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Climate

Challenge for Technology

Views and results from the CLIMTECH Programme

Extended summary

TEKES

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Foreword

Climate change has been identified as one of the largest environmental challenges to mankind. Very significant reductions of greenhouse gas emissions are needed in order to slow down global warming. Technological development is one of the key issues both in solving the problem and in reducing the costs to the national economy of the mitigation of climate change. The demand for new technologies in global markets will grow strongly owing to the restriction of greenhouse gas emissions. Finland is already leading the way in many technologies that can be used for reducing global greenhouse gas emissions. The export possibilities are expected to grow strongly in the near future.

After the negotiations in Kyoto in 1997 concerning the climate there was a large demand for a technology programme which would help Finnish companies in forthcoming strategic decisions in changing the operational environment. Against this background Tekes, the National Technology Agency of Finland, started the Technology and Climate Change programme, CLIMTECH, in 1999. The main task of the CLIMTECH programme has been to create an overall picture of the mitigation of climate change and to identify the most significant technological development fields in Finland that can be instrumental in reducing carbon dioxide emissions. Mitigation of climate change is a long-term issue and therefore the time-scale for the technologies studied extends to about 2030. The programme was funded by Tekes and coordinated by the Technical Research Centre of Finland (VTT).

One of the main tasks of the programme was wide dissemination of the results. In addition to project reports, articles, and brochures, we decided to publish a book in which the results and future prospects are presented at a more popular level. The book “Climate – Challenge for Technology. Views and Results from the CLIMTECH Programme“ was published in Finnish. This booklet is the extended summary of that book.

Helsinki, April 2003
Tekes, the National Technology Agency of Finland

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Summary

Change of climate owing to anthropogenic emissions of greenhouse gases is a serious threat to nature and mankind, although the assessment of the consequences of the climate change is still, to some extent, uncertain. The emission reduction commitments of the Kyoto Protocol are not enough to stop the climate change, but the emissions should be reduced much more. The reduction of the greenhouse gas emissions is an important step towards sustainable development.

The emissions can be reduced by improving the effectiveness of the energy production and by increasing the share of renewable, low-emission or carbon-neutral energy sources. Energy use can be improved by technical measures and by changes in consumption behaviour. Changing the structure of the economy in a less energy-intensive direction is also of central importance.

Industry uses a considerable part of the total energy; in Finland it even uses half of it. Finnish industry produces many products for the world markets, like paper and metals, the manufacturing of which requires a lot of energy. Improvement in the efficiency of energy use is a natural part of industrial activities. The generation and use of energy in the pulp and paper industry are based to a very large extent on the use of industrial wastes as fuels and on combined heat and power (CHP) production. The concept of CHP is also in wide use in the energy procurement of communities.

The markets of conventional energy sources typically grow less than some percentage points annually. However, the markets of some new renewable energy sources, like wind and solar energy, even increase tens of percentage points annually. The development of bioenergy technology and bioenergy use is also rapid. Finland has a central position as developer and manufacturer of bioenergy technology. As a manufacturer of components for wind power plants Finland has also a considerable share of the global markets. The exports of components for wind energy plants can be assumed to continue to increase rapidly.

If more resources were directed to the development and commercialisation of technologies, the costs of the reduction of greenhouse gas emissions would be lower. In the scenarios made for Finland, the use of renewable energy, especially the use of bioenergy and wind, would increase considerably. At the same time, the costs would be considerably lower and in the long term the emissions could be reduced much more than the commitments of the first Kyoto period require.

Greenhouse gases are also released by industrial processes, waste management and

agriculture. Reduction of the emissions from these sources is often cost-effective. The effectiveness of material production and use is important for the reduction of material and energy flows. The reduction of the emissions of waste management is linked to other developments in this field. The emissions of fluorinated greenhouse gases are predicted to grow rapidly e.g. owing to the increasing use of refrigeration. Technically it is, however, possible to use tighter equipment or replace fluorinated gases with more climate-friendly compounds.

Mitigation of climate change will create global technology markets where the demand will concentrate on improvements for energy systems and for other activities which cause greenhouse gas emissions. Annual investments of hundreds of billions of euros will gradually move in future decades from the technologies utilising fossil fuels towards technologies utilising renewable or carbon-neutral energy sources and towards improvements in energy efficiency. New technologies will also reduce other airborne emissions like sulphur, nitrogen oxides and particulates.

The expected change in the energy technology market is an extraordinary business opportunity. Even now the export of Finnish energy technology is relatively extensive on a global scale.

The market access of new Finnish energy technologies can be supported in many ways. Companies should recognise the long-term opportunities in order to see the profitability of technological development. A clear and robust political commitment to emission reductions would be an important message for companies. In addition, the demand for new technologies should be promoted in order to limit emissions. The market can also be developed with new business concepts. Co-operation networks and action plans also have an important task in commercialisation.

Introduction

Climate change is one of the most serious environmental threats to nature and humanity. Energy systems including energy production and use, and transport, are responsible for a major share of greenhouse gas emissions leading to the changes in the climate. Mitigation of climate change by reducing greenhouse gas emissions is of crucial importance. The emission reductions form a long-term driver guiding the development of energy systems and technology.

In addition to the energy sector, some other anthropogenic activities contribute to greenhouse gas emissions. The most important of these activities are waste management and agriculture. Emissions of some fluorinated greenhouse gases from diverse sources, refrigeration being especially important, are also increasing sharply.

Cost-effective reduction of greenhouse gases consists of a wide set of measures that utilise the least expensive emission reduction potential of various measure categories. Further benefits are obtained if the measures are linked to other development programmes aimed at guiding, for example, energy conservation, structural changes in resource utilisation, control of acidifying emissions or air quality etc.

With the exception of abundant forests, Finland's scarce natural resources have guided the development of the national industry and energy system, and further, have had impacts on technologies developed in Finland. The pulp and paper industry requires a lot of energy, and the industry has learned to produce it from its own wastes. This is done, to a large extent, in a cost-effective way by producing heat and electricity together, leading to high total efficiencies. In the cold climate a lot of energy is needed for space heating, and as communities, naturally, also need electricity, the co-production of heat and power has already been common in Finland for decades. Energy technologies have been developed in many fields in Finland: one example is boiler techniques, which are suitable for utilising inhomogenous biomass fuels effectively. Natural conditions have led the Finnish industries to develop technologies that use natural resources effectively and economically.

Technologies have a central role in the reduction of greenhouse gas emissions. The real emission reductions take place through the choice of technologies and possible consumption changes. Emission reduction requirements change energy technology markets. The demand for technologies will move towards those technologies that have high efficiencies or which can utilize renewable or low-carbon energy sources and, on the other hand, towards energy-use technologies that have high efficiencies.

Tekes, the National Technology Agency of Finland, funded a three-year technology programme (1999-2002) on Technology and

Climate Change (CLIMTECH) to investigate the development needs of technologies that can be applied to control greenhouse gas emissions. The programme included both the control of emissions in Finland and the exports of the Finnish technology to limit emissions elsewhere. The time scale for the technologies studied extended beyond the commitment period of the Kyoto Protocol to about 2030.

The CLIMTECH Programme had a special role in disseminating information and communicating with technological research and industrial communities. The results of the Programme have been published in numerous technical reports and brochures both in Finnish and in English, which can be downloaded from the web site (www.tekes.fi/english/programm/climtech or www.climtech.vtt.fi) or ordered from Tekes. Furthermore, the Programme published several overview publications in Finnish. This booklet is mainly based on one of these publications, on the Finnish book "Climate – Challenge for Technology". The objective of this booklet is to describe the development of Finnish energy technology and the results of the CLIMTECH Programme in brief.

Energy System and Greenhouse Gas Emissions in Finland

Structure of the energy system in Finland

Countries have different natural conditions and resources, and the history of the development of industry and economy in general also differs between countries. In a cold climate, energy is needed for the heating of buildings and, in a warm climate, energy might be used for cooling. In sparsely populated countries average transport distances are long. Natural resources can provide energy, like hydropower, but the utilisation of natural resources can also increase the demand for energy, as for the manufacturing of metals or forest products.

In some countries, as in Finland, the share of energy use in industry is large, especially owing to energy-intensive industries like the manufacture of pulp and paper and both ferrous and non-ferrous metals. In some other countries the relative weight in energy consumption is more concentrated on the residential/commercial and transport sectors. In the case of Finland, about 90% of the paper produced is exported, so that Finland provides paper for a population ten times larger than its own, on average. This is a result of economic development based on the utilisation of natural resources. Consequently, in Finland about half of the total primary energy and also half of the electricity are consumed in the industrial sectors.

The structure of primary energy supply varies considerably between the OECD countries, mainly according to indigenous energy resources, access to natural gas networks, and attitudes towards nuclear power. The primary energy structure is presented in Figure 1 for some OECD countries. Finland's share of CO_2 free energy is relatively high, owing to the large utilisation of biomass fuels and nuclear energy. Certain countries, like Sweden in the Figure, have abundant indigenous hydropower, while some others rely to a high degree on domestic or imported fossil fuels. With respect to nuclear power the national policies differ significantly, Sweden utilises it to large extent and some others like Denmark do not utilise it at all in the supply of domestic energy.

Biomass has a large role in Finland

The share of CO_2 free energy also varies considerably among the countries (Figure 1). Owing to abundant hydro, nuclear and biomass-based energy, Sweden has a very high share of carbon-free energy supply, but Denmark uses a lot of imported fossil

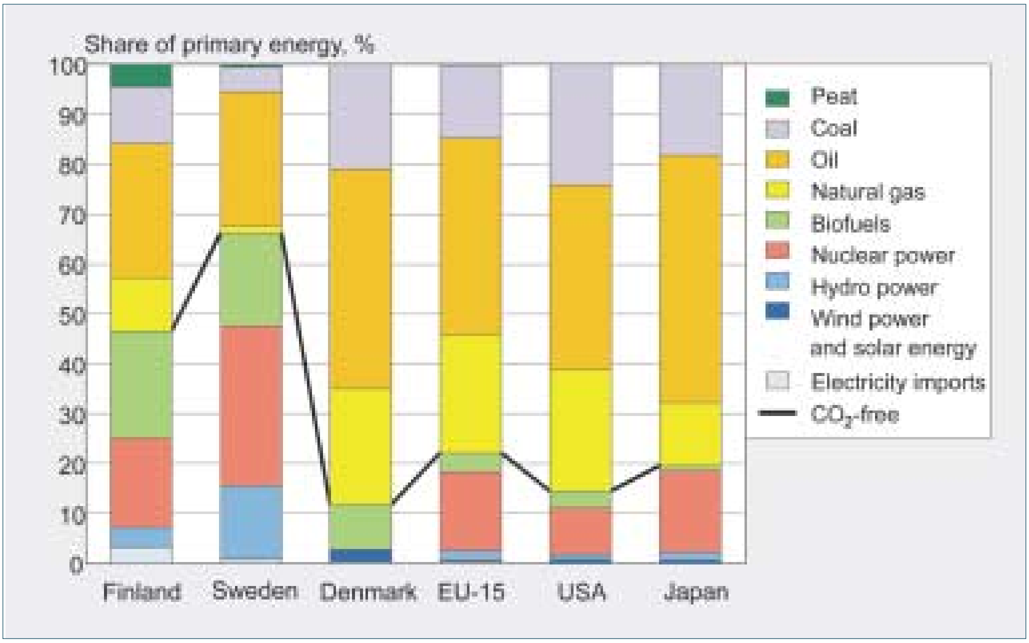

FIGURE 1. Primary energy sources in some countries in 2000. The Finnish energy supply structure is quite diversified.

energy. Finland also has a relatively high amount of nuclear energy production, and especially biomass-based energy production, and also, as a special feature, peat-fired energy production.

Finland is the leading industrialised country concerning the utilisation of biomass for energy. Furthermore, while even in many developed countries a major share of biomass use has been so-called traditional firewood, in Finland most of the utilization has long taken place in state-of-the-art cogeneration plants. In the year 2000, the biomass share of the primary energy supply in Finland was about 20%, which was about five times the average of the EU, or the USA.

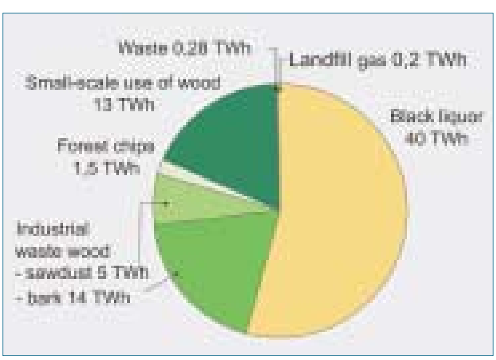

FIGURE 2. Industry is the largest user of bioenergy in Finland. Utilisation of bioenergy in Finland in 2000.

More detailed information on the Finnish use of bioenergy is given in Figure 2. The largest bioenergy source is spent black liquor from the pulping process for papermaking. Other by-products from forest industries, like bark and sawdust, are also of importance. Small-scale use of wood for energy is less than 20% of the total bioenergy use.

Cogeneration improves efficiency

Another feature that makes the Finnish energy production system very effective is the high share of the cogeneration of heat and power. Combined heat and power production (CHP) is the simultaneous production of usable heat and electricity in the same plant. In condensing thermal power plants, significant amounts of energy are wasted through the cooling systems. The total energy efficiency of such power plants is at present in the range of 40–50%. In CHP systems, the total usable energy efficiency is much higher, as the by-product heat can be utilised. Consequently, the total energy efficiency of CHP systems is typically 80–90%. Some additional efficiency gain is achieved by the smaller distribution losses in CHP generation compared with larger scale central power plants. Atmospheric emissions per unit of produced energy are reduced accordingly.

In Finland the share of electricity generated using CHP is about 35% of the total electricity produced. The average share in the EU is about ten per cent. About half of the cogeneration takes place in industry, where typically black liquor or other by-products are used as fuels. These power plants produce electricity and steam to be used in industrial processing. Another half

FIGURE 3. CHP plant using biofuels in Finland.

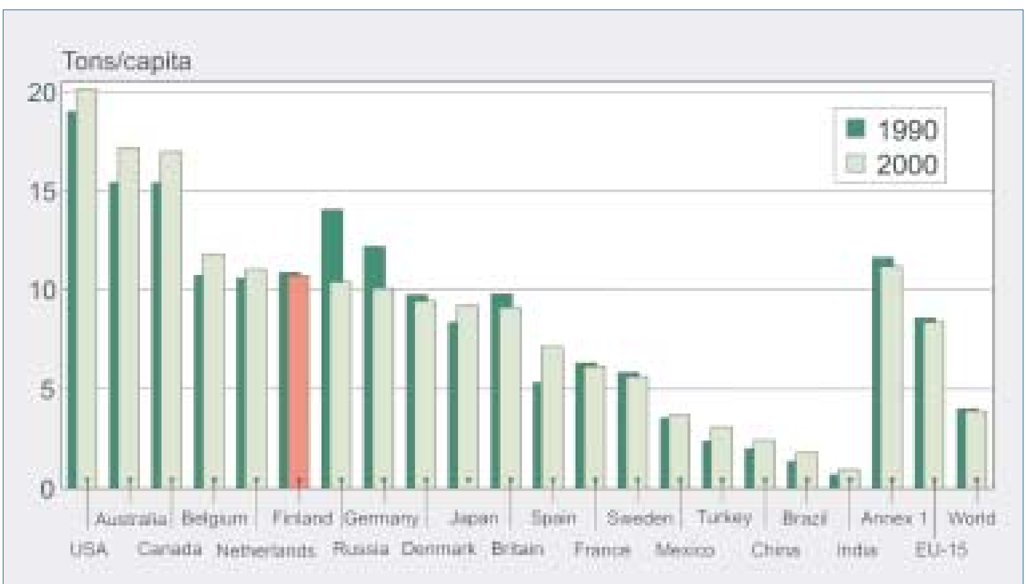

FIGURE 4. Carbon dioxide emissions from fuel combustion per capita in 1990 and 2000.

of CHP serves communities by producing district heating and electricity. Fossil fuels have been mainly used here but recently the use of biomass-based fuels has increased sharply. New boiler techniques have enabled the use of non-homogenous fuels both in small and large plants.

The structure of Finnish electricity generation by energy source resembles the EU average, apart from the much greater use of biomass in Finland. As illustrated in Figure 4, the average per capita CO_2 emissions from energy production have a large variation among countries. The average emissions are affected by the energy sources used for the production, as well as by the conversion efficiencies. Despite the relatively high-energy consumption of the Finnish economy, the Finnish average per capita CO_2 emissions are moderate. There are two important reasons for the difference: the important role of combined heat and power (CHP) production, and the exceptionally large use of biomass for thermal power generation in Finland.

Greenhouse gas emissions in Finland

Carbon dioxide is also the most significant greenhouse gas in Finland. Emissions result from the use of fossil fuels, the production of lime and cement as well as from organic agricultural lands and the production of fuel peat.

In the 1960s, the use of oil increased rapidly and resulted in a substantial growth of carbon dioxide emissions (Figure 5). The oil crisis in 1973 was followed by the

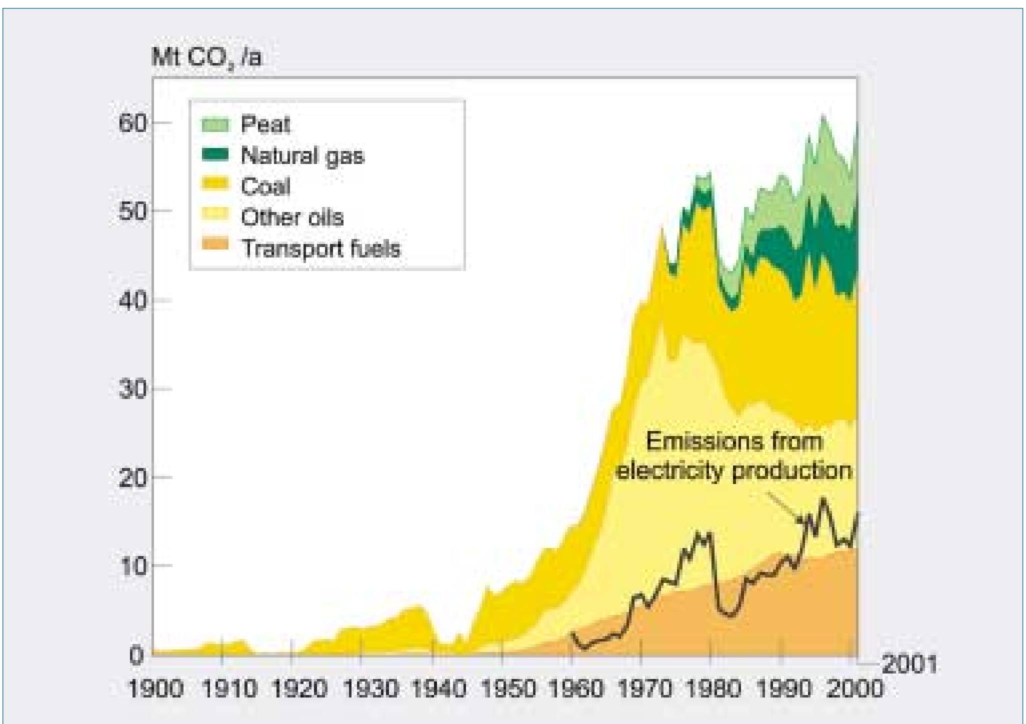

FIGURE 5. Carbon dioxide emissions from combustion of fossil fuels and fuel peat in Finland in 1900–2001. The emissions grew rapidly until the oil crisis in 1973.

introduction of new energy sources, like natural gas, peat and nuclear power.

Finnish carbon dioxide emissions vary year after year and mainly depend not only on the availability of low-priced hydropower, but also naturally on economic conditions. The emissions used to be lower in rainy years, owing to the substitution of Finnish coal-condensing power by imported electricity produced in other Nordic countries.

Nitrous oxide corresponds to roughly ten per cent, and methane to some five per cent of the total greenhouse gas emissions in Finland, expressed in carbon dioxide equivalents (Figure 6). Currently, the contribution of fluorinated greenhouse gases is only half a per cent in Finland, but this share is projected to increase significantly during the next few years, owing to the increasing use of these gases mainly as refrigerants.

Finnish National Climate Strategy

The Finnish government published the National Climate Strategy in 2001. Under the Kyoto Protocol, the EU should reduce its greenhouse gas emissions by eight per cent from the level of 1990 within the first Kyoto commitment period, 2008 – 2012. According to the burden-sharing agreed by the EU countries, Finland should not exceed the emission level of 1990 during the first Kyoto commitment period.

The Finnish National Climate Strategy assumes that the Finnish national economy will have strong growth in the ICT sector and the growth will be relatively moderate in the energy-intensive industries as in the pulp and paper sector. Energy and electricity consumption will grow, and without additional greenhouse gas limiting measures Finnish emissions will grow about 20%.

The national strategy emphasises the improvement of the efficiency of energy use, increasing the share of renewable energy and the replacement of coal-fired condensing power with natural gas or nuclear power. Emission reduction measures are promoted in all sectors of the economy: energy production, industry, heating, households, services and transport. Waste management is developing rapidly and its methane emissions will be restricted. In addition, the emissions from agriculture will be controlled.

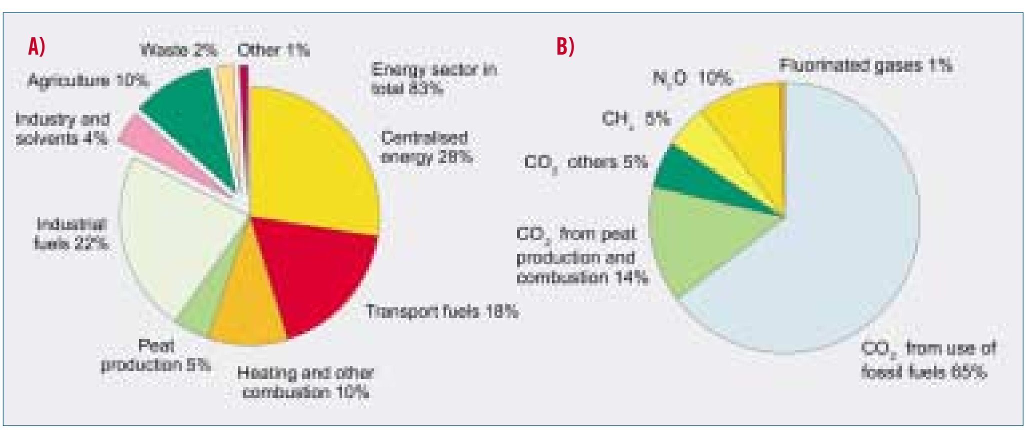

FIGURE 6. Greenhouse gas emissions by principal sectors (a) and by gases (b) in Finland in 2000. The overall greenhouse gas emissions were 75 million tonnes CO_2-eq. in Finland in 2000, resulting mainly from the energy sector.

Communication about climate change, its impacts and mitigation measures are one part of the strategy as well as promoting the adaptation to climate change.

Energy technology export from Finland is growing

The positive development of Finnish energy technology can be seen in the growing export numbers (Figure 7). Energy exports exceeded energy technology imports in the early 1990s, and thereafter the export has grown by a factor of four. During the last two years the export of energy technology has been about seven per cent of the total export. This is clearly more than that of any other OECD country. In 2001 the value of the export of energy technology was over three billion euros. The export consists of many kinds of energy production and use technologies, including large diesel engines, power plant boilers, power electronics, generators, wind turbine gears and blade materials etc.

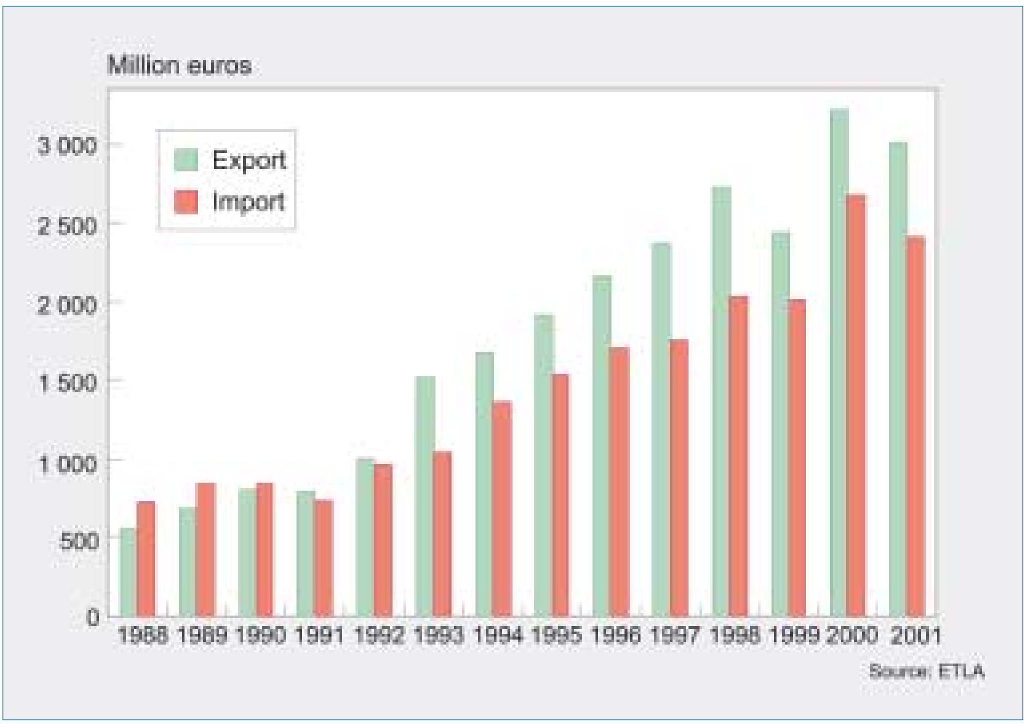

FIGURE 7. Finland's energy technology export and import. The export of energy technology exceeded the import of energy technology in the early 1990s, and thereafter the export has grown by a factor of four.

Key Results of the Technology and Climate Change Programme

Overview of the Programme

The overall objective of the CLIMTECH programme was to support the mitigation of climate change by contributing to technological choices, research, development, commercialisation and implementation. Furthermore, CLIMTECH had an interest in supporting the attainment of the national climate change mitigation objectives.

The time scale for the technologies studied extends to 2030. This time scale is short from the perspective of climate change, but long for business activities. Thus, attention was also paid to shorter periods, especially to the first commitment period of the Kyoto Protocol. However, technological development and implementation take years or decades. Within the chosen time scale until 2030, the emission limits regarding developed countries will most likely be tightened and the emissions for the developing countries will also be limited. The time scale also enabled us to study such technologies whose potential is insignificant over the first commitment period of the Kyoto Protocol, but might be very substantial in fulfilling the assumed following commitments.

CLIMTECH was run as a framework programme by VTT Processes to serve and guide other Finnish technological development that was relevant to energy efficiency improvements and greenhouse gas emission reductions. The technologies were analysed against an overall picture of emission limitation, and the technical and economic potentials as well as the potential barriers of implementation were assessed.

The programme consisted of 27 projects altogether that were implemented by seven research institutes or universities and eight companies. The projects were divided into six main subject areas: 1) Renewable energy sources and distributed energy production, 2) Energy efficiency and industry, 3) Non-CO_2 greenhouse gases, 4) Capture and utilisation of CO_2, 5) Development of models and systems, and 6) Commercialisation. The projects are listed in Appendix 1.

CLIMTECH had a very communicative role. Interactive communication with other research programmes and researchers at the national and international levels, as well as contacts to companies, were of central importance. In particular, CLIMTECH has contributed to the dissemination of information on the mitigation opportunities of climate change, and bringing the viewpoint of greenhouse gas emissions reduction to the agenda of technological development. The programme broadly arranged ten seminars

CODE - Modelling Tools for Combustion Process Development	1999–2002
DENSY – Distributed Energy Systems	2003–2007
Environmental Cluster Research Programme	1997–2002
FFusion 2 - Fusion Energy Research Programme	1999–2002
FINE Particles - Technology, Environment and Health	2002–2005
FUSION – Technology Programme on Fusion Energy	2003–2006
Process Integration Technology Programme	2000–2004
ProMotor - Engine Technology Programme	1999–2003
STREAMS - Recycling Technologies and Waste Management	2001–2004
TESLA - Information Technology and Electric Power Systems	1998–2002
Wood Energy	1999–2003

TABLE 1. Other ongoing or recently completed technology programmes of Tekes related to energy and environmental technology.

including one in New Delhi, India, during the climate negotiations (COP-8). Numerous reports, articles and brochures were produced on project and programme results, and can be found as pdf documents on the Internet pages of the programme (www.tekes.fi/english/program/climtech or www.climtech.vtt.fi).

The total budget of the CLIMTECH Programme over the three-year period was 5 Million euros. Tekes' funding of energy and environment-related R&D is about 60 Million euros annually. About half of this is channelled through technology programmes and the rest directly to R&D projects. Technology programmes related to the CLIMTECH research area are listed in Table 1.

In the following sections some results of the main subject areas of the CLIMTECH programme are presented.

The impact of climate change on energy management

A study of the impact of climate change on the Finnish energy economy was carried out under the CLIMTECH programme. The study is based on the results of the HadCM3 general circulation model and IPCC emission scenarios. The mean temperatures of Finland are estimated to rise from one to three degrees by the 2030s because of climate change. Winter temperatures will increase more than summer temperatures. The annual rainfall is also predicted to increase by about ten per cent, although the estimate is quite uncertain. These climatic changes will also lead to changes in energy management.

According to climate change simulations, more biomass for both the forest industry and energy production would be available owing to faster growing forests, especially in Northern Finland (Figure 8). The climatological potential of milled peat production would increase by a fifth. There would also be greater production potential of wind and hydropower, when favourable wind conditions in wintertime and annual precipitation are increasing.

In addition, the demand of buildings for heating energy will decrease because of shorter heating periods and the warmer climate. However, the demand for heating energy will not decrease as much as

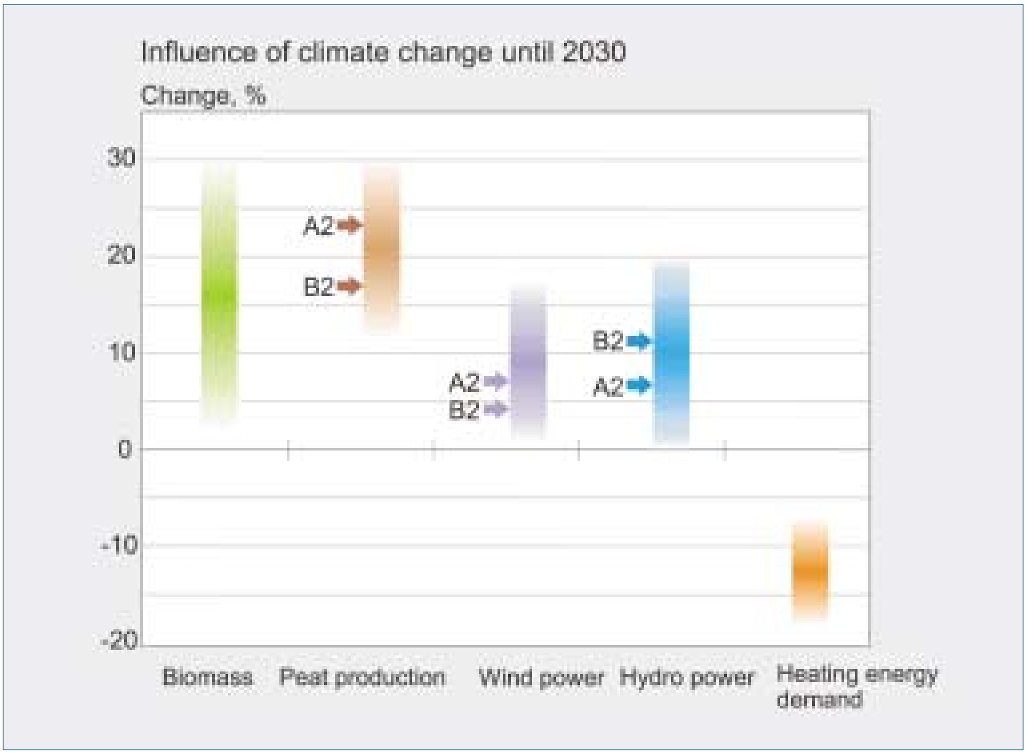

FIGURE 8. The influence of projected climate change on energy production potential and heating energy demand in Finland. Arrows depict relative changes between 1961–1990 and 2021–2050 based on the emission scenarios A2 and B2 by IPCC. The change in biomass is based on the Finnish SILMU scenarios. In addition, in the case of heating energy demand the calculations are based on different model simulations and scenarios and thus the arrows depicting A2 and B2 scenarios are not shown.

climate change would call for, owing to the increasing building stock volume, for example.

The effect of technology on energy use

Introducing new energy-efficient and low emission energy use technologies is often the easiest way to reduce energy consumption and greenhouse gas emissions. However, the costs of new technology must be competitive in order to attain large-scale use. This is often the most important barrier that must be overcome when the technology already exists. Next, some examples of technologies that reduce energy use in the forest industry and households are presented.

The impact of ICT on greenhouse gas emissions in the forest cluster

The forest industry cluster (forestry, mechanical wood, pulp and paper, printing and publishing, related and supporting industries) is a large and multi-dimensional field. Most industries within the cluster are very capital-intensive. Hence, the cluster industries have traditionally been hesitant to adopt new technology. The study within the CLIMTECH programme identified opportunities for the sector to move ahead and take advantage of new tools. Information (and its proper management) seems to be the one true pivot that exists with the possibilities to reduce GHG emissions in the forest cluster.

Three groups of technologies were identified: 1) paper, electronic media and intelligence, 2) efficient ICT systems, and 3) new commercial practices. These technologies and their impacts on GHG emissions are presented in the technology matrix below (Figure 9).

Environmental and energy-related benefits of biotechnology in mechanical pulping

The forest industry, and especially energy-intensive mechanical pulping, is a notable user of electric power in Finland. Through the implementation of biotechnological methods like the fungal pre-treatment of chips (biopulping) and enzyme-aided refining, electricity can be saved (Figure 10). The results showed that enzyme-aided refining was very competitive compared with alternative methods, and it would already reach maximal penetration of use in the realistic scenario. Bio-pulping, which

FIGURE 9. Technology matrix. The placement of new technologies in the technology matrix is based on the likelihood of their general breakthrough and their expected effect on GHG emissions. E-commerce B2B means transaction between firms and B2C between a firm and a consumer. The colours refer to the stages of development of the technologies: blue = commercial applications, red = requires further development, green = functional applications at the stage of experiments.

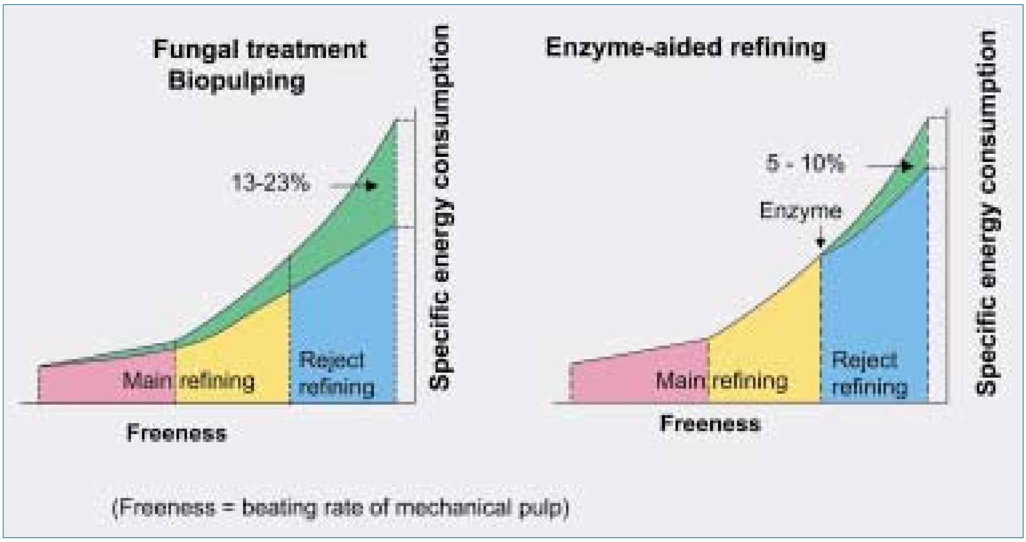

FIGURE 10. Biotechnical methods in mechanical pulping will save electricity, even 3% of the total consumption in industries in Finland in 2030.

is technically more difficult to control and also more expensive from the point of view of investment and operation, would be largely adopted in an optimistic scenario in 2020. Additionally, it was shown by the life-cycle study that implementation of the biotechnical methods reduced total emissions of greenhouse gases.

Electricity-saving possibilities in household and office appliances

The penetration of new technology and its effects on energy efficiency by the year 2010 in the electricity consumption of appliances and lighting in households and in offices were studied within one CLIMTECH project. The heating energy of premises and water was excluded. By using the best existing energy-efficient technologies, not always economically feasible, the expected consumption in 2010 in Finland will decrease, for example that of consumer electronics by 20%, of lighting by 65%, and of refrigeration by 14% compared with the business-as-usual scenario. The technically possible savings are 2050 GWh annually.

In offices, the electricity consumption of the present equipment in Finland can quite possibly be decreased by 30% by only utilising the power management of the appliances. Compared with the business-as-usual scenario, it is possible to save 67% of the consumption of the office equipment annually by the year 2010. In addition, by using the best technologies in all offices the savings would be 75% of the consumption of lighting energy by the year 2010.

Climate-friendly energy production

Bioenergy is the number one renewable in Finland

Opportunities for increasing the use of bioenergy in Finland and in that way reducing greenhouse gas emissions were analysed in the CLIMTECH bioenergy project. According to results, the use of bioenergy excluding black liquor can be increased in Finland by roughly 50% by 2010. The total share of bioenergy including black liquor in the total primary energy use is calculated to be well over 20% in 2010. The corresponding increase in electricity generation would be three terawatt-hours, over three per cent of the total generation in Finland. The potential reduction in carbon dioxide emissions would be roughly 3–4 million tons of CO_2 compared with that of 1999 when replacing fossil fuels. This is a considerable fraction of the emission cuts needed, as without additional emission reduction measures the Finnish emissions would exceed the national target by 14 million tons of CO_2.

It is most profitable to increase the utilisation of logging residues from forest regeneration areas and the energy use of waste at existing boiler plants. Increasing the utilisation of wood and wood-derived fuels in the heating of buildings is also financially competitive at the present subsidy level.

With small additional investments to existing plants and the use of biofuels with higher costs, the use of bioenergy could be increased up to a quarter of the Finnish primary energy consumption. The increase would be especially viable in the district-heating sector. Electricity generation would increase by nearly six terawatt-hours compared with that of 1999, mainly by replacement of other fuels with biomass in existing units. Carbon dioxide emissions would be reduced by a maximum of roughly 7–11 million tons compared with the figures for 1999, which would be about half of the reduction needed to reach Finland's Kyoto target.

Finnish industry is in a good position to develop technologies related to biofuels, because the sector has traditions dating back many decades as well as good facilities for demonstrating new technologies. The annual export value of new products may rise to half a billion euros in the next few years.

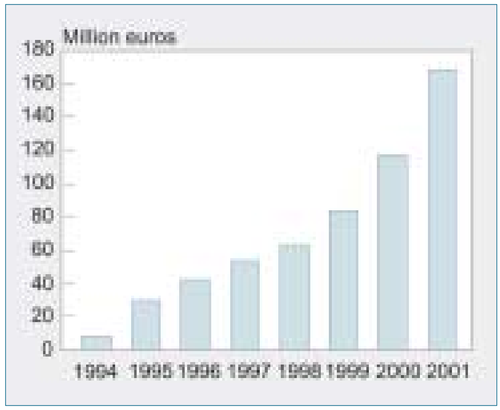

FIGURE 11. Export of wind energy technology from Finland. Wind energy technology exports amounted to over 170 million euros in 2001.

Export of wind power technology is growing

Finnish industry manufactures 10–20 per cent of the wind power plant components, generators, gearing and blade materials that are available on the global market. In addition, Finland exports tower materials and large castings. Wind technology exports amounted to over 170 million euros in 2001, which accounts for almost five per cent of the total wind power market (Figure 11).

Wind energy technology markets are growing fast, and by maintaining the present market share it will be possible to increase the export volume of wind technology many times over in ten years. The networked co-operation of enterprises provides opportunities for exports related to blade technology, tower structures, control systems and the setting-up of offshore wind farms. The new products and the introduction of the new Finnish wind power plants on the expanding market may further double the export volume.

The Finnish electrical power system is part of the Nordic power system. According to electrical power system simulation results, an increase in wind power mainly replaces coal-fired condensing power generation in the energy system of Finland and the Nordic countries. In addition, oil- and gas-fired power generation is also replaced to some extent. Replacements are implemented principally in Finland, Denmark and Central Europe, corresponding currently to CO_2 emission abatements of 700 g CO_2/kWh. In the future electricity system, where gas-fired power generation may have replaced coal condense, the emission saving as a result of wind power will be approximately 300 g CO_2/kWh.

CO_2 capture, storage and utilisation

Carbon dioxide capture is based on commercial technologies which have been used in industrial processes as well as in oil and gas production. Difficulties in CO_2 storage and the high costs of the measures are the largest barriers to introducing CO_2 capture on a large scale. The capture and compression of carbon dioxide from flue gases is estimated to cost 30 to 50 euros per ton of CO_2.

CO_2 capture is the most cost-efficient method for the plants that generate vast amounts of carbon dioxide emissions, such as oil refineries, iron and steel works, and for centralised power generation. The number of major emission sources in Finland is less than ten. In addition, the carbon dioxide storage options are poor in Finland. As a consequence, it is least risky and most economic to generate power near the place of CO_2 disposal, as in Norway, and to build new cross-border power transmission capacity for Finland. For this to be feasible, however, the market price of electricity should be doubled or tripled compared with the current level.

Storing carbon dioxide in geological formations, such as old oil, coal and natural gas fields or deep saline aquifers, is the most noteworthy option. An interesting possibility explored in the CLIMTECH project was to bind carbon dioxide to silicate rock to produce solid mineral carbonate. There are vast resources of suitable mineral in Finland, and it is also obtained as a by-product of the mining industry. However, although the technology at issue is principally promising, the chemical reaction rates achieved are slow and the mass flows of the process are large, so that this technology will not be economically feasible for a long time.

Reduction of non-CO_2 greenhouse gases

Contribution of methane, nitrous oxide and fluorinated gases to total greenhouse gas emissions is typically at a relatively low level compared with CO_2. The current share of non-CO_2 greenhouse gases is just under fifth in Finland. However, options to reduce emissions of these gases are often quite cost-effective compared with those related to CO_2 emissions.

Emissions from waste management are being reduced

Approximately 4% of the total Finnish greenhouse gas emissions, corresponding to a quarter of non-CO_2 emissions, originate in waste management. Methane is released in the slow degradation process of organic waste at landfill sites. Disposal of wastes to landfill sites can be reduced by preventing waste generation and by material recycling, composting and putrefaction, as well as by energy use of waste. Methane emissions generated at landfills could be mitigated by increasing the recovery of landfill gas and by the oxidation of methane to carbon dioxide. Reduction of these emissions is often advantageous, because many of the measures reduce both the methane emissions originating in landfills and the carbon dioxide emissions generating in energy production and use. If all the above-mentioned measures were combined, they would enable, in Finland, the emission reduction to correspond to a fourth of the total emission reduction demand estimated in the national climate strategy for the first commitment period of the Kyoto Protocol.

Technologies to reduce F-gas emissions exist

Currently, the share of fluorinated gases (F-gases) known as HFCs, PFCs and SF_6 is roughly 0.5% of total greenhouse gas emissions in Finland. However, these emissions are projected to grow rapidly, mainly owing to increasing use of HFCs as substitutes for ozone-depleting refrigerants. In addition, use of commercial refrigeration and air-conditioning systems is estimated to become more general. In the short term, emissions of F-gases could be reduced cost-effectively by improving gas handling and maintenance measures to minimise gas leakage into the atmosphere. In the longer run, economic and ecological alternative technologies and substances can be developed and adopted in many uses of F-gases.

Mitigation scenarios for Finland

In order to assess the impact of new technologies on the Finnish energy economy, scenario studies with energy systems model EFOM were conducted. The model covers the whole of Finnish energy production and the consumption system, including industry, residential, service and transport sectors. In addition to these, waste management and the agricultural sectors as well as emissions of fluorinated gases are also incorporated into the model with emission reduction measures. The model includes emissions of all Kyoto Protocol greenhouse gases. In general, all direct costs incurring in the energy system are taken into account by the model, including investment, operation, maintenance and fuel costs as well as taxes and subsidies. The model is relatively detailed at the technology level. The model seeks the solution that offers the least cost to fulfil demand requirements and other constraints such as given emission limits.

The main scenarios considered are "Conventional Technology Development" and "Optimistic Technology Development". The time frame considered extends to 2030. The technology data for these scenarios has been obtained mainly from various CLIMTECH projects. It describes the development of the most important technology-specific parameters like efficiencies and investment costs. In the "Conventional" scenario these parameters develop at a normal rate and in the "Optimistic" scenarios the parameters improve at a rate that could be reached with systematic high investments in the development of technologies. In both scenarios it is assumed that the Finnish emissions will be limited by the year 2030 to the level which is 20% lower than the Kyoto target for Finland, the emission level of 1990. A reference scenario, where the emissions stay at the level of the Kyoto Protocol even after 2012, is also considered.

Strict emission reductions increase the use of renewables

The most cost-effective technology choices related to emission reductions are clearly re-

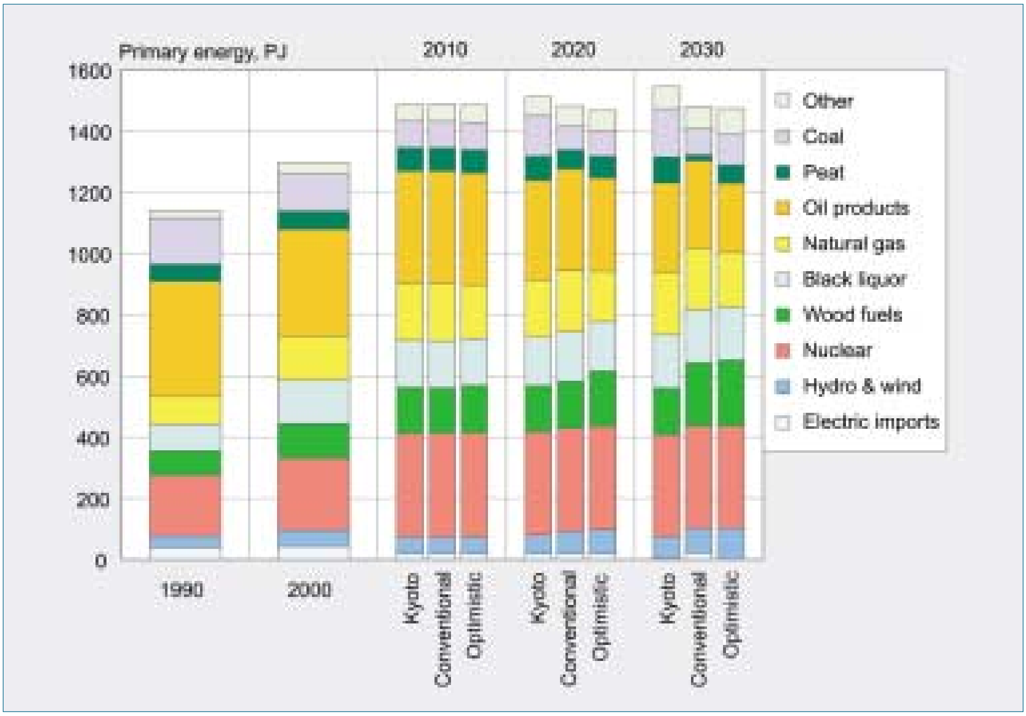

FIGURE 12. Primary energy supply by energy source in Finland in 1990–2030. In the Conventional and Optimistic scenarios the total greenhouse gas emissions are reduced by 20% from the level of 1990 to 2030. In the Kyoto scenario the emissions are kept at the level of 1990 throughout the period until 2030. In the Optimistic scenario the share of renewable energy increases most.

flected in the development of total primary energy consumption (Figure 12). The tighter the emission goal in 2030 is, the more the renewable energy sources are exploited. In the year 2030, the share of renewables in primary energy consumption will be 28% in the Kyoto scenario, 34% in the Conventional scenario, and even 37% in the Optimistic scenario, compared with 25% in 2000.

Use of bioenergy increases most in the total energy supply. According to the scenarios, the use of wood fuels will grow by 20–70% between 2000 and 2030. In addition, waste-derived fuels as well as wind and hydropower will be utilised significantly compared with current level.

The combined use of fossil fuels and peat remains approximately stable in the Kyoto scenario, whereas the use decreases in scenarios requiring tightened emission reductions beyond 2010. Although consumption of natural gas increases in all three scenarios, the relatively rapid price increase in natural gas reverses consumption after 2020.

Just over half of the current total bioenergy supply is covered by black liquor. Most of the other use of bioenergy consists of different types of solid wood fuels (Figure 13). Integrating fuel production with final fellings or thinnings can significantly increase the economic potential of wood fuel utilisation.

Bioenergy sources and forms of use may diversify considerably in the future along with production of recycled fuels, agrobiomass and pyrolysis oil as well as ethanol as a component of transport fuel.

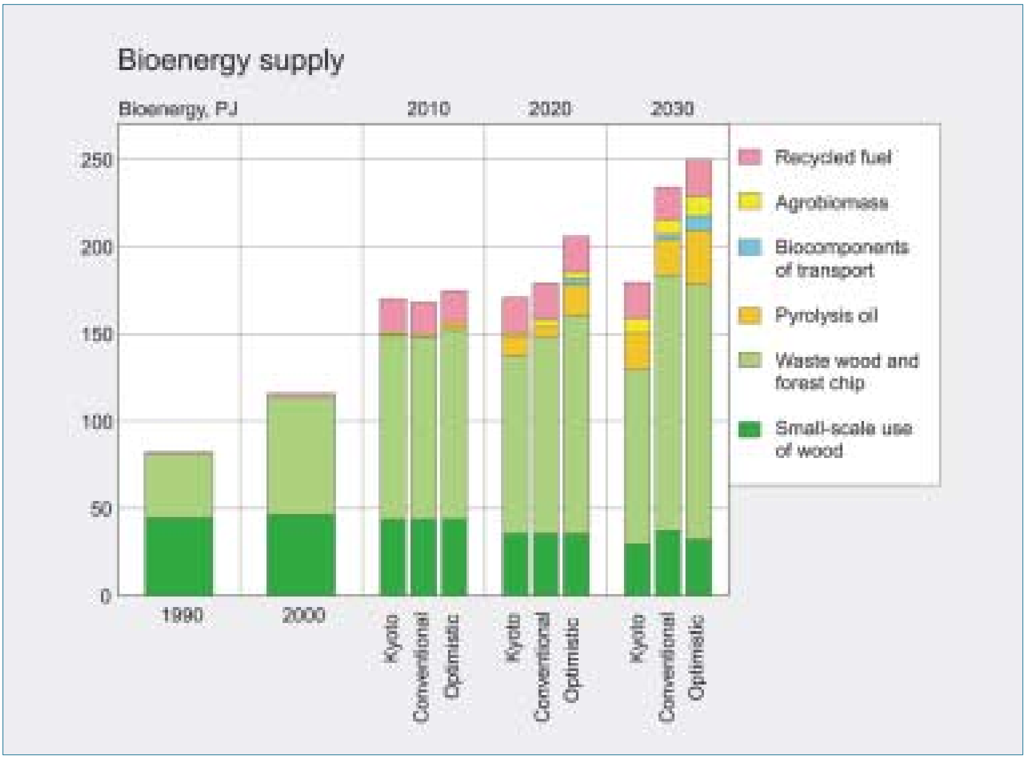

FIGURE 13. Structure of bioenergy supply excluding black liquor. The supply will increase by a factor of two in Conventional and Optimistic scenarios. New alternatives will be adopted.

Bioethanol was assumed to be imported, whereas only domestic sources were considered for other bioenergy fuels, in the scenario calculations.

According to the results, production technologies of pyrolysis oil and recycled fuels, particularly, are of central importance in emission reduction related to bioenergy sources. Development of production and use technologies of pyrolysis oil appears to be a promising option in both finding economic emission reduction potential and generating new activities in the energy business.

Technology choices in the generation of electricity are substantial in abating carbon dioxide emissions. The most significant modifications in the basic structure of electricity supply are associated with separate electricity production and electricity import (Figure 14). The more tightened the emission demands, the less is the production of conventional condensing power. The share of combined heat and power production increases but may, according to results, stabilise at a level of 40%.

In Finland, generation of wind power will increase to 14-fold and 40–160-fold by 2010 and 2030, respectively, compared with the current level. Electricity generation of wind power plants will grow to some extent owing to increased windiness caused by climate change. Development of wind power systems is one of, or even, the most significant individual technological option that allows emission reductions

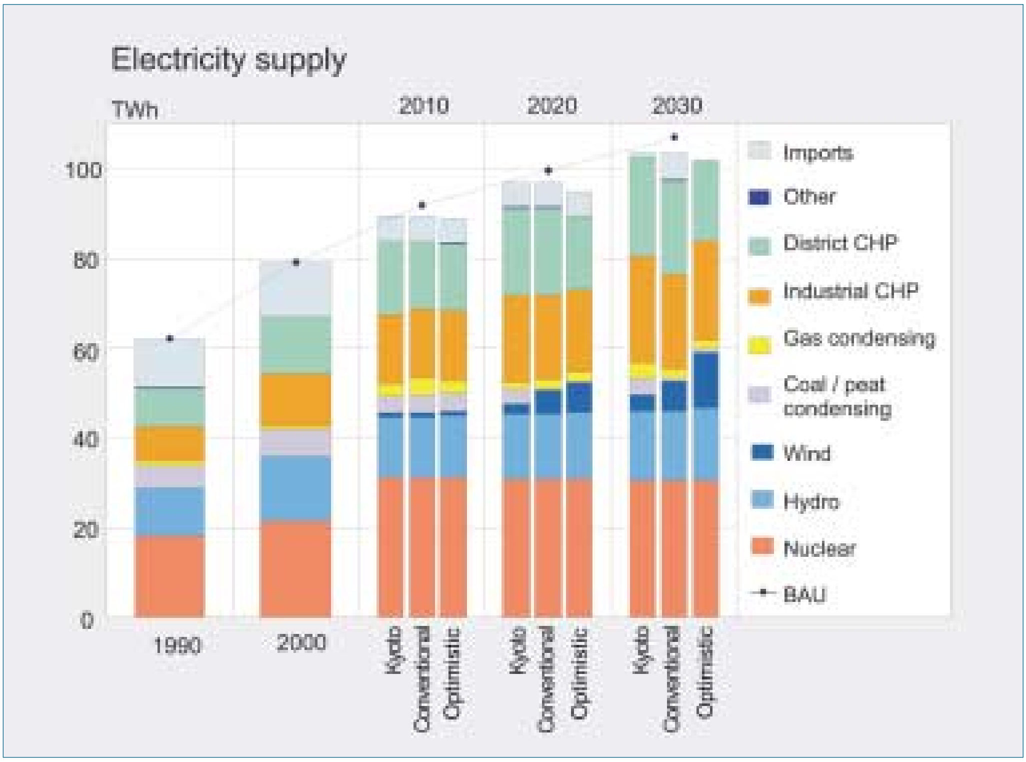

FIGURE 14. Structure of the electricity supply in Finland in 1990 –2030 in the scenarios considered. The supply of electricity is relatively diverse. In the Conventional and Optimistic scenarios the condensing power is replaced by co-production of heat and power and by renewable energy.

with moderate costs in the long term in addition to nuclear power.

New power plant technologies

According to the results, existing technologies related to steam and gas turbines in combined heat and power plants will continue to play a major role together with new technologies until 2030. The natural gas combined cycle power plant will be the most significant individual technology in district heating generation, especially in the case of conventional development.

It will be economic to install gasifiers of biofuels in large steam turbine plants using coal from 2010, according to the scenario results. In addition, natural gas combined cycle power plants may later be the issue. Development of gasification technologies may have a significant role in the efficient use of solid biofuels both in combined heat and power production and in small heating plants.

In the case of rapid technical development, the use of oil in district heating plants can be reduced considerably, if old oil boilers are replaced with new ones using pyrolysis oil. Commercial utilisation of bio-oil requires, however, substantial development in boiler technology.

According to the scenarios, the soda-recovery boiler using a steam turbine will still remain the most significant individual generation technology in industrial combined heat and power production in 2030. The power-to-heat ratio can be improved remarkably in new soda-recovery boilers compared with current units. Gasification combined cycle technology is another promising alternative for a more efficient use of black liquor.

Heat demand is decreasing

Specific heat demand of both new and old buildings is projected to decrease by the warming of the climate, tightening of building codes and support of renovation. As a consequence, the total consumption of buildings' heating energy will decrease, despite the fact that building stock is projected to increase considerably. According to the scenarios, the market shares of district heating and direct electric heating as well as of wood fuels will grow, in concomitance with the significant decline of oil heating. Development work related to automatically fed stoker-boilers, pellet fireplaces, and particularly to pyrolysis oil boilers has a considerable role in reducing the use of mineral oil in order to abate emissions. In the case of optimistic development, solar heating will gain access to the market on a relatively broad scale in 2030.

Costs are reduced by early R&D

The potentials of technologies can only be used in full if investments in the development of functionality and economy of technologies are made in time, owing to slow

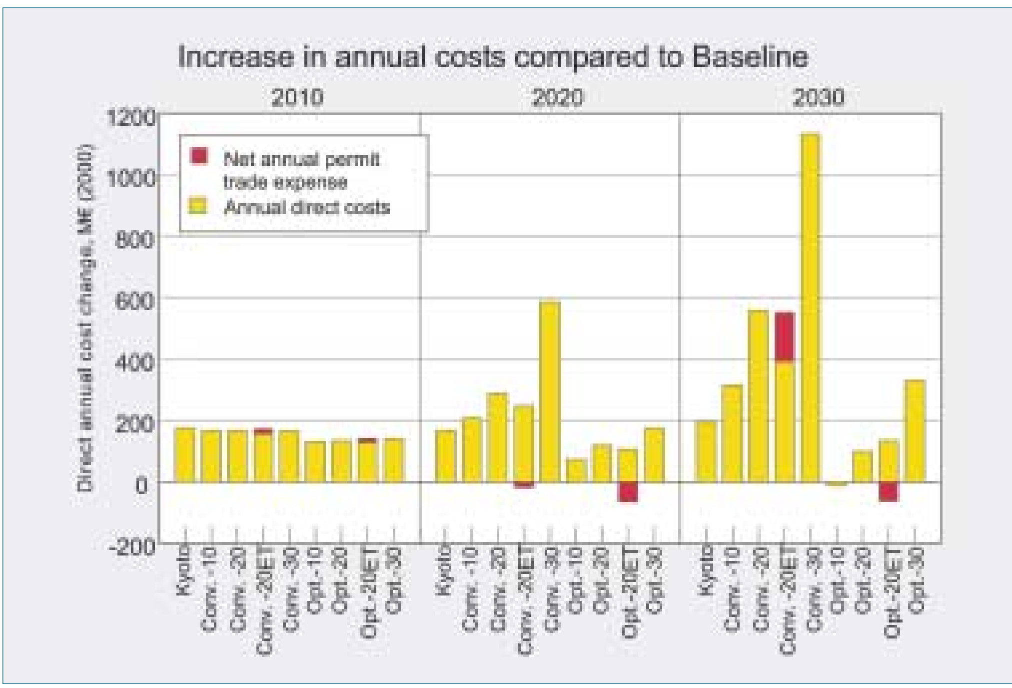

FIGURE 15. Annual direct costs in scenarios. Direct costs include both investment and operating costs. The net cost of emission trading is also shown for the Optimistic scenario with 20 % emission reduction in 2030. The great cost difference between the Conventional and the Optimistic scenarios indicates that investing in technological development would considerably lower the total costs of emission reduction.

changes in the energy system. By staying at the cutting edge of technology know-how the export possibilities will be substantial.

According to the results of the scenario studies, the development of technologies has a significant impact on direct costs resulting from emission reductions (Figure 15). The tighter the emission abatement goals are, the wider the difference in costs among the scenarios is. Furthermore, the earlier clean technology is developed and implemented, the greater the cost savings will gradually be achieved.

Emission trading lowers costs

The potential impacts of emission trading on the Finnish energy system were also analysed in the calculations of both Conventional and Optimistic technological development (Figure 16). The market price of emission rights was assumed to be 10 € / tCO_2 in 2010 and then increasing linearly to 30 € / tCO_2 in 2030. The differences among the scenarios are emphasised in 2030: it appears to be profitable to purchase relatively many emission rights in the case of the conventional scenario, whereas selling them is profitable in the optimistic case. The rapid development of technologies creates opportunities for selling emission rights instead of purchasing. As a consequence, a substantial benefit can be achieved by investments in development work.

In addition, emissions of other air pollutants have also been found to de-

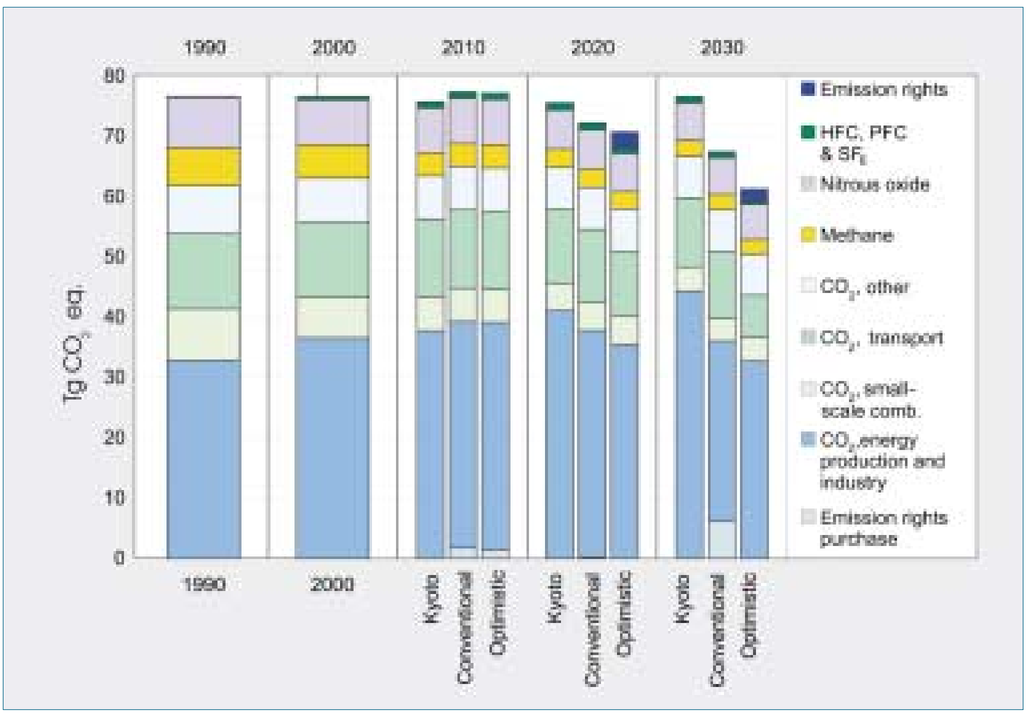

FIGURE 16. Greenhouse gas emissions by gas in Finland in 1990–2030 in the scenarios considered. The development of technology and the market steer the allocation of emission reduction measures on sectors and gases cost-effectively. Emission rights sold and purchased are also shown. The market price of emission rights is assumed to be 10 € / tCO2 in 2010 and then increasing linearly to 30 € / tCO2 in 2030.

crease considerably by implementing actions for the limitation of greenhouse gas emissions. The opportunity to solve the problem related to air pollutant emissions in concomitance with greenhouse gases may significantly accelerate the demand and implementation of climate-friendly technology.

Commercialisation of new climate-friendly technologies

Mitigation of climate change generates market-requiring improvements of energy systems. Finnish enterprises can be helped to enter the market through the promotion of the introduction and commercialisation of new technology.

Emission reductions generate demand for efficient low-emission energy technologies. As a consequence, requirements of emission abatements can be seen as a business opportunity. Several projects related to commercialisation as well as one project concerning the market of new energy technologies were undertaken in the CLIMTECH programme.

Markets of renewable energy technologies are growing fast

The global market of technologies related to energy production and use achieves 300–400 billion US dollars annually, corresponding to two to three times Finland's GDP. This market will gradually focus on technologies exploiting renewable energy sources or which save the use of energy. In addition, technologies that abate emissions of non-CO_2 greenhouse gases will also be in demand.

Production of electricity by biofuels and wind power as well as the global market of technologies related to these energy sources are estimated to multiply within the next ten years. Furthermore, demand for many other climate-friendly technologies is projected to increase significantly. Investments in technological development are of central importance to keep or even to increase the position of Finnish technology in these highly expanding market.

The development of new climate-friendly technologies will lower the costs of emission abatement requirements, which will have a strong impact on business and the national economy. In the case of Finland, this impact is estimated to be even hundreds of millions of euros annually, depending naturally on the emission reduction levels of the next few decades.

Energy demand is calculated to increase, particularly in developing countries. As a consequence, the total market of energy technologies in these countries will soon exceed the level of the industrialised world. New distributed technologies are often suitable for developing countries with a limited infrastructure. Technologies reducing the emissions of greenhouse gases typically also have a favourable environmental influence on other emissions like local air pollutants and acidification. In developing countries, particularly, this may be an issue prior to the abatement of greenhouse gas emissions.

Business from energy saving

The potential of new methods in emission reductions was also estimated in the CLIMTECH programme. An energy-saving company (ESCO) is an example of such methods. It includes the outsourcing of energy saving and possibly also of emission reduction (emission saving) to some other company. The investment in an ESCO project is amortised through the energy cost saving it generates. The potential of industrial ESCO projects for reducing greenhouse gas emissions is about 10% of the total emission reduction potential relating to energy conservation. As regards an industrial enterprise and an ESCO company, the direct repayment period of ESCO projects is usually 2-6 years. This often makes them feasible investments, regardless the prevailing climate policy.

A project within the CLIMTECH Programme explored the possibilities of constructing a market for climate-friendly energy technologies by applying an interactive learning process, i.e. societal embedding of innovations. The project consisted of two case studies that focused on the adoption of the ESCO energy service in the municipal sector and on increasing the use of wood pellets in single-family houses. The term "societal embedding" refers to an interactive learning process amongst three groups of key actors: producers, users and societal actors. The innovation is shaped in co-operation to suit the needs of the market. Another aim is to create

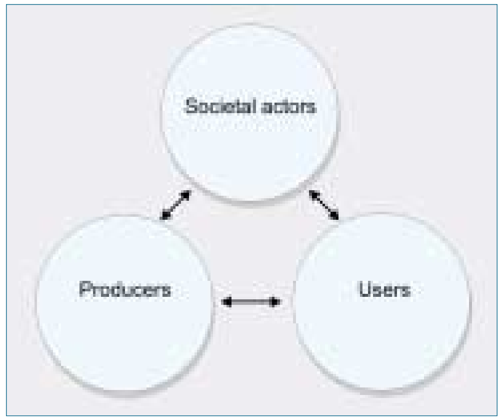

FIGURE 17. Key actors in societal embedding.

FIGURE 18. Renewable Energy Certificate System (RECS) helps to verify the source of energy and can increase the demand for clean energy production technologies.

conditions in which the new technology can be adopted.

Renewable Energy Certificate System

The CLIMTECH programme participated in a project to develop and test procedures and a system for the trading of green certificates in Europe. RECS (Renewable Energy Certificate System) procedures for Finland were developed for the purpose of auditing production devices and for issuing and trading the certificates. A web-based certificate register was also developed and implemented. At the European level, the number of certificates issued was equivalent to 14 TWh production at the end of 2002. Of the certificates issued about 40% were Finnish production.

Risk financing is available

Ways to finance the commercialisation of climate-friendly energy technologies in Finland were sought in a CLIMTECH project. Investors and the representatives of 15 companies and public sources of financing were interviewed.

The study indicates that financing is not a major problem in the development of climate-friendly energy technology. Capital investments in the branch have increased, and both domestic and international investors are interested in Finnish environmental technology. Companies in the branch consider the public financial services fairly good.

Investors, however, take a more critical attitude towards the public sector financial system available for the energy technology companies than the companies in the branch, and they expect the public actors to take higher risks. The low level of risk-taking by the public financiers is partly reflected by the fact that there are clearly too few good investment objects available for venture capitalists in the energy and environmental technology sector.

Summary of commercialisation

There are several measures to promote energy technology development, commercialisation, and export. First, a clear long-term and broad political commitment of emission reductions is needed to enable companies to focus more on technological development. In addition to technological development, the demand for technology must also be promoted. The market can also be promoted by new business concepts. Co-operation networks and action plans (road maps) have an important mission in commercialisation. According to interviews carried out with investors the public sector should take more risks in funding technology development projects that take technology onwards.

APPENDIX 1. The projects of the Technology and Climate Change (CLIMTECH) Programme

Subject area 1: Renewable Energy Sources and Distributed Energy Production	**Contractors**
- The possibilities of wind power for mitigating climate change	VTT[1]
- Road map for solar energy technology and markets in Finland	Solpros Ltd.
- The possibilities of bioenergy in reducing greenhouse gas emissions	VTT[1]
- Distributed energy production: technology, fuels, markets, and CO_2 emissions	Gaia Group Ltd.
- Hydrogen technology survey	HUT[2]
Subject area 2: Energy Efficiency and Industry	
- Electricity-saving possibilities in household and office appliances	TTS-Institute[3] & VTT[1]
- The operation of Energy Service Companies (ESCO) in view of climate change mitigation	Motiva Ltd.
- Development scenarios of high-efficiency power plant technologies in centralised electricity and heat production and their impacts on greenhouse gas emissions	Fortum Ltd. & VTT[1]
- New technologies to reduce greenhouse gas emissions in the forest industry	JP Consulting Ltd.
- Environmental and energy-related benefits of biotechnology in mechanical pulping	VTT[1]
- Industrial ecology and the reduction of greenhouse gas emissions	Fortum Ltd. & HUT[1]
Subject area 3: Non-CO_2 Greenhouse Gases	
- Emissions abatement of fluorinated greenhouse gases	FEI[4] & VTT[1]
- Mitigation of greenhouse gases from waste management	VTT[1] & FEI[4]
Subject area 4: Capture and Utilisation of CO_2	
- CO_2 capture technologies and their potential	Fortum Ltd. & TUT[5]
- CO_2 storage and utilisation technologies	VTT[1] & HUT[2]
Subject area 5: Models and Systems	
- Development of energy system models for Finland in co-operation with the IEA ETSAP programme	VTT[1] & HUT[2]
- Participating in the IEA project "Greenhouse gas balances of biomass and bioenergy systems" (IEA Bioenergy Task 38)	VTT[1]
- Carbon sink and other greenhouse gas impacts of wood products	EFI[6] & VTT[1]
- Developing and testing of the Renewable Energy Certificate System (RECS)	Fingrid Ltd.
- The impact of information technology and Internet economy on energy economy, energy technologies and greenhouse gas emissions	VTT[1]
- Reducing carbon dioxide emissions of transport in Finland	TUT[5] & VTT[1]
- The impact of climate change on energy management	FMI[7]FEI[4]& Fortum
- Local means of livelihood in mitigating climate change – the case of Southeast Finland	"AFLRA"[8]
- The impact of climate change mitigation on air pollutant emissions	Progr. coord., VTT[1]
Subject area 6: Commercialisation	
- Societal embedding of innovations related to renewable energies and energy saving	VTT[1] Technology Studies
- Methods for promotion of commercialisation and implementation of new climate neutral technologies	LTT Research Ltd.
- Markets of new energy technologies	Progr. coord., VTT[1]

[1] VTT = Technical Research Centre of Finland; [2] HUT = The Helsinki University of Technology; [3] TTS-Institute = Work Efficiency Institute, Finland; [4] FEI = The Finnish Environment Institute; [5] TUT = Tampere University of Technology; [6] EFI = European Forest Institution; [7] FMI = Finnish Meteorological Institute, [8] "AFLRA"= The Association of Finnish Local and Regional Authorities

APPENDIX 2. Some publications of the CLIMTECH Programme

Numerous reports, articles and brochures have been produced on project and on programme results. More information and all the reports and brochures (as pdf documents) can be found on the Internet pages (www.tekes.fi/english/programm/climtech or www.climtech.vtt.fi) of the programme. The final report of the CLIMTECH programme:

Soimakallio, S., and Savolainen, I. (eds.) 2002. Technology and Climate Change CLIMTECH 1999-2002 – Final Report. Finnish National Technology Agency (Tekes), Helsinki, Finland. Technology programme report 14/2002. 259 p.

In addition to the final report and project level reports and brochures the programme also published three more general studies or books in Finnish on the role technologies in the mitigation of climate change:

Savolainen, I., Tuhkanen, S., Ohlström, M., Pipatti, R., Pingoud, K., and Johansson, A. 2000. Teknologia ja ilmastonmuutos – Lähtökohtia Climtech-ohjelmalle. [Technology and Climate Change – Starting point for the CLIMTECH technology programme. (In Finnish)]. Tekes, Helsinki. 65 p. Technology Review: 85/2000.

Savolainen, I., Tuhkanen, S., and Lehtilä, A. (eds.). 2001. Teknologia ja kasvihuonekaasupäästöjen rajoittaminen – Taustatyö kansallista ilmasto-ohjelmaa varten. [Technology and Mitigation of Greenhouse Gas Emissions – Background Study for the Finnish Climate Change Action Plan. (In Finnish)]. Ministry of Trade and Industry, Publications 1/2001. Edita ltd, 2001. 198 p.

Savolainen, I., Ohlström, M., and Kärkkäinen, A. (eds.) 2003. Ilmasto – Haaste teknologialle. Näkemyksiä ja tuloksia Teknologia ja ilmastonmuutos (Climtech) - ohjelmasta [Climate – Challenge for Technology. Views and results from the Technology and Climate Change (Climtech) Programme (In Finnish, with an extended English abstract (this publication)).] Edita, Helsinki 2003. 208 p.

Some project level reports were written in English (more reports in Finnish with English abstract):

Hottinen, T. 2001. Technical Review and Economic Aspects of Hydrogen Storage Technologies. 2001. Helsinki University of Technology, Department of Engineering Physics and Mathematics (Master's thesis). 81 p.

Kallioinen, A., Pere, J., Siika-Aho, M., Lehtilä, A., Mälkki, H., Syri, S., and Thun, R. 2003. Biotechnical methods for improvement of energy economy in mechanical pulping. VTT Research Notes 2183, Espoo. 86 p. http://www.inf.vtt.fi/pdf/tiedotteet/2003/T2183.pdf

Kohlmann, J., Zevenhoven, R., Mukherjee, A. B., and Koljonen, T. 2002. Mineral carbonation for long-term storage of CO2 from flue gases. Report TKK-ENY-9, Helsinki University of Technology. Espoo, June 2002. 60 p.

Koljonen, T., Siikavirta, H., and Zevenhoven, R. 2002. CO_2 capture, storage and utilisation in Finland. Project report PRO4/T7504/02, VTT Processes, Espoo. 95 p.

Koljonen, T., Siikavirta, H., Zevenhoven, R., and Savolainen, I. 2002. CO_2 Capture, Storage, and Reuse Potential in Finland. The Sixth International Conference on Greenhouse Gas Control Technologies, 1–4 October 2002. Kyoto, Japan.

Oinonen, T., and Soimakallio, S. 2002. Abatement Options and Costs of Reducing HFC, PFC and SF6 Emissions in Finland. In: van Ham J., Baede A., Guicherit R., Williams-Jacobse J. (eds). Non-CO2 Greenhouse Gases: Scientific Understanding, Control Options and Policy Aspects. Pp. 421–426. Millpress, Rotterdam Netherlands 2002. 714 p.

Pingoud, K., Perälä, A.-L., Pussinen, A., and Soimakallio, S. 2003. Greenhouse gas impacts of harvested wood products. Evaluation and development of reporting methods. VTT Research Notes 2189. Espoo

Siikavirta, H., Järvinen, P., and Linnanen, L. 2002. Industrial Ecology and greenhouse gas control. Helsinki University of Technology, The Publication Series of the Institute for Regional Economics and Business Strategy, Lahti. 69 p. ISBN: 951-22-6298-3

Vasara, P., and Peuhkuri, L. 2002. ECLOGUE – the Impact of Information Technology on the Reduction of Greenhouse Gas Emissions in the Forest Cluster. Jaakko Pöyry Consulting. 50 p.

The energy system of Finland can be characterised by diversified energy sources, large utilisation of combined heat and power production (CHP), and by large use of biomass derived fuels. Some half of the energy consumed in Finland is used by manufacturing industries. This industrial field, however, also produces a lot of energy mainly from by-products generated in forest industries.

The reduction of greenhouse gas emissions has impact on both energy production and consumption technologies, and on other technologies linked to activities causing greenhouse gas emissions. The reduction of emissions incurs costs but on the other hand it creates demand for new efficient technologies which can be utilised in the global scale. Finnish industry is already leading the way in many technologies that can be used for reducing global greenhouse gas emissions. The export possibilities are expected to grow significantly in the near future.

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