing the use of biofuels are that by increasing the use of bioenergy

- CO_2 emissions from energy production can be reduced
- economically viable uses for wood from first thinnings can be created through integrated production methods that increase the production potential of wood for both merchantable wood and energy production
- the degree of self-sufficiency in energy production can be improved, and potential for new companies and new employment can be created
- technology and equipment exports in the field can be enhanced.

Finland has set targets for reductions in nitrogen oxide, sulphur dioxide and carbon dioxide emissions in the 1990s. The best results have been achieved in sulphur emissions: the objective of an 80% reduction from the 1980 level has almost been achieved. The objective to reduce nitrogen oxide emissions by 30% by 1998 will probably not be attained. The stabilisation of carbon dioxide and other greenhouse gas emissions at the 1990 level in accordance with the Rio Convention is the most difficult goal. Increasing the use of biofuels will decrease carbon dioxide and sulphur emissions above all. In 1997 the EU set target to reduce CO_2-emissions by 10 % compared with 1990 level. Finland's share is to reduce to the 1990 level. This means 8 % reduction with today's level.

Finland has an abundance of bioenergy resources. The annual volume of peat used is only a fraction of the resources available, and the growth rate of Finland's forests is greater than the volume of wood cut down annually. It is estimated that nurseries and the management of young forests would yield the equivalent of nearly 0.5 million tonnes of oil (toe) in wood fuel in a year. The production potential from first thinnings is also about 0.5 million toe annually. However, the main production potential is in the logging residue of final cuttings, which could easily produce about 1.0 million toe of

wood chips for burning annually. In all, the production potential for wood fuel is about 2.0 million toe; this means an annual volume of over 10 million cu.m of wood biomass, taking technical, economical and environmental aspects into account.

The Council of State approved the bioenergy promotion programme on 7 April 1994. The objective is to increase the use of bioenergy by at least one quarter from the present level over the next 10 years. This would mean an increase of the equivalent of 1.5 million toe by the year 2005.

The present Council of State took a decision in principle on energy policy on 21 December 1995. This decision states that the Government will continue to implement the bioenergy promotion programme. The main focus of the programme is on increasing the use of wood for energy production. The significant status of bioenergy and other renewable energy sources in publicly funded energy technology research and commercialisation is emphasised. In order to promote the competitiveness of domestic energy sources, demonstration plants and R&D that creates new industry and increases exports are subsidised. Investment and tax subsidies biased in favour of the energy market are being phased out, but separate goals established for bioenergy use are being taken into account. The goverment energy strategy proposed in summer 1997 also emphasises to increase the use of bioenergy, espesially forest fuels.

In 1994, the Commission published an estimate of the present and future use of bioenergy in the EU Member States. This estimate shows that the objective is to increase the relative significance of bioenergy. The Commission has set a target of raising the share of renewable energy sources in total energy production from 4% in 1991 to 8% by the year 2005 (8% is equivalent to 109 million toe). The objective in electricity production is to triple production to 135 TWh (excluding large water power stations). The objective in transport is that biofuels have a 5% market share by 2005. According to the Green Paper on renewable energy sources, distributed by the EU in November 1996, the Commission proposes that the objective should be for the share of renewable energy sources to be 12% in 2010. Bioenergy would account for the largest part of this. The estimates for future use of biomass are large compared with Finland, so the export potential for the technology being developed is considerable.

Suomi on asettanut tavoitteet sekä typenoksidi-, rikki- että hiilidioksidipäästöjen vähentämiselle 1990-luvulla. Parhaat tulokset on saavutettu rikkipäästöjen vähentämisessä: 80 % vähentämistavoite vuoteen 1980 verrattuna on lähes saavutettu. Typenoksidipäästöjen osalta 30 % vähentämistavoite vuoteen 1998 mennessä jäänee saavuttamatta. Hiilidioksidin ja muiden kasvihuonekaasujen päästöjen vakauttaminen vuoden 1990 tasolle Rion pöytäkirjan mukaisesti on vaikein tavoite. Biopolttoaineiden käytön lisääminen vaikuttaa erityisesti hiilidioksi-, mutta myös rikkipäästöjä vähentävästi.

1.2 Objectives

The main objectives of the BIOENERGIA Research Programme are:

- to develop new methods of producing biofuels with the aim of making them competitively priced compared with imported fuels. The most promising pro-

duction methods will be demonstrated through pilot schemes.
- To develop 3 - 4 new pieces of equipment or methods connected with the handling and use of bioenergy and bring them at least to the demonstration stage.
- To produce basic information on conversion techniques and evaluate the quality, usability and environmental impacts of the products as well as the overall economy of the entire production chain and to create 2 - 3 conversion methods for follow-up development by industry.

Clear-cut objectives have also been defined for the programme's research areas (the production of wood and peat, the use of bioenergy and biomass conversion).

For large consumers, the costs of producing wood-based fuel on site will fall to FIM 45/MWh, which means that the annual use of wood-based fuels can be increased by nearly 1 million toe/a. Peat production costs will decline by 20% compared with the 1992 level (FIM 5 - 6/MWh).

Prioritising the production of wood-derived fuels

BIOENERGIA is concentrating on fields that are important for Finland's energy supply structure, self-sufficiency and overall economy since international research information is not available on all these aspects of the energy picture.

The principal research areas are:
- development of production technology for wood-derived fuels
- Peat production
- The use of bioenergy
- Biomass conversion

In addition, the programme includes separate projects in which scientists are studying the production of biofuels in open fields and the utilisation of solid wastes and sludges in energy production.

Production technology for wood fuels

Development work is being carried out in both the separate production of wood-derived fuels and in their integrated production. The viability of the methods will be tested in pilot-scale demonstrations.

Integrated methods in which wood fuel is brought to the power plant from the forest in connection with roundwood procurement for the wood-processing industry offer a number of advantages. A shift from the individual timber grade method to undelimbed harvesting can nearly double the amount of wood obtained from the same area. The benefits of mass-production methods can be applied to wood handling, with consequent cost savings.

The R&D projects are directed at improved methods of harvesting undelimbed or partially delimbed trees, the separation of whole-tree chips to produce fuel and industrial raw material as well as the bundled delimbing and debarking of roundwood.

In separate wood fuel production the wood is harvested only for energy use. In this case use is made of stands that are unsuited for industrial raw material as well as the harvesting residue of stands felled for industrial use. Most often the wood has to be harvested in forests consisting mainly of small-diameter trees, which results in high harvesting costs per unit.

The programme is studying the production of wood fuels from the harvesting residues of final fellings, harvesting techniques for small-diameter trees that are unsuitable for industrial use, and wood fuel product on farms.

Peat production

The main focus of the research is to find better ways of obtaining peat from shallow bogs and to develop production methods and machinery. The goal is to lower production costs and to reduce emissions from the production process. Production costs can be lowered by shortening the preparation time of bogs, by employing covered drains in the production fields and by using modern production design and control methods as well as work and traction machines incorporating a maximum amount of automatic functions. Other ways of lowering total production costs are the efficient utilisation of shallow bogs and post-farming peat areas as well as the integrated use of peat production machinery in the production of wood and other biomass.

Use of bioenergy

Research into the use of bioenergy is concentrating on applications in the small size class (under 20 MWth) as well as the handling of biofuels in all size classes. The objective is to eliminate the technical obstacles standing in the way of increasing the use of wood and peat fuels as well as to develop economical and environmentally sound energy production technology for small-scale applications.

The forest industry offers a natural area for pilot demonstrations of the use of biofuels. Not only is the forest industry the largest consumer of energy in Finland, it is also the largest producer of energy from forest sources. Other potential demonstration sites are different-sized heat and power plants that burn indigenous fuels.

Biomass conversion

Research into biomass conversion is concentrating on solid biofuels and spent liquors from the forest industry. The objective is to convert these and other by-products into gasified, liquefied and solid fuels. Their main users are likely to be small-scale power plants that are based on steam turbine, diesel and gas turbine technology.

The programme also addresses the production of fuels and lubricants for road vehicles from raw materials produced on farms and in the pulp industry. The main research projects deal with liquid fuel production from the by products of the pulp industry (black liquor, lignin, sulphate soap and tall oil) as well as the production of liquid fuel from wood and peat by means of the flash pyrolysis method.

It is possible to use set-a-side agricultural land for non-food production. In 1995 the

management group of the research programme, together with the Ministry of Agriculture and Forestry, assessed the need to extend the research programme to the study of agrobiomass by setting tangible goals for this area. It was decided to continue the work on a project basis, and to produce a separate report at the end of 1996 when the present project ends.

1.3 Programme financing

The original projected financing framework for the bioenergy research programme comprises FIM 210 million, or FIM 35 million per annum. Contributors include the Ministry of Trade and Industry and the Ministry of Agriculture and Forestry.

Total funding granted in 1993-1995 totalled nearly FIM 150 million, which exceeded the plan by nearly 50%. The share of companies and other financiers in the overall funding continued to increase to nearly 60% in 1995.

Table 1. Financing for the BIOENERGIA research programme.

Financer	Planed financing Total, milj.mk					
	yearly	1993-98	1993	1994	1995	1996
TEKES/MTI total	16	96	27	20	19,4	9,76
-research projects	*8*	*8*	*8*	*5*		
-corporate projects	*8*	*7*	*5,2*	*2*		
- demonstration projects	*11*	*5*	*6,2*	*1,8*		
- EU structural fund	*2,4*					
MAF	7	42	1,5	2,8	2,7	2,5
Companies and other financiers	12	72	22	23	29,4	19
TOTAL	**35**	**210**	**50,5**	**45,8**	**51,5**	**33,1**

2 Results in main research areas

The speciality of the BIOENERGY research programme is tangible goals and a strong corporate input in management group work and research institution project assessment. In 1995, the BIOENERGY research programme was the third largest of the then current Tekes technology programmes.

Some of the goals in wood fuel and peat production technology have already been attained, well ahead of schedule. Demonstration of new technologies has begun. Many projects have already progressed from research to demos, and new export products have been created.

2.1 Wood fuel production technology

The wood fuel production research area has produced new information for development work in working methods for final cuttings, the biomass balance and properties of

pine and spruce from early thinnings, the basics of chain delimbing and debarking, the basics of compressing, the separation properties of wood chips and pneumatic conveyors. A cost calculation model has been prepared for small scale production, and the bases for measurements and quality of chopped firewood have been established.

Firewood production

Six commercial prototypes have been tested for forest work in the 'farmer' class. This represents a significant technological advance from chainsaws to new felling and forest transport technologies. Also, 'heat entrepreneurship' has been developed in wood chip production; this means that the wood chip supplier also carries responsibility for heat production, thus avoiding the difficult problem of assessing the energy content of the wood chips delivered.

New equipment is being commercially tested for the machine production of traditional chopped firewood, applying recyclable processing and distribution technology «from the forest to the customer».

Wood fuel production in nursery thinnings

Nursery management instructions have recently been upgraded to state that thinning should be done later than previously, i.e., when the trees are 4 to 7 m high. The trees felled are then large enough to produce a cumulative total of 40 to 50 cu.m of biomass per hectare (at least 100 cu.m of wood chips).

The annual need for nursery management area is about 200,000 ha. It has been cautiously estimated that nursery management and young forest maintenance could easily yield 2.5 million cu.m (nearly 0.5 million toe) per annum.

Wood fuel production in commercial thinnings

The main development focus in wood fuel production from first thinnings has been the integrated production of merchantable wood for industry, and wood fuel.

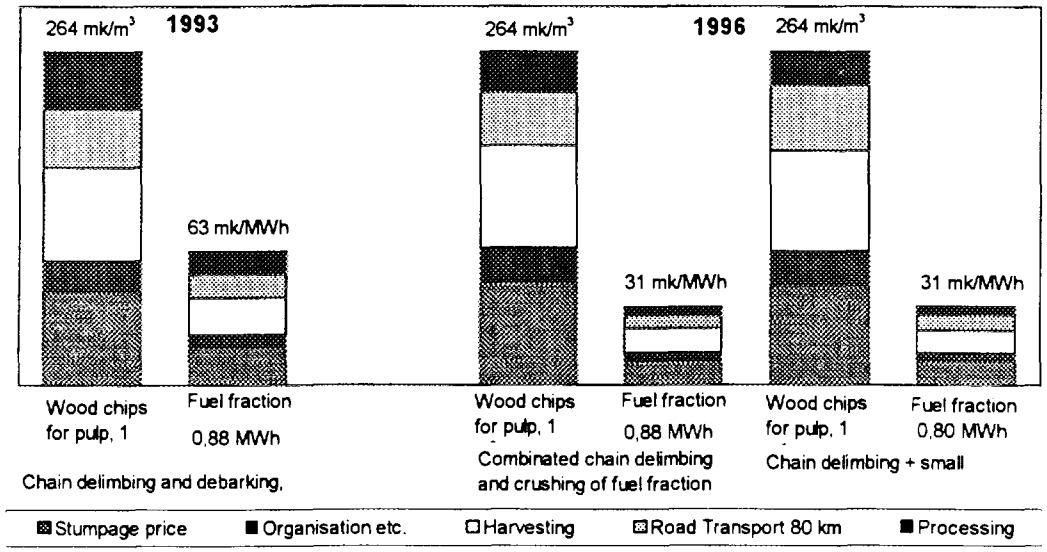

Fig. 1. Wood fuel production costs. Pine from first thinnings.

The cost comparison of the use of pine from first thinnings as wood fuel shows that integrated methods provide a competitive alternative for the acquisition of wood from first thinnings, on condition that the raw material is of acceptable quality for the forest industry. The goal of FIM 45 per MWh in wood fuel production costs seems to be attainable with the proposed methods.

The calculation is based on a comparison between the single-tree method and the bulk handling method, where the bulk handling method has reduced the cost per cu.m from FIM 276 to FIM 264 between 1992 and 1996. The price of the energy component is FIM 45 per MWh. In comparing the new methods, the price of wood chips for pulp has been kept the same.

The production potential for the whole of Finland has been estimated at about 0.5 million toe per annum. The stage of development of the production methods shown in the table varies: some could be implemented immediately with existing equipment, while others still require product development for essential equipment or a demonstration of the entire chain.

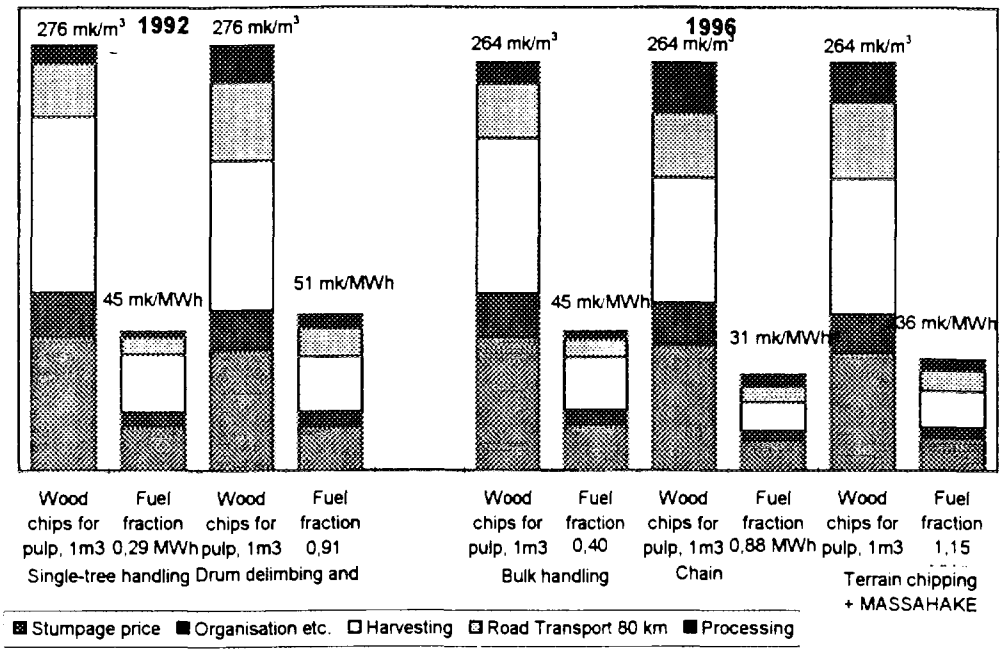

Fig. 2 Development of methods in the research programme and techno-economical comparison.

The harvesting of wood from first thinnings and wood fuel production has been examined mainly with pine. This is justified in that stands with pine as the major tree comprise about 80% of all early thinnings. The requirement for early thinnings in private forests amounts to at least 6 million cu.m of stemwood per annum.

The chip harvester developed by Oy Logset Ab has already reached the commercial stage. Four machines are in operation and four more on order. Exports to Germany are also getting under way.

The multi-tree harvester for the handling of small trees attained a 20% more efficient result per working hour in the sites examined than single-tree felling. This translates to about FIM 5 to 15 per cu.m in the purchase price. The development work was undertaken by Outokummun Metalli Oy and Metsäteho in co-operation with Enso Oy. The machine is a commercially finished product.

The general technical feasibility of the MASSAHAKE method was established in a demonstration plant that was started up in Kankaanpää in June 1995. The research programme has continued to develop sub-categories within this method.

The problem in chain delimbing and debarking is the high proportion of bark in wood chips in winter. To reduce this, a study of chain delimbing and debarking with a research device has been started. A pilot installation applying chain delimbing and debarking technology combined with small drum debarking was completed at a wood processing terminal in 1995. The demonstration project managed by Hooli Oy has produced a machine combination based on chain delimbing and debarking together with

hammer crushing; this product was tested in 1995.

Wood fuel production from final cuttings

According to the cost comparison performed in the research programme, the goal of FIM 45 per MWh set for the costs of production methods suitable for the harvesting of logging residue from spruce-dominated final cuttings is attainable.

The production potential in final cuttings in Finland is 1.0 million toe per annum. The development stage of the production methods outlined in Fig. 3 varies: some methods could be introduced immediately with existing equipment, while in most projects essential equipment needs to be further developed or the entire chain demonstrated. Fig. 3 shows the current status according to the goal of 100 km transport distance defined in the programme. In practice, many of the new methods are already competitive with transport distances under 60 to 80 km.

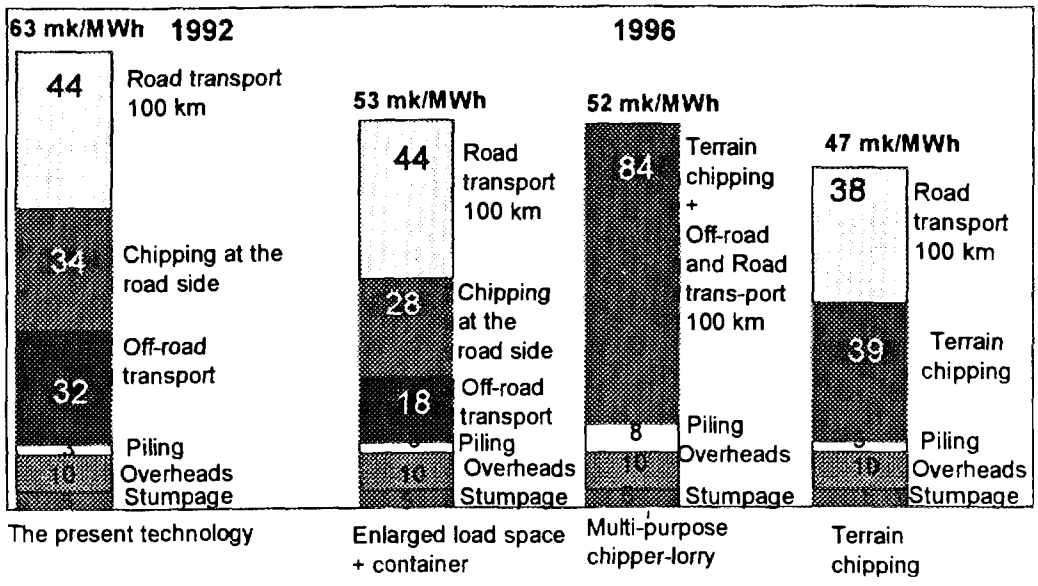

Fig. 3. Cost comparison of production chains of logging residue chips researched and developed in the research programme.

Forest transport distance 250 m, road transport distance 100 km

The basic method in harvesting logging residue in final cuttings has at its best, in a demonstration project in the Mikkeli area, gone below FIM 43 per MWh using commercially available technology. The method costs were assessed at FIM 60 per MWh in 1992. The method has been further developed by Kotimaiset Energiat Pekka Lahti Ky, producing a new efficient chipper called Evolution. The new final cutting method

based on the Chipset terrain chipper has already reached the commercial stage.

A competitive price can be attained using a production chain featuring a MOHA-SISU truck fitted with a chipper, and transfer containers. MOHA-SISU enables a new kind of production logistics for firewood chips, with advantages over the traditional method and other production chains. The method was introduced for commercial testing in 1995.

Developing the method on the basis of the Jaakko Pöyry concept offers further potential. The logging residue would be harvested with the same equipment and at the same time as the fibre wood is transported to the roadside. The chipping is managed with a transfer container fitted with a chipper, and a three-container module for long distance transport.

An integrated harvesting method for fibre stemwood and energy wood based on whole-tree felling has also been tested in spruce-dominated final cuttings; in this method, the harvesting costs for logging waste would be as low as FIM 10 per cu.m. This would resolve into less than FIM 45 per MWh in production costs over an 80 km range, provided that the development of temporary storage arrangements can be solved. The method is ready for demonstration.

2.2 Peat production

The main objects of research in peat production are ditching and maintenance technology, drying technology, machine technology, method technology, integration of wood harvesting and peat production, and implementing the results of the Optimiturve research programme in practice. The theoretical side in peat production research has also gained importance. Knowledge of the basics of drying in particular forms a foundation for other development work and is an important link in the chain. Research has also produced new information on new materials, underground drainage and the use of wood chippings as covering for peat stockpiles.

The main results during 1993 - 1996:

- It has been verified, by using a calculation model, that it is possible to increase the distance of open ditches from 20 m to 60 m by using underdrainage. The results will be verified in practice.
- A numerical model, which enables to construct the optimal structure of the peat layer, has been developed for the drying of peat.
- A compressed peat production process (Compeat) has been developed to increase the drying efficiency of peat. The main parts of the process have been investigated in the laboratory and in practice.
- A peat conveyance method (Tarkkaturve) and a sod peat spreading wagon method to reduce the amount of residual peat on the peatland have been developed.
- A light and fireproof equipment chain comprising a plastic miller, a light weight loader and a collecting wagon has been developed for the Tarkkaturve method.

- Dust emissions have been eliminated in the new pneumatic harvester developed. It is also by 10% more efficient than the conventional collecting wagon. Development work on the more efficient pneumatic harvester is being continued.
- The present state and development needs of small-sod production have been surveyed. The small-scale producers are a significant group of peat producers. There were about 200 small-scale peat producers in Finland in 1996. Their total production amounted to 3.3 TWh, and the amount of peat produced for non-energy purposes was 0.265 million m^3.
- Combined harvesting of peat and wood has been developed. The use of wood chips for covering peat stockpiles has been extensively studied by Vapo Oy. The method is suited for use in particular in Northern Finland.

The research results show that the objective of the peat production research area is attainable if the partial goals are reached. Increasing the distance between open ditches from 20 m to 60 m will lower production costs by 5 %. Increasing the use of solar energy from 30 % to 40 % will lower production costs by 8 %. The reduction of the amount of peat remaining at the bottom of the peatland from the equivalent of 3000 MWh to 1500 MWh will lower production costs by 6 %, the development of light and fireproof machines by 3 % and combined wood harvesting by 3 %. Achieving these subgoals will reduce peat production costs by over 20 % altogether.

2.3 Bioenergy use

New information in the area of bioenergy use has been produced on the basics of drying, drying models, basics of fireplace combustion and catalytic cleaning of flue gases.

The bioenergy use projects have focused on fuel treatment and drying technologies and on developing building-sized heating equipment. In fuel processing, projects have focused on fuel input in pressurised power plant processes.

Development work on two different types of dryer has been started as corporate projects. One of the dryers is being tested on an installation scale at a small power station in Kuusamo. This bed-mixing dryer gets its drying energy from the hot sand of the fluidised bed. The dryer increases the district heating output of the plant by about 20 percentage points. The method is ready for demonstration at a larger power plant. In the second dryer type being developed, the fuel is dried with flue gases in the bed. The target of final moisture is 15% to 20%. The method is ready for demonstration.

New demands are being placed on fuel handling technologies in pressurised power stations. Two different types of sequence-guided piston feeders are being developed as corporate projects for fuel input. The design of both is intended to cut investment and operating costs in comparison with the bin system. The feeders have been tested under near-actual conditions with good results. The devices are ready for demonstration.

Högfors Lämpö Oy has demonstrated an automatic heating system the development

work on which was begun in the research programme. On the basis of experience gained from the prototype boiler (200 kW), a 600 kW boiler was built and, after laboratory testing, installed as the heating system at a market garden in 1995. The experience in using this boiler has been very good. The only problems have been caused by unhomogeneous quality of the fuel.

Catalytic cleaning of flue gases from furnaces has succeeded, but for naturally ventilated fireplaces it seems that it is necessary to build a bypass duct for the ignition stage. Results show that introduction of a catalyst would be possible with present technology in all fireplaces except storage furnace, which need further development. The application is ready for product development.

2.4 Biomass CONVERSION

In 1995, the research on biomass conversion has concentrated on upgrading by-products of the pulp industry and conversion of solid biomass into liquid fuel through flash pyrolysis. Characteristics, combustion properties and basics for use in diesel engines of pyrolysis oil are examples of data produced by research in this area.

CONVERSION OF CRUDE SOAP

Alternatives of converting different liquid fuels from extractives of black liquor in pulp mills have been surveyed. These fuels could possibly be used both in boilers and in engines either in mills, in transports or for sale to the neighbourhood. The work has focused on mixed soap containing birch, as it cannot be used in pine oil distilleries due to its poor grade, but is burnt in the recovery boiler. The soap contains inorganic salts and sulphur and hence should be converted into a cleaner final product of suitable viscosity. High-pressure treatment in liquid phase has been studied by laboratory tests, and high-grade fuel oil or diesel oil were obtained as products. Preliminary evaluations proved that inexpensive fuel oil can be produced with the method applied, but a rather high investment is required. Preliminary tests with an atmospheric concept will be continued and alternatives of using product oils in engines, as chain saw oils or for other lubrication purposes, will be surveyed.

Research on flash pyrolysis has been continued by determining the characteristics of the fuel particularly for use in the diesel fuel and light fuel oil classes. Flash pyrolysis means decomposition of fuel in an oxygen-free environment very rapidly, in less than a second. This method is very well suited to biofuels. According to a study by Neste Oy, the use of flash pyrolysis oil as a substitute for light fuel oil is most feasible when pyrolysis oil is mixed with light fuel oil, but even then the burners need to be modified. Research on the production and use of flash pyrolysis oil has been continued by acquiring three laboratory-scale testing apparatuses. The goal is to develop the so-called ITP concept of the Technical Research Centre of Finland (VTT) to the demonstration stage in the next few years. Tests on a 1.5 MW power station engine were begun in early 1996 with 60 tonnes of imported wood pyrolysis oil. The test results were promising, and development work on a stationary power station engine for pyro-

lysis oil will be continued.

BIOMASS GASIFICATION AND GAS ENGINE POWER PLANTS

A new atmospheric circulating fluidised-bed gasifier has been constructed at VTT Energy. The first test runs concerned the effect of operation conditions on the reduction of tar content in the product gas. Different catalytic and other cleaning devices and a small gas engine have been installed in the test rig. Techno-economic assessments of gasification-engine power plants fired with different fuels have also been carried out. Gas cleaning at high temperature to eliminate water scrubbing, and applications of more profitable dryers, e.g., a storage dryer, were identified to be future objects of development. A survey of various biomass power plants in different parts of the world was also carried out to create a basis for the future development of small-scale power plants. It was concluded that competitive production costs, not only efficiency but also investments, will be of decisive significance to the success of these power plants, not so much the availability of biomass. Although the quantities of biomass available are very large, tailor-made solutions based on present power plants are required in different countries. New innovations are required, in particular, when considering the use of different agrobiomasses, sugar cane and bagasse, RDF, etc., for energy production.

CFB gasification has also been developed for various types of RDF fuel, with regard to using the cleaned product gas in existing big local PC boilers. Fixed-bed gasification will be developed for engine applications.

3 Result effectiveness

3.2 Technological improvements

Table 2 shows the technological improvements achieved in each area. The results have also been grouped as 'knowledge', 'technology', 'small equipment' and 'methods'. The progress of each project (development, demo, commercial) has also been shown. Otherwise, the technological results have been presented above in section 2.

Wood fuel production		
Knowledge	Technology	Small equipment
- final cutting work methods - early thinning pine and spruce: biomass balance, properties - basics of chain delimbing and debarking - basics of compression - chip separation properties - pneumatic transfer - small-scale production cost calculation model, basics/development - chopped firewood measurement and quality, basics - heat generation entrepreneurship, work methods, basics/demo	- plot chipper (Chipset), commercial - multi-function chipper lorry (Moha), demo - integrated energy wood production (Hooli), demo - mobile chipper (Lahti), demo - chipper, development - bundling technology, development - multi-tree handling, demo - combine harvester-forwarder, demonstration - harvester branch guide, development - wood fuel guidance system, commercial	- cage conveyor systemcommercial - wood chip and firewood system based on farmer tractor, commercial - production systems based on chopped firewood processing and harvester, development - firewood distribution and marketing systems, commercial
Peat production		
Knowledge	Technology	Methods
- drying - new materials - underground drainage - using wood chips to cover peat stockpiles	- light machine chain: plastic miller - loader - collecting wagon - scraper-ridger	- Tarkkaturve, demo - Teho method, commercial - sod peat method, demonstration - Compeat method, development - wood chip stockpile covering
Bioenergy use		
Knowledge	Technology	Methods
- basics of drying - drying model - basics of fireplace combustion - catalytic purification	- feeder (IVO), ready for demo - feeder (FW), ready for demo - dryer (IVO), demo - dryer (FW), ready for demo - burner, demo	- wood chip entrepreneurship, commercial - superpulp, ready for demo
Biomass conversion		
Knowledge	Technology	Methods
- properties of pyrolysis oil - combustion properties of pyrolysis oil - basics of using pyrolysis oil as a diesel substitute		- ITP method development
Agroenergy		
Knowledge	Technology	Methods
- properties of reed canary grass - diesel properties of rapeseed - fractionation		- growing and harvesting reed canary grass, demonstration

Table 2. Technological improvements

4. Bioenergy combustion research

The combustion and gasification research programme, LIEKKI 2, has as its aim to support the development of energy conversion technologies related to combustion and gasification in Finland. The programme focuses on issues such as fluidized-bed-based conversion techniques, emission control, fuel characterization, ash behaviour, etc., for any kind of fuel. Biomass-based fuels such as peat, wood wastes, and black liquor (spent liquor from pulp cooking) as well as various other combustible waste materials, have received special attention during the past few years.

LIEKKI 2 has been active since 1993. This programme is an extension of the programmed national combustion research initiated in 1988, which has gathered specialists in the field into a group capable of close co-operation. A total of 115 persons were engaged in the activities of LIEKKI 2 last year.

Modern combustion engineering is environmental engineering. Control over the environmental effects is today a self-evident starting point for developing all combustion equipment. Indeed, a strong shift from conventional mechanical and heat engineering towards chemical engineering and chemistry is typical of the modern research in this area.

Combustion technology is now more than ever being bent into the direction of the principles of sustainable development. Concerning carbon dioxide emission, the new combustion techniques have many possibilities. The improved efficiency of the new techniques reduces the carbon dioxide emission in the same proportion as the efficiency improvement attained. Furthermore, many of the new solutions are especially suited for renewable fuels such as wood and other biofuels.

The results obtained in the programme have been excellent. The co-operation in research work has greatly improved over the entire field, although many competing enterprises participate in the programme. The co-ordination of the whole wide range has allowed focusing the different projects sharply enough to attain an international lead in a number of special issues.

The LIEKKI 2 programme is divided into six specific areas (Table 3).

Table 3. The six topics of research in the LIEKKI 2 programme, and the number of projects in 1995.

Modelling of the furnace processes	13 projects
The chemistry of gaseous emission components	11 projects
Ash aerosols and the behaviour of particles	18 projects
New combustion and gasification technologies	8 projects
Black liquor	5 projects
Conventional combustion technology waste incineration	5 projects

The total number of projects in 1995 was 60, and the total financing was FIM 58 million, of which 24.5 million was contributed by the Technology Development Centre of Finland (TEKES).

Finland represents the international top in several sectors of know-how in combus-

tion technology. The Finnish experience in the applicability of different combustion techniques and fuels for both industrial and municipal energy supply is wide and deep. Aside from that, combustion equipment is part of the most important Finnish export products. Fluidized bed boilers, pulp mill recovery boilers as well as heavy diesel power plants have been particularly successful on the world market. The total export value of these products alone has in recent years been several billion FIM.

The aim in modern combustion technology is to eliminate the flue gas emissions in the combustion process itself, so that there would be no need to further clean the flue gases. Efforts to reach this end has required, and continues to require, intensive research into the combustion pollutant chemistry and the details of the flows in the furnaces and burners. When it comes to the emissions from fluidized-bed combustion, gasification and black liquor combustion, the Finns are international pioneers.

5. Bioenergy environmental research

Research Programme Energy and Environmental Technology, SIHTI 2, has many connections to bioenergy research in Finland. The general objectives of the programme give basis also to other energy research programmes like Bioenergy: to produce information about environmental impacts of energy production and utilization, to develop optimum strategy for adaptation of emission standards and to develop emission abatement technology. Specific goals have been reduction of emissions during the whole chain in the utilization of peat and bioenergy as fuels. Beside the development of abatement technologies, environmental management tools have been introduced in many SIHTI projects (life cycle analysis, total cost assesment, environmental impact assessment). One goal has been the introduction of clean process technology in one industrial branch, pulp and paper industry. Important areas have also been utilization of residues and end-products after combustion and development of emission monitoring techniques. These both areas concern bioenergy research as well.

SIHTI 2 research programme has been divided into the following areas:

- strategic environmental studies
- clean production in forest industry
- emission control technologies
- measurement technology
- emissions during the peat production
- secondary emissions of power plants
- use of energy in waste materials

At the moment research is mainly focused on three areas:

- strategic environmental studies
- emission control technologies and
- control of mass flows in processes (mainly solid residues and process and waste waters)

Results of the most research projects can be applied to cases in which biofuels are used. In SIHTI 2 projects different kinds of partners are involved: large energy companies, smaller technology enterprises, consultants, research institutes, universities and administrative bodies. Thus SIHTI 2 carries out cooperation widely across Finnish environmental research.

SIHTI 2 projects have shown that the emissions after the combustion of biofuels and peat are at internationally low level when using domestic boilers (fluidized-beds, bubbling beds). A remarkable reduction in the odorous and other gaseous emissions and in the waste waters has also been achieved in many projects. In environmental management studies the most important results have been obtained in projects concerning forest industry. These include life-cycle analysis of the forest industry products and other projects in the field of environmental auditing, total cost assessment and environmental impact assessment. Some important technology development projects have been carried out under SIHTI 2 programme, e.g., introduction of evaporation technologies for waste and process water treatment in paper mills. A new watershed model and new methods for water treatment during peat production have also been developed. projects, in which the quality of solid residues after biomass combustion or gasification has been improved, have been carried out.

As regards future plans in the SIHTI 2 programme, there are still many bioenergy related on-going or starting projects. They focus mainly on forest industry. Investigations on LCA of the forest of the forest industry products are continuing. Characterization and treatment of the condensates and concentrates after waste water evaporation will continue. A project on mass flows of the pulp factory was started this year.

In the project group of emission control technology there are many generic projects, results of which can also be used in bioenergy applications. These projects focus mainly on scrubbers: NOx and fine particle removal, scrubber chemistry and modelling. One specific project concerning forest industry in this area is a chemical model for gas-liquid reactions for flue gas scrubbers and kraft recovery liquors.

Under the project group control of mass flows in processes all new projects will focus on bioenergy or process industry. In the projects efficient utilization of solid residues after biomass combustion will be investigated. One possibility is to use ash as a nutrient. Mass flows after co-combustion of peat, wood and biosludge will also be studied. Research will also be carried out to reduce emissions into the watersheds after peat mining. In addition to these projects, several company projects will be carried out under SIHTI 2 research programme to find environmentally sustainable solutions for energy technology.