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1. EXECUTIVE SUMMARY

1. FINLAND AND THE GREENHOUSE EFFECT

Finland is an industrialized country with extensive forest lands. Because of the structure of industry and the country's geophysical conditions, large amounts of energy are consumed. In 1995, CO_2 emissions from fossil fuels and peat and from industry totalled 56 Tg, as compared to 54 Tg in 1990. Wood burning released another 21 Tg of CO_2 in 1995, but this is not counted in total emissions because even more carbon was bound up in the growing stock in the forests. Methane (CH_4) emissions totalled 241 Gg in 1995, nitrous oxide (N_2O) 18 Gg, nitrogen oxides 259 Gg, carbon monoxide (CO) 434 Gg and volatile organic compounds from human activities (NMVOC) 182 Gg. Emissions other than carbon dioxide were jointly equivalent to some 25 Tg of CO_2 in terms of their direct or indirect greenhouse effect.

These estimates are consistent with the Intergovernmental Panel on Climate Change (IPCC) guidelines for estimating national greenhouse gas emissions and sinks. The minor deviations from the guidelines have been presented in this report.

Trends in national greenhouse gas emissions and sinks to 2000 and beyond have been estimated in consultation with appropriate government departments, industry sectors, research institutions and other bodies. Wherever possible, these projections take into account the effect of current and planned policies and measures aimed at reducing emissions and enhancing sinks.

2. FINLAND'S CLIMATE STRATEGY

The main focus in Finland's climate strategy is to intensify those programmes for reducing greenhouse gas emissions that are already under way, such as efficiency improvements in the energy production and utilization system, and use of energy and carbon taxes. As well as limiting emissions of CO_2 and other greenhouse gases, the Finnish action programme also includes measures to enhance carbon reservoirs and sinks.

In its energy report to Parliament in autumn 1993, the Government adopted the goals of stopping increases in CO_2 emissions from energy production and use by the end of the 1990s. Finland has been practising sustainable forestry for decades now, and consequently the forests are also expected to sequester considerable amounts of atmospheric carbon in the future. In 1994, the Government ratified the Forestry Environmental Programme concentrating on protecting the biodiversity of the forest ecosystem. This means that even more carbon will be bound in the forests.

In December 1995, the Finnish Government decided on a new energy efficiency programme for the years 1996–2010. The programme consists of both economical and normative measures that promote energy saving. Additionally, voluntary agreements with the industry and other energy users will be used to reduce energy consumption.

In line with the Convention on Climate Change, Finland is taking action to mitigate climate change by limiting emissions of greenhouse gases and enhancing sinks and reservoirs. The country's potential for doing this is limited by its special geographical and economic conditions, which should be taken into account according to the Convention. Finland will work with other countries to promote the widespread adoption of measures to mitigate climate change, with the maintenance of sustainable and balanced economic development as a goal.

3. CARBON DIOXIDE EMISSIONS FROM ENERGY SECTOR AND INDUSTRY

In 1995, CO_2 emissions from Finnish energy production and industry, estimated according to the IPCC reporting instructions, totalled some 56 Tg. Most of these emissions derived in various ways from energy production and consumption. Emissions from industrial processes, mainly from the cement and lime industry, totalled 0.8 Tg.

Other activities connected with energy production, but whose emissions are not counted in the CO_2 total, are bunkers, use of wood-based fuels, and emissions equivalent to imported electricity. The CO_2 emissions of bunkers totalled 1.8 Tg in 1995. Some 21 Tg derived from the use of wood-based fuels. Finland has in recent years imported 10–15% of its needed electricity from neighbouring countries. In 1995, net imports of electricity accounted for 12% of total consumption of electricity, which would have caused some 8 Tg of CO_2 emissions if it had been generated by Finnish coal fired condensing power.

Finland's industrial output rose by a third between 1980 and 1990. During the same period, however, fuel consumption only increased about 20%. In terms of CO_2 emissions, it was beneficial that the increase in fuel consumption stemmed mainly from wider use of natural gas and wood-based fuels. Today's nuclear power capacity came on line in the early 1980s, and by 1990 it accounted for a third of total electricity production. Oil consumption by industry halved during the 1980s, and emissions from industry and energy production at the end of the decade were nearly the same as ten years earlier, though the economy and energy consumption had grown.

CO_2 emissions from domestic traffic rose from 8.4 Tg to 11.5 Tg between 1980 and 1990, largely as a result of the increase in passenger and goods traffic related to the fast economic growth (nearly 40% in 1980–90). Judged in passenger kilometres, traffic increased 30% in the 1980s. During the same period, distances travelled by lorries rose 16%.

Around the end of the 1980s, however, the Finnish economy plunged into a recession that proved extremely severe compared both with other countries and Finland's own past history. The output dropped for three years in succession (1991–93), and the unemployment rate hit almost 20%, compared with a mere 3% in the late 1980s.

Starting from 1994, an upturn has taken place, although the unemployment has shown only a slight decline. Prognoses suggest that the Finnish economy has all the preconditions for reasonable growth in the latter half of the 1990s. This growth is also an important goal of economic policy, if the unemployment and debt problems caused by the recession and the overheated economy that preceded it are to be overcome.

The estimates of CO_2 emissions for 2000–2020 are based on three main scenarios. These scenarios include many assumptions and measures, which are unlikely or which have not been implemented. The major factors affecting the demand for energy are economic growth, structure of the economy, technology available, relative price of energy, and consumers' habits and attitudes. According to the Energy Market Scenario (EMS), the total consumption of energy will, in 2020 be 40% higher than in the mid-1990s and the use of electricity will be 70% higher.

The Energy Policy (EPO1) scenario contains several factors with a restraining effect on the demand for energy; not only the rise in world market prices but also a more stringent energy taxation, an accelerating penetration of new energy technologies and a more stringent normative regulation on the use of energy because of positive attitudes. By means of energy taxation, choices between different types of fuels will be steered into a direction leading to reduced CO_2 emissions. In the EPO2 scenario, an increase of 2000 MW in nuclear power production would occur before the year 2010. As compared to EPO1, less natural gas would be used for electricity generation.

According to the EMS scenario, CO_2 emissions from fossil fuel and peat would be about 70 Tg in 2010 and 79 Tg in 2020 (Fig.1–1). In the EPO1 scenario, the corresponding values would be 60 Tg and 53 Tg; and for the EPO2 scenario the estimates are 55 Tg and 48 Tg. In both scenarios, wood-based fuels would release 27 Tg of carbon dioxide in 2010. In 2020, the emissions from wood-based fuels would be about 10% higher in the EPO scenarios as compared to the EMS scenario.

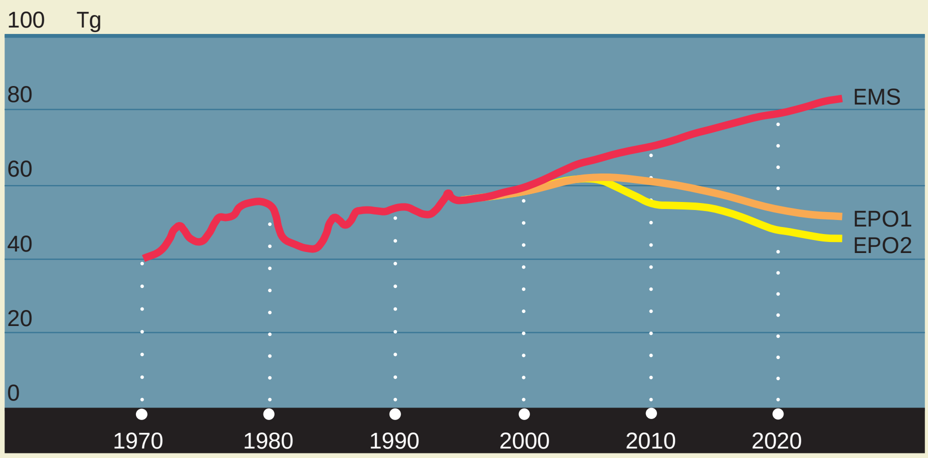


Figure 1–1. **Carbon dioxide emissions in Finland in the energy market (EMS) and energy policy (EPO1 and EPO2) scenarios (Ministry of Trade and Industry 1997).**

In all scenarios, the CO_2 emission equivalents of imported electricity are assumed to decrease somewhat from their present level, as indicated in Table 1–1.

4. BIOSPHERIC CARBON RESERVOIRS AND SINKS

The forests are Finland's most important natural resource. Of the total land area, 76% is classified as woodland. The forests have been managed according to sustainable principles for several decades now, and fellings have exceeded forest growth only during a short period in late 1950s and early 1960s. As a result, growing stocks in the forest have been considerably rising. The forests and the timber resources in them are still increasing substantially, thanks to their age structure and efficient silviculture. In 1995, the volume of growing stock in Finland was 1 980 million cubic metres, and the carbon storage in the forests continues to rise, since the overall amount of timber harvested each year is considerably lower than the increment.

According to the current Forestry Environmental Programme, an annual increment of some 5–10 million cubic metres is estimated to be untouched by commercial exploitation, as a result of environmental protection goals such as the conservation of biodiversity. In 1995, the Finnish forest ecosystem, including mineral soils, had stored 1 500–2 000 Tg of carbon, with trees accounting for 695 Tg. The net carbon dioxide sink of trees in 1995 is put at around 14 Tg of CO_2.

Finland also has huge areas of peatland and mire. The carbon stored in the peat is put at 4 500–5 500 Tg. Virgin mires are estimated to accumulate some 4 Tg of

Table 1–1

CO_2 emissions from energy production, consumption and industry in Finland in 1990 and 1995 and estimates for 2000, 2010 and 2020 (Tg).

Source	1990	1995	2000	2010	2020
Fossil fuels and peat	52.6	55.1	57–59	55–70	48–79
Industrial processes	1.2	0.8	1	1	1
Bunkers	2.8	1.9	2	2	2
Wood-based fuels	17.1	20.7	24	27	30–34
Emissions equivalent to imported electricity	11.0	8.0	7	6	5

Table 1–2

Biosphere-related CO_2 uptake and removal in Finland in 1990 and 1995 and estimates for 2000, 2010 and 2020. Carbon dioxide removal from forests includes timber harvesting, logging and silvicultural waste and natural mortality; CO_2 removal from peatlands consist of fuel peat and horticultural peat. All figures are in Tg CO_2.

Source / sink	1990	1995	2000	2010	2020
Forests:					
CO_2 uptake	103	97	107	112–114	114–124
CO_2 removal	72	83	91	91–100	91–100
Balance (= sink)	31	14	16	12–23	4–34
Peatlands:					
CO_2 uptake	9	9	9	9	9
CO_2 removal	6	7	7	5–6	4–5
Emissions from cultivated areas	3–10	2–5	1–3	1–3	1–2
Emissions from non-viable drainage areas	1–5	1–4	0–3	0–1	0

carbon dioxide every year. Of the country's original ten million hectares of peatland, some six million have been drained for forestry and farming. In most of the areas drained, tree growth has improved and carbon absorption has increased, a fact partly reflected in rising forest resource figures. The accumulation of carbon in the peat layers seems to continue also after drainage; the present estimate indicates an annual surplus of 5 Tg of CO_2 in drained peatlands.

Peatlands drained for agricultural use have begun to undergo peat disintegration not counterbalanced by carbon binding in growing plants; thus they form a CO_2 source of 2–5 Tg per year. Similar processes seem to occur in drained peatlands where drainage has not resulted in the desired increase in forest growth. This source of carbon dioxide is put at 1–4 Tg per year at present.

Two different scenarios concerning the development of forest resources have been made for the years 2000–2020. In both scenarios the wood demand is assumed to increase by 2% per year until 2000; this is based on recent trends and relatively large new investments by the forest industry. Thereafter the demand is assumed to level off in the first scenario, while in the second scenario it increases by 1% per year. In both scenarios, growth is assumed to be at the earlier level, i.e. at 3.9% annually of the growing stemwood stock.

According to the first scenario, the carbon reservoir of the Finnish forests would increase from 1995 by 158 Tg or 23% by the year 2020. According to the second scenario, the corresponding values would be 87 Tg or 13%. Possible effects of climate change have not been taken into account.

As to the peatlands, their CO_2 uptake is assumed to remain at its present level, while the use of peat will decrease somewhat. Carbon dioxide emissions from cultivated areas and from non-viable drainage areas would considerably decrease within the next two decades.

Biosphere-related CO_2 emissions and sinks are summarized in Table 1–2.

5. STRUCTURE OF FINNISH ENERGY PRODUCTION

Finland's energy production system is diversified and utilizes several energy sources (Fig. 1–2). This reduces the economy's vulnerability to problems caused by sudden fluctuations in the price or availability of individual fuels. The most important domestic energy sources are hydropower and biomass in the form of pulp and paper industry wood waste. This latter accounts for 13% of all use of primary energy.

The total electricity production in Finland was 60 TWh in 1995 (Fig. 1–3). Over a third of Finland's electricity is generated in combined heat and power (CHP) systems, that is, either district heating plants or industrial backpressure utilities. At such installations,

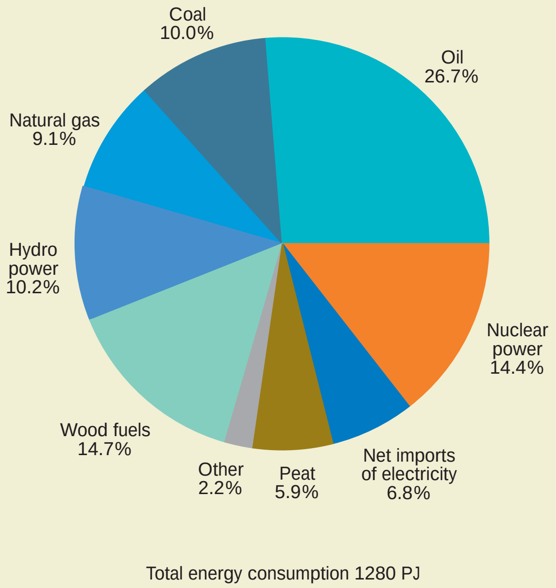


Figure 1–2. **The energy consumption by source in Finland in 1995. The total consumption was 1280 PJ (31.5 Mtoe).**

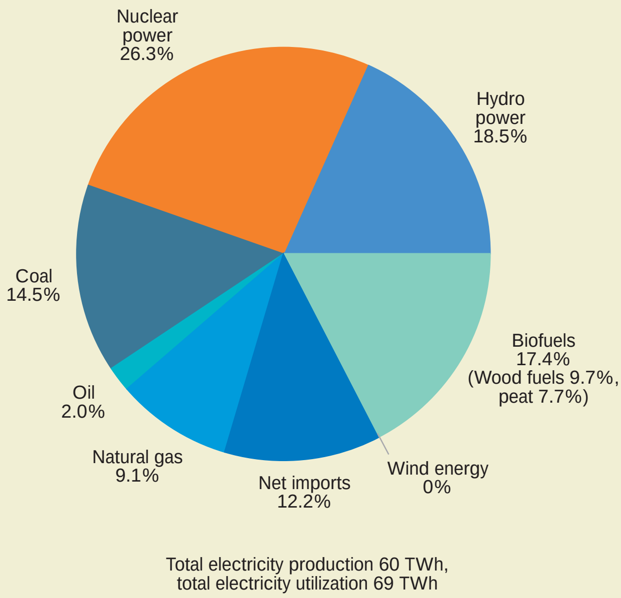


Figure 1–3. **Primary energy sources in Finland's electricity production in 1995.**

80–90% of fuel energy is exploited, compared with 35–40% at condensing power plants. The potential for district heat production combined with electricity and the coverage of the district heating network is already widely utilized. Specific releases of CO_2 from the energy system are therefore already low, at around 42 g CO_2 per MJ.

6. ENERGY POLICY

Finland has a long history of implementing measures to save energy and make energy use more efficient; additionally, several energy reports and programmes have been drawn up since 1973. These actions were largely motivated by economic and environmental reasons.

Because of the cold climate, buildings have always been designed and constructed partly with energy economy in mind. Really effective forms of insulation were introduced in the 1960s and triple glazing, for instance, was made compulsory in all new buildings as early as the 1970s. Official regulations, energy counselling and financial incentives have succeeded in reducing building-specific heat consumption to the level found in many countries that are very much warmer than Finland. These past actions have thus reduced the number of cost-effective options open in the future.

The Government made in December 1995 a decision on the implementation of energy conservation measures. The decision established a new energy efficiency programme with the aim to lower the total consumption of energy by 10% to 15% compared with the ”business as usual” scenario.

The energy efficiency programme is based on the current energy economic position and the forecasts concerning the development of energy prices. The programme takes into account the developments in the EU's common energy policy. One basic assumption is that the promotion of energy efficiency cannot depend on increased state subsidies. The Government also made Motiva, an information centre for energy efficiency a permanent body at the beginning of 1997. Originally, Motiva was started as a project organization for the period 1993–96.

The new programme is based on the implementation of various policy measures including the use of economic instruments, laws and regulations and voluntary agreements. For all the measures, preparations got under way during 1996. It should become possible for the Government to submit the necessary bills to Parliament, and for the various other bodies to make their proposals, during 1997 at the latest.

The Building Code will be revised with a view of reducing energy consumption in new buildings. Energy economy will be taken into account in subsidizing renovations of buildings. In new buildings, each apartment will be equipped with a system permitting the metering of and charging for hot water and electricity consumed. For heat, metering will be required if warranted by the pilot projects and technological progress.

In the utilization of bioenergy, Finland tops the statistics for the industrialized world. This is particularly due to the use of bioenergy in pulp and paper industry. In 1995, bioenergy, including energy generated with peat, accounted for 21% of the total energy consumption and for 17% of electricity produced. It is the declared goal of the government to increase the use of bioenergy by a minimum of 25% (60 PJ) by the year 2005.

As early as 1990, Finland became the first country in the world to introduce a CO_2 tax. At that time, this tax was imposed on fossil fuels (except automotive fuels) according to carbon content. After several changes and tax increases, the CO_2 tax was reformed at the beginning of 1997, to take into account the liberalization of the energy markets and to maintain the competitiveness of the Finnish electricity generation. A uniform tax was imposed on all electricity consumed and the taxes on the input fuels for electricity production were removed. The electricity tax is differentiated between sectors. Industry and professional glasshouse growers are entitled to pay tax approximately at a rate equal to the one effective in the former system. For all other users of electricity, the rate was nearly doubled in the reform. In the case of heat generation, the component based on energy content was removed whereas the component based on the carbon content was approximately doubled.

To ensure that the structure of energy production remains diversified and based on both new technologies and renewable energy sources, the Government has been putting more money into the development of Finnish energy technology, and launching, financing and directing research programmes and development and demonstration projects for the home market and for export. This has been going on for several years now, and in 1993 the Ministry of Trade and Industry launched new energy technology development programmes ranging up to 1998.

Because new nuclear energy is currently ruled out politically, the only hope for even modest improvement depends on fuel-switching to natural gas. There are only two potential sources – Norway and Russia. Norwegian imports would require a major new pipeline, which could be justified economically only if Sweden also buys a very large share of the gas. Russian gas already flows to Finland in small quantities, and there is possibility that new, larger pipeline might be built. But Finland is already highly dependent on other energy imports from Russia (oil and electricity) and there may be some concerns about too great a degree of dependence on any single source.

7. TRANSPORT AND COMMUNICATIONS

Because of its small population and large area, Finland is a sparsely populated country with long distances from place to place. We are also rather far away from our main markets. These factors, combined with the distinctive structure of industry, tend to increase traffic volumes and thus greenhouse gas emissions from traffic. The distances driven by heavy goods traffic are about double the European average, and though the actual car density is around the European average, people drive about one and a half times more kilometres.

Since 1990, a rapid decrease has been achieved in emissions of nitrogen oxide, hydrocarbons and carbon monoxide by traffic, thanks to technical improvements and tax reliefs on cars with catalytic converters. In 1992, Finland started applying US-standard exhaust gas limits to new cars, since 1995 the EU-standard has been applied.

Exhaust gas emissions from lorries and buses have also been cut rapidly in the last five years, in line with EU directives. The maximum nitrogen oxide emission permitted for new heavy diesel engines is only half what it was at the end of the 1980s.

The Finnish tax on new cars has always been rather high by international standards. It has also acted to discourage the purchase of high-powered cars, though this might otherwise have seemed natural considering the long distances that have to be travelled. The high car tax has also helped to restrain growth in the overall number of cars.

The Finnish tax on traffic fuels is a little higher than the average West European level. At the moment, the tax on gasoline is one of the highest in Europe, and that on diesel oil just above the EU minimum, though well below the average. The tax on both fuels has been raised sharply in recent years, and this, together with the recession in the early 1990s, has halted growth in traffic volumes.

The use of alternative gas fuels containing less carbon, as well as the use of bioalcohols and rapeseed methyl esters as fuel, has been studied and gas-powered lorries and buses have been developed as far as the production stage.

Emissions from trains have been reduced by electrifying rail traffic. This process and basic improvements continue.

8. EMISSIONS OF METHANE AND NITROUS OXIDE

Methane emissions from agriculture derive from the digestive processes and manure of domestic animals, and totalled 88 Gg in 1995. The use of chemical fertilizers and manure spreading and, to a lesser degree, the spreading of treatment plant sludge on fields also cause nitrous oxide emissions, totalling 5 Gg in 1995. Reducing these emissions is also a key element in cutting the loads to water systems caused by farming. Improvements to cowsheds and manure containers, and better manure handling procedures have succeeded in reducing methane emissions somewhat.

The Rural Environment Programme, approved in 1992, and the Agri-environmental Support Programme, which was an element in Finnish accession to the European Union, both include actions to reduce greenhouse gas emissions from farming and greenhouse cultivation. It is difficult to predict the changes that will take place in farming and in the number of livestock, but a slow decline of emissions is expected to occur in the next few years.

In Finland, as in most industrial countries, wastewater is mainly treated aerobically, resulting in low methane emissions. Emissions from industrial waste water treatment in 1995 are put at about 10 Gg.

In 1990, Finland had 680 landfills, and some 1 000 had already been closed. The waste management development programme calls for a substantial decrease in the number of landfills; the aim is for only 200 by the year 2000. Reducing the number of landfills will result in more efficient management and supervision, and reduce harmful environmental effects, although an increase in transportation distances is also inevitable.

Methane emissions from landfills were put at 123 Gg in 1995. The emissions will decrease substantially in the next two decades. A few landfills already recover the methane released and use it as a fuel for small-scale energy production.

The decline in total methane emissions by 2010 is estimated to be about 20% and by 2020 about 30%. The decline in the total emissions is slow because of the large time lag between less waste being landfilled and a corresponding drop in methane emissions. The potential reduction in methane emissions is higher than these figures imply.

The trend in anthropogenic nitrous oxide emissions in Finland is rising. In the agricultural sector, nitrogen fertilization is expected to decrease and the emissions to decline. However, emissions from the energy sector are expected to increase with more energy production, and greater use of fluidized bed combusters and cars with catalytic converters, which add to the emissions.

9. GREENHOUSE GAS EMISSIONS IN CARBON DIOXIDE EQUIVALENTS

As converted to CO_2 equivalents, the Finnish emissions of non-CO_2 direct and indirect greenhouse gases were 24.6 Tg in 1995. In 2010, the corresponding figure is estimated to be 22 Tg, in 2020 it would be 23 Tg (Table 1–3).

The indirect greenhouse gases are taken into account here, because they are involved in reactions leading to the formation of ozone, which is a direct greenhouse gas. However, the GWP coefficients for these gases cannot be accurately quantified at present.

10. EXPECTED EFFECTS OF CLIMATE CHANGE IN FINLAND

An interdisciplinary effort called the Finnish Research Programme on Climate Change (SILMU) was initiated in 1990 to coordinate most of the research climate change in Finland. The principal goals were to increase the knowledge about climate change, its causes, mechanisms and results; to promote research on climate change; to further opportunities for Finnish scientists to participate in international research projects; and to prepare and disseminate information to form a basis for decisions on adaptation to and prevention of climate changes.

The key research areas in the programme were the climate changes anticipated in Finland, estimation of the effects of changing climate on ecosystems, and the development of adaptation and prevention strategies. The programme continued for six years (1990–1995), and the budget was FIM 12–15 million per year. Altogether, the programme comprised over 80 research projects and involved some 200 researchers.

Three scenarios of temperature and precipitation change were developed. The central temperature scenario gives a mean annual warming of 2.4°C by 2050 and 4.4°C by 2100. This is about one and a half times the average global warming expected over the same period. The central scenario for annual precipitation is an increase of 1% per decade.

The potential effects of the SILMU scenarios on natural ecosystems and economic activities in Finland were evaluated using a range of approaches, including experimentation, mathematical modelling and expert judgement. The main focus of the studies was on land ecosystems, including forests, peatlands and agriculture, and aquatic ecosystems, including inland waters and the Baltic Sea. The results are summarized in Chapter 7.

As to the implications of climate change in Finland, no systematic vulnerability assessment has been made.

Table 1–3.

Finnish emissions of greenhouse gases in Tg of CO_2 equivalent in 1990 and 1995, and estimates for 2000, 2010 and 2020.

Gas	GWP over 100 years	1990	1995	2000	2010	2020
CO_2	1	53.8	56.0	58–60	56–71	49–80
CH_4	21	5.2	5.1	4.7	4.0	3.8
N_2O	320	5.8	5.8	6.4	7.7	9.3
NO_x	40	11.8	10.4	9.0	8.0	8.0
CO	3	1.5	1.3	1.2	0.9	0.9
NMVOC	11	2.3	2.0	1.7	1.2	1.2
Total		80.4	80.6	81–83	78–93	77–108

Some preliminary research has been made and estimates presented, particularly in those sectors where harmful consequences are potentially high.

The Finnish economy is deeply dependent on the forest sector. Because of the long time periods in forestry, the forest might be more sensitive to climate change than other ecosystems or agriculture. Over the next few decades warming could enhance forest growth. However, Finland should also be prepared for a greater risk of forest damage.

The adaptation of agriculture to climate change depends – in addition to the farmer – on technological progress and agricultural policies at the regional, national and international level. One challenge will be the development of new crop varieties, which are able to exploit the future conditions optimally. Maintaining soil properties suitable for crops might also require considerable efforts in the future.

As for water resources, changes in hydrological regimes and leaching should be anticipated in Finland. An increase of winter flows can also alter considerably the conditions for hydropower production.

11. INTERNATIONAL COOPERATION

Finland assists developing countries in furthering the goals of the FCCC through bilateral and multilateral aid programmes that support countries in adopting advanced environmental technology, in increasing general know-how and capacity concerning environmental protection, and in the maintenance of greenhouse gas reservoirs and sinks, especially forests. In 1994–96 Finland contributed USD 26.4 million to the Global Environment Facility (GEF) in compliance with the agreed sharing of the burden.

Environmental cooperation with countries in economic transition also began recently. The focal areas are the southern neighbours – Estonia, Latvia and Lithuania – and northwestern Russia, particularly the St. Petersburg region, the Republic of Karelia and the Murmansk area.

The primary aim of the cooperation is to prevent transboundary air and water pollution. Relative to the costs involved, cooperation with the neighbouring regions is a very efficient way of protecting the Finnish environment.

Since 1991, the Ministry of the Environment has issued nearly USD 50 million in grants for a total of 140 investment projects in Finland's neighbouring regions. Furthermore, 430 joint technical aid projects have been given assistance totalling USD 17 million to promote training and education, research, institutional strengthening and environmental monitoring.

2. INTRODUCTION

The United Nations Framework Convention on Climate Change (FCCC) took effect globally on March 21, 1994. Finland ratified the Convention on May 31, 1994.

This Second Report outlines Finnish action and strategies to fulfil the commitments of the FCCC. It strives to follow, as far as possible, the guidelines drafted by the meetings of the FCCC Intergovernmental Negotiating Committee concerning reporting and calculation methods. Background material related to the Report and other additional information can be obtained from the ministries concerned; the Ministry of Agriculture and Forestry, the Ministry of the Environment, the Ministry of Finance, the Ministry for Foreign Affairs, the Ministry of Trade and Industry and the Ministry of Transport and Communications.

The Report is based on various ministries' programmes and decisions in the 1990s that are of significance for climate policy. Some of the programmes were approved specifically to implement climate policies, but, equally, some have other national justifications. The Report surveys all the actions taken by Finland towards meeting the objectives of the Framework Convention, that is, the reduction of emissions and the protection of carbon reservoirs and sinks.

Emissions of greenhouse gases from energy production and consumption are monitored in detail in Finland. The Report also deals with changes in the greenhouse gas balances of the biosphere caused by other human activities, though we as yet lack comprehensive data in this area. The present estimates of these changes demonstrate just how important a role the protection and reinforcement of carbon reservoirs and sinks may play in combating climate change.

3. NATIONAL CIRCUMSTANCES

3.1. GEOGRAPHIC AND CLIMATIC PROFILES

Finland lies between latitudes 60°N and 70°N; and a quarter of the country is north of the Arctic Circle. To the west and south, it has a long coastline on the Baltic Sea with numerous islands. With a total area of 338 145 km^2, it is Europe's seventh largest country.

Nearly the whole of Finland is in the boreal coniferous forest zone, and 76% of the total land area is classified as woodland, while only about 9% is farmed. Finland has 33 552 km^2 of inland water systems, or about 10% of its total area (Table 3–1).

In January 1997 Finland's population was 5 132 000, making it one of the most sparsely populated countries in Europe, with an average density of only 16.8 people per square kilometre of land. Population density varies in different areas, however, with 133 people per square kilometre in the southernmost province and only 2.2 in Lapland. About 66% of all Finns live in towns. The population of Helsinki is around 530 000; the five next largest cities have populations between 100 000 and 200 000.

The mean annual temperature in southern Finland is 4...5°C and in Lapland –2...+2°C. In January, mean temperatures in Finland vary between –5°C and –15°C, making it the coldest country in Europe (Fig. 3–1).

Heating degree days, calculated according to 17°C indoor temperature, vary in Helsinki from 3 400 to 4 800 per year. In northern Finland, in Oulu, the corresponding range is 4 500–6 000.

Even in southern Finland, about 30% of the annual precipitation comes in the form of snow, which remains on the ground for about four months. In Lapland the

Table 3–1.

Land use in Finland in 1960 and 1990.

Land use class	1960 km²	1990 km²
1. Agriculture	31 400	28 160
2. Forest and other woodland	224 400	233 665
3. Built-up land	3 400	9 390
4. Open wetlands		20 828
5. Dry open land with special vegetation cover	9 642	
(Items 4 and 5 total)	42 260	30 470
6. Waters	32 600	33 552
7. Unclassified	3 740	2 908
Total area	337 800	338 145

Source: Environment Statistics 1994.

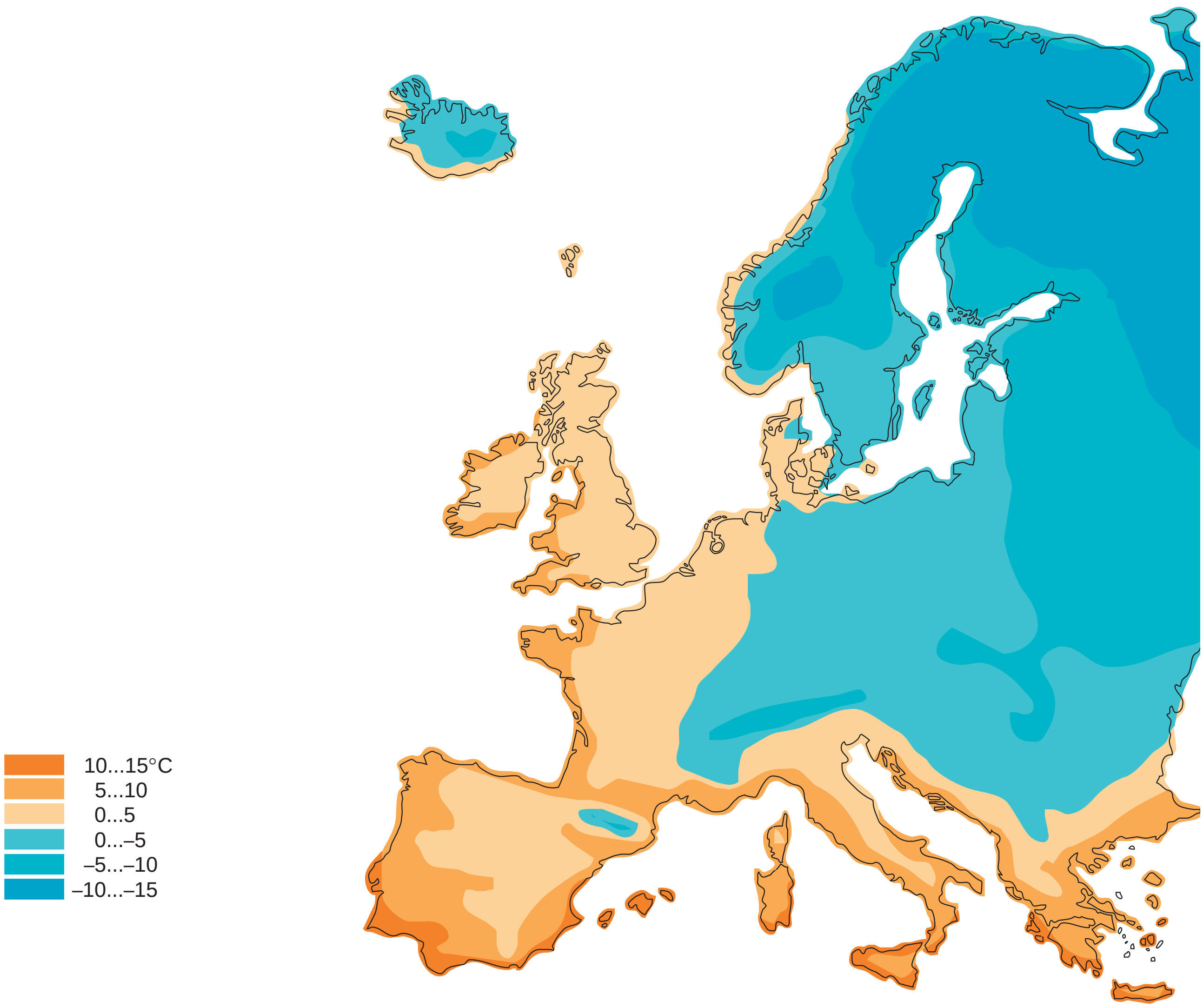


Figure 3–1. **Mean temperature (°C) in January in Europe.**

Table 3–2.

Trends in forest resources from 1950s to 1990s.

	1951–53	1964–70	1971–76	1977–84	1986–94	1989–94
Area of forest and scrubland (mill. ha)	21.9	22.4	23.3	23.2	23.0	23.0
Volume of growing stock (mill. m^3)	1 538	1 491	1 520	1 660	1 887	1 937
Annual increment (mill. m^3)	55.2	57.2	57.4	68.4	77.1	75.4
Total drain (mill. m^3/a)	49.3	56.1	49.7	51.7	54.0	54.2

Source: Yearbook of Forestry 1996.

corresponding figures are 50–70% and 6–7 months.

The growing season (mean daily temperatures above 5°C) is short; 170–180 days on the south coast and about 130 days on the Arctic Circle. This also means that the main areas for crop production are located in the southern part of the country.

The last few decades have been a time of great change for Finnish society. In the 1960s and 1970s, people moved increasingly into towns and industrial occupations. With faster industrialization, the need for social and other services also grew. Transport systems were improved; trade, transport and services doubled in volume between 1950 and 1990.

Over the decades, changes in economic and social structures have also altered the land use profile. The amount of cultivated arable land has slowly decreased, while peatland drainage has increased the total area used by forestry. Partly as a result of new traffic arteries, the area of built land nearly tripled from 1960 to 1990. The total protected area amounted to 2.9 million hectares in 1995.

Finland's most important natural resource is the forest, and almost 90% of it is managed. However, the sustainable use of forest resources is safeguarded under law, and deforestation only occurs because of new roads or other construction activities. Regulation of forestry in fact goes back to the 17th century. Later, the 1886 Forest Act actually prohibited the destruction of forest and thus endorsed the principle of sustainable yield. The Private Forest Act, passed in 1928, ensured that no woodland can be deforested, that the growing capacity is properly managed and that felling is followed by reforestation.

The forest resources of Finland have grown particularly fast in the last couple of decades (Table 3–2). In 1995 the total volume of stemwood was assessed at about 1 980 million m^3, with annual growth at about 75 million m^3.

Between the early 1950s and the year 1990, stemwood volume rose 22% and annual increment 43%. These increases were mainly due to efficient silviculture, forest improvement in areas of low yield and extensive drainage programmes. However, after 1990 the growth has decreased slightly in spruce stands in southern Finland. Because total drain (industrial use, use of fuelwood, other use, export, logging and silvicultural wastes, natural mortality) has, at the same time, gone up, the balance has decreased from about 24 million m^3 in 1990 to about 11 million m^3 in 1995. The growth depends on the structure of forests and particularly on climatic conditions; variations from year to year are considerable.

Total drain fluctuates mainly as a result of changes in industrial use of wood, that is, changes in the industrial demand of wood-based products. In 1989 total drain was 59 million m^3, but in 1991 only 45 million m^3 because of the depression. Thereafter, total drain has again increased, being 64 million m^3 in 1995.

Finland also had originally about 10 million hectares of peatland (Table 3–3). Of this total, over 5 million hectares have been drained for forestry use and 0.7 million hectares for agriculture, leaving some 4 million hectares in a natural state. There were extensive drainage programmes in the 1960s and 1970s and some new projects still in the 1980s. Nowadays new ditches are made in previously drained bogs while old ditches have been closed in some bogs, where forest growth has turned out to be minimal. Less than half of agricultural peatlands are still in agricultural use.

The estimate is that, overall, peatland drainage has added some 15 million m^3 to annual forest growth, that is, 20% of the total. The present extent of peat mining areas is about 50 000 hectares, with an additional 30 000 hectares prepared for production.

Table 3–3.

Finnish peatlands.

	Mill. ha
Original mires before drainage	10.4
Current mire area	9.0
Virgin peatlands	4.3
Peatland drained for forestry	5.3
Cultivated peatland	0.26–0.42
Peat mining areas	0.05–0.08

Source: Geological Survey of Finland 1993.

3.2. ECONOMIC PROFILE

During 1960–90 the Finnish economy expanded threefold, a fast rate by any international yardstick. Industrialization and the advance of the service sector came later here than in older industrial countries. There were several reasons for this fast economic growth: favourable bilateral trade with the Soviet Union right up to the late 1980s and early 1990s, good demand on Western markets and energetic investment in research and development.

Around the end of the 1980s, however, the economy plunged into a recession that proved extremely severe compared both with other countries and Finland's own past history (Fig. 3–2). The output dropped for three years in succession (1991–93), and the unemployment rate hit almost 20%, compared with a mere 3% in the late 1980s.

Starting from 1994, an upturn has taken place, although the unemployment has shown only a slight decline. Prognoses suggest that the Finnish economy has all the preconditions for reasonable growth in the latter half of the 1990s. This growth is also an important goal of economic policy, if the unemployment and debt problems caused by the recession and the overheating that preceded it are to be overcome.

The gross domestic product at market prices was 106 838 FIM per capita in 1995. Within the last ten years, it increased by only about 10%, as compared with over 30% during 1975–85. By type of economic activity, its distribution in 1994 was as follows (in per cent):

agriculture	2.6
forestry	2.6
manufacturing	28.3
construction	5.3
trade and transport	20.0
financing and insurance	3.6
housing	9.5
business services	6.1
other services	21.9

Finland's total exports amounted to FIM 175 billion in 1995, total imports being FIM 126 billion. Traditionally, there have been wide swings in the Finnish balance of trade; however, the surplus of FIM 49 billion in 1995 was the largest in the country's economic history.

The Finns voted to accept their country's membership in the European Union in the October 1994 referendum, and the support for membership has remained rather stable. However, the Finns do not seem to favour a "deepening" of the EU, that is, transferring powers from national governments to Union institutions.

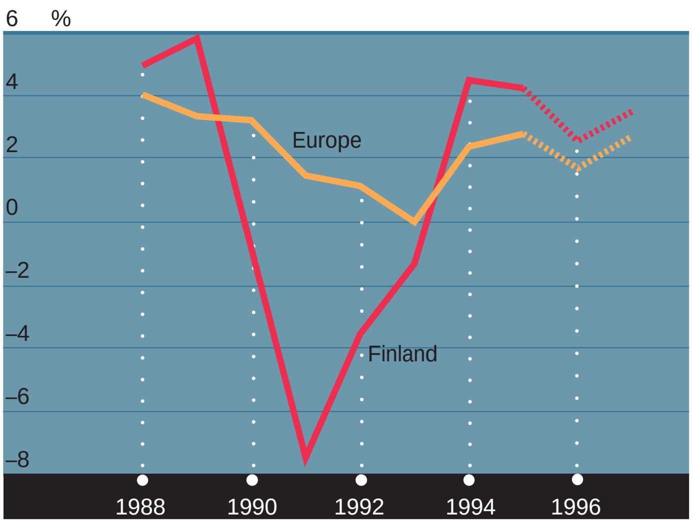


Figure 3–2. **Annual changes of GDP in Finland and in OECD Europe in 1988–95 (Business Finland 1997).**

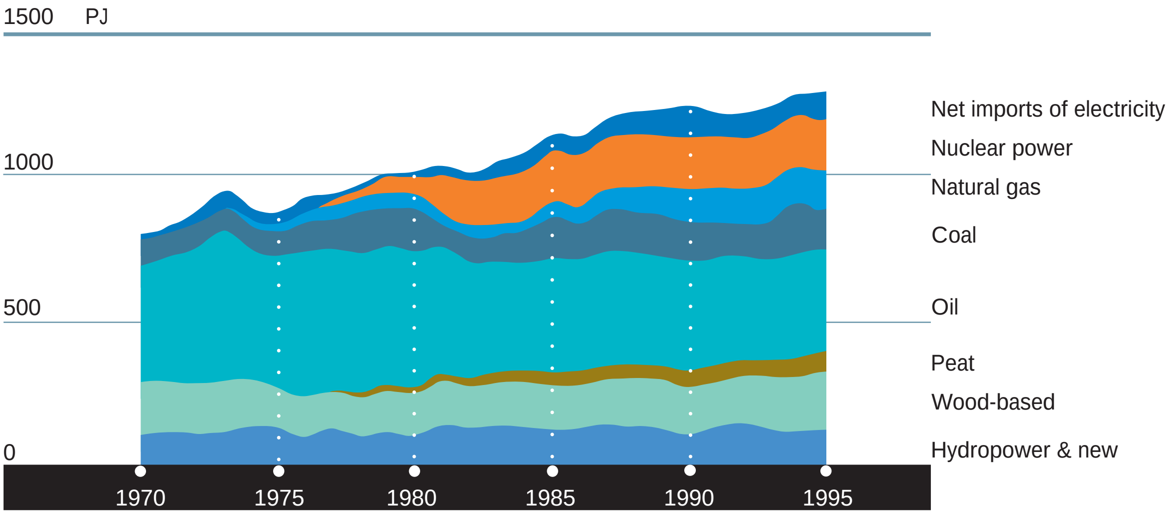


Figure 3–3. **Consumption of primary energy in Finland by source in 1970–95.**

3.3. ENERGY PROFILE

The energy sector in Finland depends to a significant extent – about 70% – on imported primary sources. The main imported energy sources are crude oil, coal, natural gas, nuclear fuel, and a net import of electricity. The main domestic sources are hydropower and biomass residues from the forest industry, supplemented by peat (Fig. 3–3).

Most of the hydropower capacity was built before the end of the 1960s, half of it between the years 1945 and 1960. In the 1950s and 1960s oil captured market shares from coal and from firewood-based heating systems in single dwellings. Combined heat and power production, both in district heating stations and in industry, speeded up especially in the 1960s. The next decade brought two important new energy sources to the Finnish energy markets; natural gas and electricity generated by nuclear power. The use of oil began to decline rapidly except in transport.

The relatively large dependence on fossil fuels results in considerable carbon dioxide emissions. Thanks to the hydro, nuclear and biomass primary energy sources, and to the efficiency of cogeneration of heat and power, the CO_2 emissions per total primary energy unit are nevertheless lower than in several other countries (Fig. 3–4), for example about 25% lower than the average in OECD Europe.

Finnish industry is energyintensive compared with other West European countries; the industry uses 46% of total primary energy and 55% of total electricity in Finland. A considerable part of the energy-intensive industry is export oriented. Up to 87% of the paper and

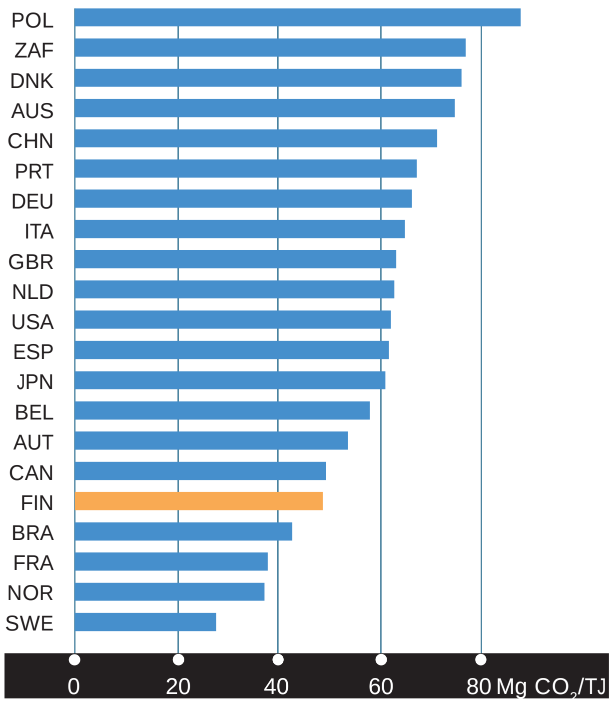


Figure 3–4. **Ratio of CO_2 emissions to total primary energy consumption in selected countries in 1994 (Lehtilä *et al.* 1997).**

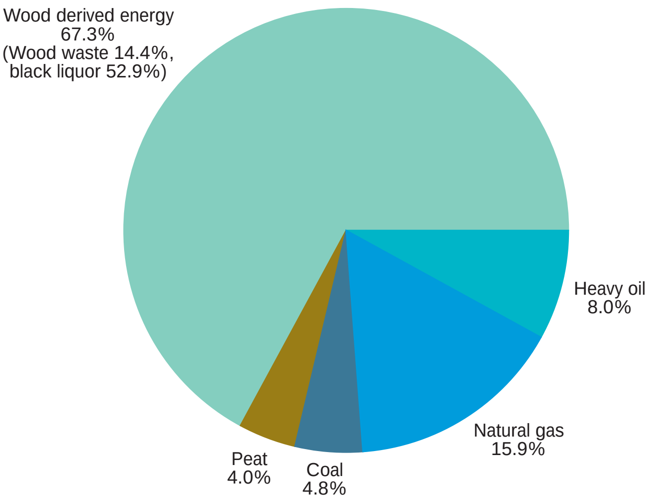


Figure 3–5. **Direct fuel consumption in Finnish forest industry in 1995. The total direct fuel consumption was 260 PJ; in addition the forest industry acquired some 130 PJ of electricity.**

board production is exported and the proportion of export products is high in the base metal industry as well. Thus, a lot of energy is used to supply other countries with energy-intensive products.

Because of high energy demand, Finnish industry has also worked hard to improve its energy efficiency. For example, from 1980 to 1990 industrial output rose by a third, while the consumption of energy only rose by about 20%. In addition, the forest industry relies to an appreciable degree on biomass to meet its energy needs; waste wood, spent pulping liquors and other biomass energy sources are effectively utilized (Fig. 3–5).

In all, the forest industry produces about 10% of the country's total energy. All Finland's pulp and paper mills are self-sufficient in heat energy and all the new mills produce energy in excess of their own requirements. In many forest industrial localities, the energy left over from the manufacturing process is channelled to the municipal district heating network.

Because of the country's northern location, Finland uses a lot of energy for heating (Fig. 3–6). This is the source of most CO_2 emissions by households, and by the public and tertiary sectors. However, during the past two decades it has been possible to reduce the consumption of energy per unit of heated space by 40%. This has been largely due to the standards used in the construction industry, which were tightened up considerably, especially in the 1970s. Energy conservation has received technical support from advanced insulation and window design as well as from the development of heat-recovery, air-conditioning and ventilation systems.

Similarly, because of the sparse and scattered population, the economy is burdened by the long distances goods have to be transported, compared with many other European countries. The markets for our exports also tend to be remote.

Thus, the country's geography, combined with its role in the international division of labour in industry, means that our economic preconditions for effective action to combat the greenhouse effect are not exactly good by international comparison. Furthermore, many measures to increase efficiency, which also reduce emissions of greenhouse gases, were actually taken here in earlier decades, dictated by our demanding circumstances.

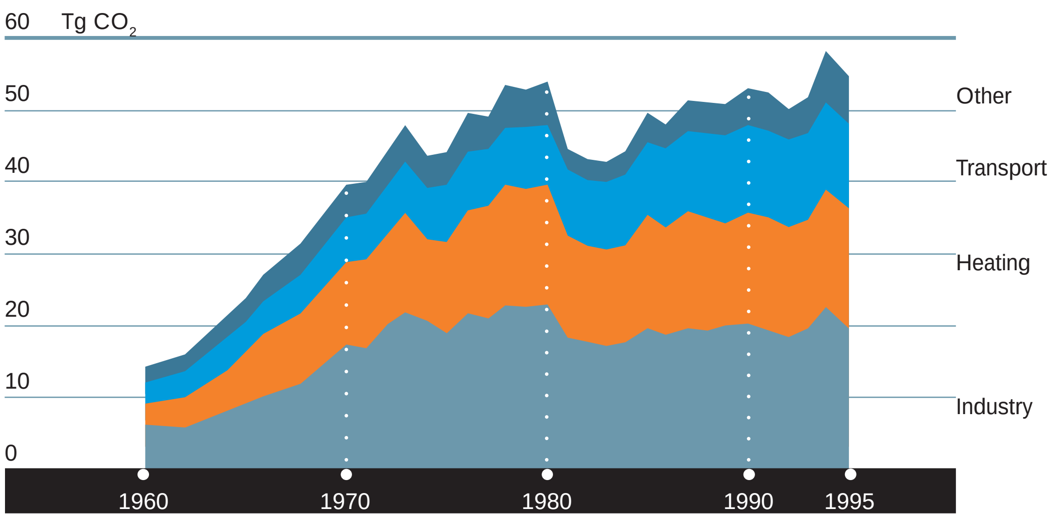


Figure 3–6. **Finnish CO_2 emissions by energy end-use sector (Lehtilä *et al.* 1997).**

COMBINED HEAT AND POWER PRODUCTION

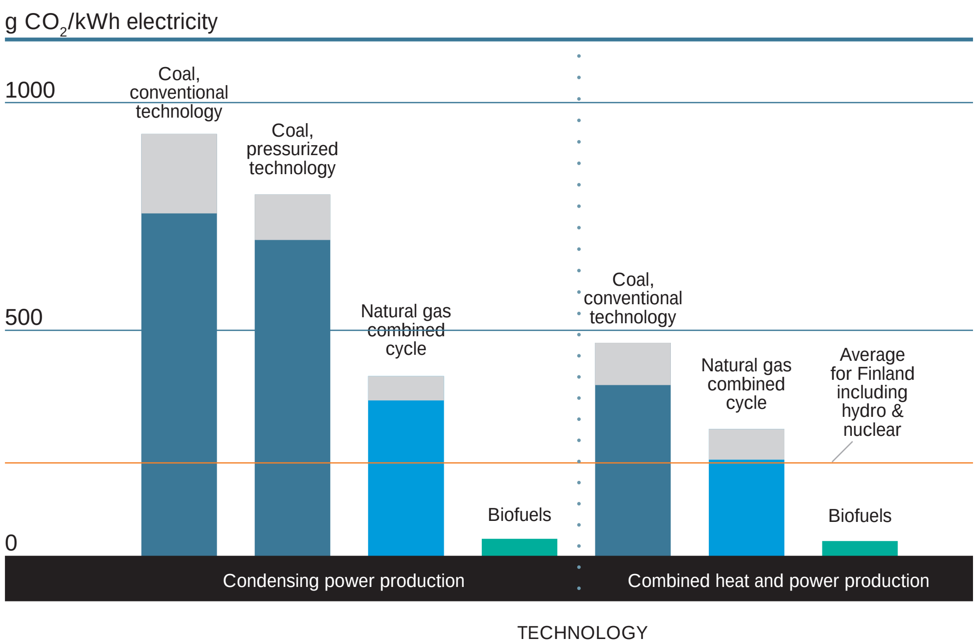
In combined heat and power (CHP) production the waste heat produced by thermal electricity generation is utilized in industrial processes or for heating purposes, thus greatly boosting the overall efficiency and economy of energy production. Conversely, at plants where heat remains the main product, there, too, the principle is to utilize the hot steam produced during the generation of electricity. Over 30% of all electricity produced in Finland is generated at CHP plants.

The net efficiencies of condensing power plants using fossil fuels are 35–40% (including the removal of sulphur and nitrogen oxides), while the total net efficiencies of CHP plants are 80–90%. Compared with separate power and heat generation, this cuts down the amount of fuels needed by as much as 30%.

The efficiency of CHP in reducing CO_2 emissions depends on the fuels used (fossil fuels or renewable energy sources), the balance between heat and power produced, and the degree to which the waste heat can be exploited and substituted for fossil fuel based energy production.

At the moment, CHP technology based on the conventional steam-cycle is available for all commercial fuels. More advanced combined-cycle technologies are available for natural gas. In the case of biomass, better techniques are still under development. In the long-term, combined-cycle CHP plants based on pressurized gasification could double the electric output of biomass fuelled CHP generation.

In 1995, total electricity production in Finland was 60.5 TWh, of which 20.7 TWh (34%) was due to CHP. If the proportion of CHP in Finland had been as low as the average in the EU (6% in 1990), Finland's CO_2 emissions would have increased by 10%.

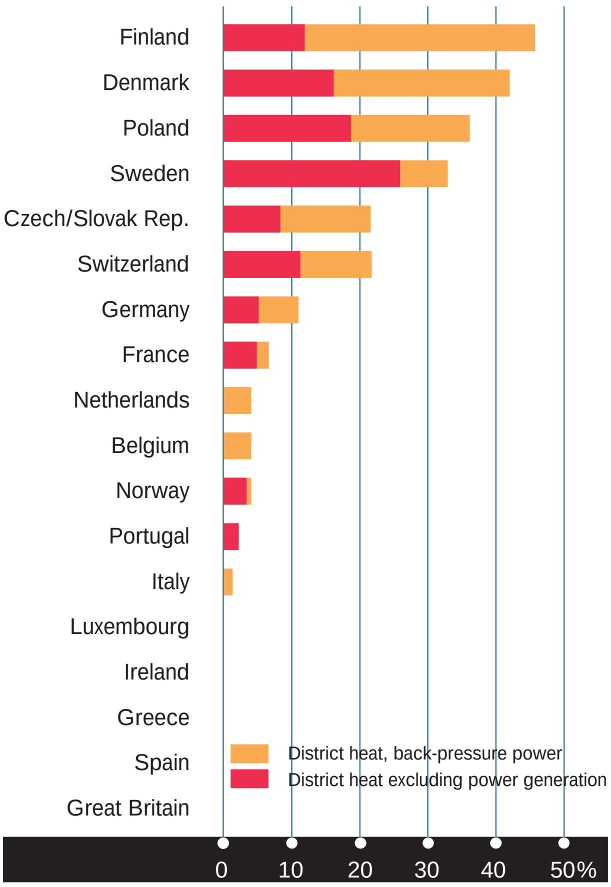


CO_2 emissions from a power plant when comparing condensing and CHP production (electricity only). The shadowed area shows the variation between the best and the typical figure, or the variation between the first commercial and the future units.

DISTRICT HEATING

Buildings in Finland need a lot of heat because of the climate, but have always been constructed to use energy economically. A substantial proportion of the building stock is also supplied with efficient district heating.

In modern systems, district heating reaches the consumer through insulated transmission networks where the water temperature is 60–90°C or 70–120°C and the return temperature 50–70°C. The heat losses are very much less than in systems based on steam (which operate at 150–200°C), and the potential for electricity production is greater. In urban transmission networks, insulation losses range from a few per cent to 10–15%.



Percentage of district heating in some European countries.

WOOD AND PEAT AS FUELS

About 17% of all primary energy is produced from wood fuels, and 6% from peat. Industry uses wood fuels from production processes to generate energy, and firewood or woodchips are also used to heat buildings. Two-thirds of all the wood-based biofuels used by industry is black liquor from the chemical pulp production process, one-third is wood waste.

The above-mentioned fuels call for special combustion techniques. Black liquor is burned in recovery boilers and other fuels in fluidized-bed boilers. These methods have replaced conventional grates and PF-firing systems. In the new methods, the fuel input ranges from 10–20 MW right up to 300 MW. They have the advantage that several fuels, including coal, can be burned at once; for instance, waste paper can be burned at the same time as wood and peat.

Biomass and peat are mostly used in Finland for CHP production. Government-subsidized research is concentrating on increasing power yield using IGCC (Integrated Combined Cycle) technology. The first demonstration plant using Finnish gasification technology was started in Sweden in 1995. Its thermal input is 20 MW and it produces electricity and district heat.

Use of wood, fuels and peat in 1995 (PJ).

	Wood fuels	Peat
Industry	154	7
District heating	8	34
Heating buildings	28	3
Separate power production	1	23
Farming, etc.	6	0
Total	197	67

3.4. SOCIAL PROFILE

Over 68% of all Finns live in their own dwellings. The floor space per person is around 33 m^2, as compared to 19 m^2 in 1970. The proportion of dwellings having more than one person per room, with kitchen counted as a room, is around six, down from 35% in 1970.

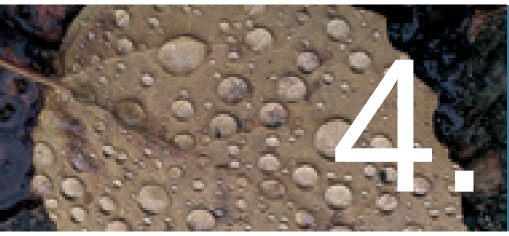
The number of passenger cars in Finland is 1.9 million, equivalent to 373 per 1000 inhabitants. The traffic performance of passenger cars was 35.8 billion km in 1995, as compared to 9.5 billion in 1970.

The total amount of passenger kilometres by state railways was 3.2 billion in 1995. The increase since 1970 has been 40%. The total number of embarked and disembarked passengers at Finnish airports was 9.2 million in 1995, up from 4.5 million in 1970. By vessels between Finland and foreign countries, the number of passengers was 13.9 million in 1995.

The traffic performance of lorries was 2.6 billion km, freight traffic of railways 39.4 million tonnes. The imports by sea were 37.0 million tonnes, the exports 34.1 million tonnes. All data are from the year 1995.

Social welfare expenditures increased considerably in Finland in the 1970s and 1980s. This was caused by improvements in health care and social welfare services and development of pension schemes. In the early 1990s, the expenditures further increased particularly because of unemployment benefits.

The financing structure for social welfare expenditure varies considerably even within the EU. In Finland, general tax revenues and employers' contributions form the bulk of the financing system, while in most EU member countries the share of the insured is significant.



4. INVENTORIES OF ANTHROPOGENIC GREENHOUSE GAS EMISSIONS AND REMOVALS

4.1. INVENTORY FOR 1990–95

4.1.1. CARBON DIOXIDE

The summary of Finland's carbon dioxide emissions during 1990–95 is presented in Table 4–1.

In 1995, total CO_2 emissions from fuel combustion (without biomass) were 55.13 Tg, excluding the fugitive emissions of 0.08 Tg. Energy and transformation industries accounted for 39% of the emissions, industry 25%, internal transport 20% and other sources 16%. The CO_2 emissions from industrial processes were 0.84 Tg and those from international bunkers 1.85 Tg. The proportion of the CO_2 emissions from oil products in 1995 was 45%, coal (including blast furnace and coke oven gas) 32%, natural gas 11% and peat 12%.

Historically, there was a particularly rapid increase of CO_2 emissions in the 1960s (Fig. 4–1). Emissions from coal decreased considerably in 1981, but then increased again up to 1985. In the 1990s they have been rather stable.

Total CO_2 emissions decreased slightly in the early 1990s, mainly as a consequence of the economic depression. Particularly in sector IA1 (energy), the variation from year to year has been considerable.

CO_2 emissions in 1995 were lower than in 1994, but higher than in other years of the early 1990s. Preliminary data indicate that emissions in 1996 were even higher than in 1994. Electricity consumption has grown by 10% from the worst recession year, 1991. This is connected with the rise in production by heavy industry, which is expected to have an impact on the unemployment situation.

In more detail, the following changes in energy consumption have occurred (year 1990 = 100):

	1994	1995
Total energy consumption	103	103.5
Electricity consumption	109.5	110.6
– in industry	111	113
Heavy fuel oil consumption	93	90
Road transport fuels	96	94.4
Forest-based biofuels	117	123

Table 4–1.

Summary of carbon dioxide emissions in Finland in 1990–95, by main sectors (Tg).

	1990	1992	1993	1994	1995
Total national emissions	53.8	52.42	53.11	59.25	56.05
1. All energy (fuel combustion + fugitive)					
A Fuel combustion	52.6	51.40	52.25	58.34	55.13
1 Energy & transformation industries	19.5	17.43	19.85	24.53	21.72
2 Industry (ISIC)	13.7	13.72	13.49	14.10	13.57
3 Internal transport	11.5	11.59	10.99	11.41	11.13
4 Small combustion (commercial/ institutional and residential)	5.8	6.79	6.06	6.71	7.11
5 Other (agriculture and forestry)	2.1	1.87	1.86	1.59	1.60
6 Biomass (wood and wood waste)	17.1	16.92	19.96	20.98	20.67
B Fugitive emissions from fuels	0.1			0.08	[1]0.08
1 Solid fuels					
2 Oil and natural gas					
2. Industrial processes	1.2	1.02	0.86	0.84	[1]0.84
3. Solvent and other product use					
4. Agriculture					
5. Land use change & forestry					
6. Waste					
7. Other					
International bunkers	2.8	3.0	2.5	2.12	1.85

[1] data from 1994

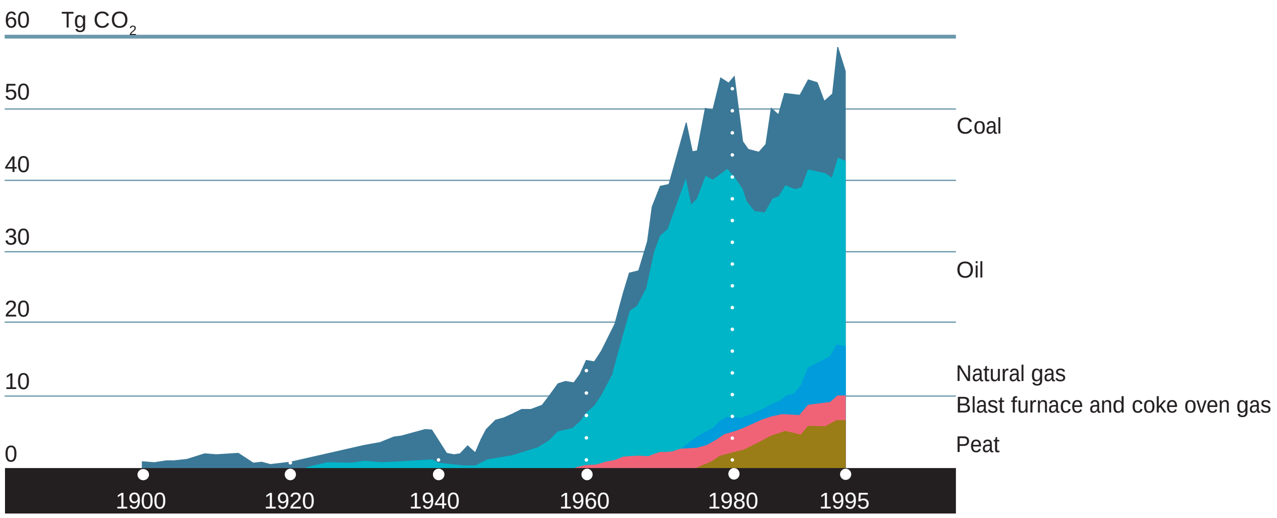


Figure 4–1. **Finland's energy-related CO_2 emissions from fossil fuels and peat in 1900–95 (Lehtilä *et al.* 1997).**

The greatest amounts of electricity and forest-based biofuels are used for the production of pulp and paper (Finland produced 15% of the European consumption).

Forest-based fuels include black liquor, industrial waste sludge, bark, sawdust and fuelwood. These fuels released 20.67 Tg of carbon dioxide in 1995.

ROLE OF ELECTRICITY IMPORT

In 1990, the net electricity import to Finland was 17% of total electricity consumption. If this amount of electricity had been generated by the existing power plants, CO_2 emissions would have increased by 11 Tg. Similarly, the following changes in annual CO_2 emissions in case of zero net electricity import can be calculated:

Year	1992	1993	1994	1995
CO_2 increase (Tg)	8.4	7.8	6.3	8.0

4.1.2. METHANE

Finland's methane emissions in 1990 to 1995 have been about 250 Gg CH_4/a (Table 4–2). The most significant anthropogenic methane sources in Finland are waste management (about 130 Gg/a) and agriculture (about 90–100 Gg/a). Fuel combustion and industrial processes contribute less than 10% to the total anthropogenic methane emissions in Finland. Estimates of the emissions from the individual sectors are unreliable because of the variable and complex nature of the sources, and also because of inadequacies in statistical information on input data. Even so, the order of magnitude for the total methane inventory is estimated to be at a moderate confidence level and reflects the current scientific understanding.

EMISSIONS FROM ENERGY SECTOR AND INDUSTRIAL PROCESSES

In the energy sector, methane is emitted to the atmosphere mainly as a result of incomplete combustion. Small-scale wood combustion results in nearly half of the methane emissions by the energy sector in Finland, even though it is less than 3% of energy production. Transportation results in less than one-fifth of the methane emissions by the energy sector. Emissions from international transportation were estimated to be about 1 Gg/a.

Table 4–2

Anthropogenic methane emissions in Finland in 1990–1995 (Gg).

	1990	1991	1992	1993	1994	1995
1. All energy	15	NE	16	15	16	16
Stationary sources	11	NE	12	12	13	13
Transportation	3	NE	3	3	3	3
2. Industrial processes	4	4	4	4	4	4
4. Agriculture	101	97	94	93	93	88
Enteric fermentation	90	86	83	83	83	78
Manure management	11	11	10	10	10	10
6. Waste	126	128	132	134	132	133
Landfills	116	118	122	124	122	123
Landfill gas recovery						
Wastewater treatment	NE	NE	NE	NE	10	NE
TOTAL*	246	NE	246	246	245	241
International bunkers	1	NE	1	1	1	1

NE = Not estimated

Because of rounding errors given totals are not always equal to the sums of the given numbers.

* Emissions from wastewater treatment are assumed to be equal to 10 Gg CH_4 for each year.

Methane emissions are produced by a variety of industrial processes, but the importance of the industrial emissions in the total inventories is estimated to be small. In Finland, only methane emissions from the iron industry (coke, sinter and pig iron production) need to be considered; during the time period 1990 to 1995 they were approximately 4 Gg CH_4 per year.

EMISSIONS FROM AGRICULTURE

Methane emissions from agriculture are mainly derived from the digestive processes and manure of domestic animals. The basic input data needed in the estimate are presented in Table 4–3. Details of the calculations are given in section 4.2.2.

Finnish agriculture is based mainly on livestock. Livestock production comprises about 70% of the total value of Finnish agricultural production whereas in the European Union the equivalent figure is 50%. The Finnish farms, almost entirely family run, are typically small; in 1994 the mean arable area on active farms was about 19 hectares. Dairy farms had, on average, 12 cows and other cattle farms, on average, 26 head. Most of the pig farms could also be categorised as small or medium-sized.

The estimate for methane emissions from enteric fermentation in 1995 was 78 Gg, as compared to 90 Gg in 1990. The decrease was due mainly to a decline in the number of cattle. From animal wastes, the emissions were around 10 Gg CH_4/a in 1995, almost the same as in 1990. This is because the main emission source, the treatment of liquid pig manure, has been fairly constant.

Table 4–3

Summary of key variables and assumptions in the projections analysis.

	1990	1995	2000	2005	2010	2020
World coal prices (US $/ton)	38	38	50	53	58	65
World oil prices (US $/bbl)	15	17	18	21	23	28
Domestic energy prices	100	102	107	112	117	128
GDP (bill. FIM)	490	440	520	600	690	840
Population (millions)	5.05	5.11	5.17	5.21	5.23	5.32
New vehicle efficiency (litres/100 km)	6.7	6.5	6.4	6.3	6.2	6.0
Average vehicle km travelled	18000	17500	16600	16400	16200	15900
Primary energy demand (PJ)	1200	1285	1390	1500	1580	1750
Index of manufacturing production	100	100	123	145	168	211
Index of industrial production (1990 = 100)	100	100	126	146	160	186
Agriculture:						
Dairy cattle (1000 animals)	490	399	363	343	343	343
Milk production (l/cow/a)	5 547	5 982	6 340	6 700	6 700	6 700
Other cattle (1000 animals)	870	749	653	617	617	617
Swine (1000 animals)	1 381	1 400	1 400	1 400	1 400	1 400
Poultry (1000 animals)	4 845	4 175	3 875	3 690	3 690	3 690
Sheep (1000 animals)	103	159	130	130	130	130
Horses (1000 animals)	44	50	50	50	50	50
Mineral fertilizer use (t N/a)	228 470	195 460	170 000	165 000	165 000	165 000
Legumes (area cultivated, ha)	3 400	5 700	6 000	6 000	6 000	6 000
Crop residue (t N/a)	14 070	11 000	11 000	11 000	11 000	11 000
Landfilled wastes:						
Municipal solid waste (mill. t/a)	2.5	1.9	1.1	0.6	0.6	0.6
Industrial solid waste (mill. t/a)	2.5	2.7	7.5	5.7	5.5	5.5
Construction/demolition waste (mill. t/a)	3–6	0.6–1.2	0.4–0.8	0.2–0.5	0.2–0.5	0.2–0.5
Community sludges (Gg dry matter/a)	50	30	30	30	30	30
Industrial sludges (Gg dry matter/a)	190	210	190	150	110	120
Landfill gas recovery (Gg CH_4/a)	0	3	15	30	35	30

EMISSIONS FROM WASTE MANAGEMENT

Solid waste disposal on land (landfills and dumps) and wastewater treatment result in significant methane emissions from the decay of organic matter generating methane under oxygen-free conditions. The waste sector is a very important anthropogenic contributor to methane emissions in Finland.

Methane emissions from municipal and industrial waste landfills and treatment of both community and industrial wastewater are estimated. Estimates in earlier reports have been complemented with the emissions from solid waste disposal of industrial waste, and construction and demolition waste. The emissions from sludge disposal in landfills that were reported earlier under the wastewater treatment section are now reported under the landfill section in accordance with the IPCC Guidelines (1995).

Historically, the amount of waste taken to landfills has grown continuously from the turn of the century to the beginning of the 1990s. During the last few years, there has been a decline in wastes being disposed of in landfills because of waste minimization, increased recycling and alternative waste treatment methods. As the time lag between landfilling of waste and the subsequent emissions of methane is large, a corresponding decline in methane generation can be seen only after many years.

The total amount of methane generated at landfills was estimated to be 123 Gg in 1995, as compared to 116 Gg in 1990. The breakdown of the emissions is as follows (in Gg):

	1990	1995
Municipal solid waste	71	73
Industrial waste	15	17
Construction and demolition waste	8	10
Community sludge	4	5
Industrial sludge	18	21

Landfill gas recovery is practised on a minor scale; in 1996 there were five landfills with gas recovery. Thus the impact of recovery is still small, estimated to be less than 5 Gg CH_4 at present. In the forthcoming years, the importance of landfill gas recovery is predicted to increase substantially.

The emissions from waste incineration are reported in the energy sector.

4.1.3. NITROUS OXIDE

Anthropogenic nitrous oxide emissions in Finland total less than 20 Gg/a but the amount is rising (Table 4–4). The agricultural (8–10 Gg/a) and energy (5–6 Gg/a) sectors are the most significant emission

Table 4–4

Anthropogenic nitrous oxide emissions in Finland in 1990–1995 (Gg).

	1990	1991	1992	1993	1994	1995
1. All energy	5	NE	6	6	6	6
Stationary sources	3	NE	4	4	4	4
Transportation	2	NE	2	2	2	2
2. Industrial processes	3	3	2	3	3	3
4. Agriculture						9
Nitrogen load	6	6	5	5	5	5
Peatlands	NE	NE	NE	NE	NE	4
TOTAL*	18	NE	17	18	18	18
International bunkers	1	NE	1	1	1	1

The totals are not always comparable with the sum of the numbers given in the table because of rounding.
NE = Not estimated.
The emissions from energy and agriculture include the emissions caused by N-deposition from NO_x and NH_3 emissions.
* The emissions from peatlands are assumed to be 4 Gg N_2O/a for the whole period.

sources. Emissions from nitric acid production (about 3 Gg/a) are also estimated to be important. N_2O emissions from international bunkers were estimated to be around 1 Gg/a.

EMISSIONS FROM ENERGY SECTOR AND INDUSTRIAL PROCESSES

Most combustion processes produce insignificant amounts of nitrous oxide. Fluidized bed combustion is an exception and the nitrous oxide emissions can be significant. Some NO_x-reduction measures like urea addition can also increase the amount of nitrous oxide emitted from the combustion processes, but quantitative data on the emissions are not available. Catalytic converters in cars increase the nitrous oxide emissions from transportation.

Nitrous oxide emissions from the production of nitric acid and adipic acid can be significant. In Finland only nitric acid is produced. Nitric acid production and hence the emissions have been fairly constant during the 1990s.

Nitrogen deposition resulting from NO_x and NH_3 emissions from energy production, transportation and industry increases the nitrogen load of soils and hence N_2O emissions. During 1990–95 this contribution was about 1.6 Gg N_2O/a, of which less than 10% came from industry.

EMISSIONS FROM AGRICULTURE

N_2O emissions from nitrogen sources used by agriculture were estimated to be around 5 Gg in 1995. This includes the impact of nitrogen deposition caused by agricultural ammonia emissions on the nitrogen load of soils. The contribution of ammonia emissions to N_2O emissions is estimated to be 0.5 Gg N_2O/a. The assumptions used in the estimation are discussed in detail in section 4.2.2.

Cultivation and fertilization of peatsoils increase the decomposition of the organic matter in the soils and also enhance nitrous oxide emissions. In the Finnish Research Programme on Climate Change (SILMU) the upper range for nitrous oxide emissions from Finnish cultivated peatlands was estimated to be around 4 Gg N_2O/a. This estimate is based on a limited number of field measurements and is considered very unreliable.

Nitrous oxide emissions can also occur during earlier stages of manure management (animal housing, manure storage, etc.). Since the data for estimating these emissions are scarce and uncertain, no estimate was made.

Nitrous oxide can be produced during wastewater treatment but according to current knowledge these emissions are negligible in Finland.

4.1.4. OTHER GASES

Several anthropogenic pollutants (nitrogen oxides, volatile organic compounds, carbon monoxide) are involved in reactions leading to the formation of ozone in the troposphere. These compounds are referred to as indirect greenhouse gases. In addition, they also alter the oxidizing capacity of the atmosphere, which affects the concentrations of direct greenhouse gases. Current limitations in the understanding of the photochemical processes involved mean that these indirect effects cannot be accurately quantified at present.

NITROGEN OXIDES

A summary of the emissions of nitrogen oxides and three other indirect greenhouse gases in 1990 and 1995 is given in Table 4–5.

Nitrogen oxide emissions in Finland totalled 259 Gg in 1995, as compared to 295 Gg in 1990. Over half of the emissions originated from traffic and the rest mainly from energy production. Only about 2 Gg in 1995 was released by industry from sources other than energy production.

As compared with the year 1990, the NO_x emissions were smaller in all other sectors except in small combustion. The growing use of catalytic converters in cars reduced the characteristic emissions from gasoline. As for emissions from coal, peat, heavy fuel oil and natural gas, a similar trend occurred because of low-NO_x burners.

Finland signed the Protocol on Reduction of Nitrogen Oxides Emissions in Sofia under the auspices of the UN/ECE in 1988. The parties to the Protocol undertook to keep their emissions of nitrogen oxides and their transboundary fluxes, after 1994, at or below the level in 1987.

In addition to the actual Protocol, 12 nations, including Finland, signed the declaration, according to which the signatories will strive to reduce their nitrogen oxide emissions by about 30% by 1998 at the latest.

CARBON MONOXIDE

Carbon monoxide emissions totalled 434 Gg in 1995, with traffic accounting for almost three-quarters. However, the emissions from traffic have decreased by 17% since 1990. Measures responsible for this trend include improving engine technology, adopting catalytic converters and changing the composition of fuel.

Table 4–5.

Summary of indirect greenhouse gas emissions in Finland in 1990 and 1995 (Gg).

	NO_x		CO		NMVOC		SO_x	
	1990	1995	1990	1995	1990	1995	1990	1995
Total national emissions	295	259	487	434	213	182	260	96
1. All energy (fuel combustion + fugitive)					135	121		
A Fuel combustion	291	257	484	424	126	113	152	66
1 Energy & transformation Industries	64	40	9	8	0	0	71	31
2 Industry (ISIC)	41	35	32	43	0	0	81	35
3 Internal transport	160	139	368	306	91	81	9	4
4 Small combustion (commercial/ institutional and residential)	8	26	61	46	35	32		4
5 Other (agriculture and forestry)	18	17	14	21	0	0		
6 Biomass (wood and wood waste)					0	0		
B Fugitive emissions from fuels					9	8		
1 Solid fuels								
2 Oil and natural gas					9	8		
2. Industrial processes	4	2	3	10	19	13	98	30
3. Solvent and other product use					57	46		
4. Agriculture								
5. Land use change & forestry								
6. Waste					2	2		
7. Other								
International bunkers	22	19		6		3		2

NMVOC

Anthropogenic NMVOC emissions totalled 182 Gg in 1995, as compared to 213 Gg in 1990. The largest sources were energy production and industrial use of solvents. From natural sources, the NMVOC emissions in Finland are estimated to be around 300 Gg per year.

In 1991, Finland signed the Protocol on Control of Volatile Organic Compounds under the auspices of the UN/ECE. In this protocol Finland undertook to reduce its annual emissions of NMVOCs by at least 30% to the 1988 level by 1999.

SULPHUR DIOXIDE

Total emissions of sulphur dioxide in Finland fell from 487 Gg in 1980 to 260 Gg in 1990. This trend has continued in the 1990s; in 1995 the emissions were only 96 Gg, less than one-fifth of those in 1980.

4.2. DOCUMENTATION OF METHODS

A detailed description of the methodology of greenhouse gas inventories in Finland is given in the following.

4.2.1. EMISSIONS FROM ENERGY SOURCES

Greenhouse gases from fuel combustion activities have been calculated by using the Air Emission Calculation Model, ILMARI. This model was developed by Statistics Finland in 1992–94 to calculate air emissions from Finland's fuel consumption for various purposes; statistics, research, decision-making and international air emission reporting.

Under this system, emissions can be examined by type of process, by industrial sector, by fuel or partly by region, according to need. The system includes emissions of particles and sulphur, nitrogen oxides, carbon dioxide, carbon monoxide, methane and other hydrocarbons, and nitrous oxide. The data are updated annually and data on the year's emissions are available in the autumn of the following year.

The main source of data for the model is the emission register maintained by the Finnish Environment Institute. The register contains the data in the obligatory annual air emission reports of the establishments. Emission and fuel data are thus obtained at establishment and at subprocess levels, and it is therefore easy to summarise the emissions according to flexible criteria. The emission calculation system covers data on about one thousand plants and some 2 200 sub-processes.

Data on traffic emissions are from the LIISA computing system developed by the Technical Research Centre of Finland (Mäkelä & al. 1996). The LIISA model is used to calculate and predict the air emissions from road transport. It covers almost 100% of motor gasoline and diesel fuel consumption in Finland. The model is based on road traffic measures, and it contains a lot of information on motor vehicle properties and their changes.

The third source of information for ILMARI is the annual Energy Statistics of Finland (ESoF) produced by Statistics Finland. It is a collection of energy data, based on several data sources (e.g. Finnish Association of Electricity Supply, Finnish District Heating Association, Finnish Petroleum Federation, the Energy Federation of Finnish Industries, Power Producers' Coordinating Council, Industrial Statistics of Statistics Finland). It combines the energy data to cover total fuel and energy consumption and production. It contains some sectoral data (industry, space heating, agriculture, etc.), which are used in the ILMARI model for those cases that are not covered by the two sources mentioned above.

The other emissions are estimated, chiefly from the fuel consumption data based on the ESoF and from emission factors obtained from various sources, particularly from a database of emission factors of boilers and processes. This database contains data on emission factors of different types of boilers and processes, taking into account installed emission reduction equipment.

The reliability of the emission factors for methane and nitrous oxide emissions cannot be considered high. The emissions of both gases are very dependent on the combustion conditions and even if the combustion technology and energy sources (fuels) are accounted for in the inventory, the actual operating conditions (combustion temperature, oxygen content, etc.) are not known.

The ILMARI model was developed to obtain a reliable calculation method of energy based emissions, to make the energy data and the emission data consistent. The consistency is now relatively good, although there are still some difficulties, which will be discussed later.

Summaries of emissions can be made freely according to the user's criteria. The selections are made on a summary form designed for each emission separately. The emissions can be calculated either according to individual criteria or as an arbitrary combination.

The main criteria concerning emission sources are the branch of industry, branch of subprocess, fuel type, combustion technique and fuel capacity. The criteria by emissions are, for example, emission type, energy-based and non-energy based emissions, fuel consumption and average emission factors. Some of these data are available on the level of the municipality, region or province.

BASIC CALCULATION METHODS

The fuel consumption and NO_x (and SO_x) emission data of enterprises are obtained from the Finnish Environment Institute. These data are obtained for emission sources, which are usually (sub)processes or boilers. NO_x (as well as SO_x) emissions from multi-fuel fired boilers are disaggregated to separate fuels used in these boilers.

CO_2 emissions are calculated based on the amount of fuel used in each boiler or process. Other emissions (CO, CH_4, N_2O, NMVOC) are calculated for fuels using emission factors depending on the type of boiler or process. The database includes emission factors for approximately 200 different types of boilers or processes.

To these data from stationary sources are combined the data on transport and other fuel consumption, which analogically have emission factors depending on the fuel and/or process (forestry machinery, construction machinery, space heating, etc.).

These fuel and emission data can be aggregated by several different criteria, for example, by fuel and by ISIC sector.

DIFFERENCES IN FUEL CONSUMPTION

There are some differences between the fuel consumption data in ESoF and ILMARI. The most significant of these are (for 1994, PJ):

	ESoF	ILMARI
Hard coal	167	155
Peat	66	70
Black liqour	104	112

There are some obvious reasons for these differences. Total fuel consumptions in the ESoF are reported in tonnes, and then converted to joules by multiplying by average conversion factors. These conversion factors have not been updated annually, which can cause errors. The fuel consumption data in ILMARI are reported by establishments in terajoules.

In regard to these three fuels, the ILMARI data have been used in this inventory. A comparison between the unit-based data of ILMARI and the ESoF data shows that the differences are explained by different conversion factors. This is even more likely in the case of black liquor. There are two conversions in the ESoF data; first from tonnes to tonnes of dry matter, then to terajoules. Both of these conversion factors may differ from plant to plant, and national averages may be incorrect.

This problem does not exist with residual fuel oil, gas oil/light fuel oil, natural gas and LPG. Usually these fuels, which are not included in the air emission register, are used for small combustion, such as space heating, agriculture and machinery.

There are also some small quantities of other fuels, which in this inventory are included with other oils (naphtha, kerosene except jet kerosene, waste oil) or other fuels (municipal solid waste, biogas, some other wastes of industry).

There is another problem concerning the amount of refineries' own use. According to the ILMARI data, refineries' own use seems to differ somewhat as compared with the ESoF data. This may be due to conversion factors as in the cases of coal, peat and black liquor.

One major problem in this inventory has been the chain from coking coal to coke, coke oven gas and blast furnace gas. The problem has been solved by calculating the CO_2 emissions from coke (which includes both imported and produced coke) and coke oven gas. These emissions are included in coal totals. Blast furnace gases are included as an energy source in the ILMARI model, but their CO_2 factor is zero. The energy content of blast furnace gases has not been included in total fuel consumption in this inventory to avoid double counting.

Nitrogen deposition resulting from NO_x emissions from energy production and transportation increase the nitrogen load of soils and can contribute to the N_2O emissions. The emissions were estimated with emissions factors given for agricultural soils in IPCC Guidelines (1995). The emissions from the energy sector for the year 1995 were estimated to be 0.3–2.8 Gg N_2O, of which traffic causes more than half (54%). These emissions are included in the estimates given in Table 4–4.

EXCEPTIONS TO IPCC METHODOLOGY

There is one major exception to IPCC methodology in this inventory. Fuels and emissions for auto-generation of electricity (95% of which is CHP generation in Finland) are reported in sector 1A2 (industry). This is due to the fact that ILMARI does not at the moment disaggregate the fuels of CHP plants to heat and electricity (because of the lack of confidential information on electricity and heat produced in these plants/units).

At national level, approximately one-sixth of fuels used in CHP auto-generating plants could be allocated to electricity and the rest to steam production. Total fuels used in CHP auto-generating plants are about 242 PJ; thus, the amount of fuels that should be in the energy sector instead of industry, is approximately 40 PJ. This accounts for a good 10% of total fuels in 1A2 Industry (336 PJ, of which 156 PJ biomass). In 1994, CHP auto-generation and fuel consumption were as follows:

Electricity	9 500 Gwh
Heat (steam)	50 000 Gwh
Heat sold (district heat)	1 600 Gwh
Fuels used	242 PJ
– of which biomass	141 PJ

It must be noted, however, that there are several possible ways of allocating fuels to heat and power. These figures are rough estimates and they are calculated only to show the magnitude of this phenomenon.

Public CHP plants are included in the sector 1A1 (energy and transformation industries).

Another exception to the IPCC methodology is that sectors 1A4a (commercial/institutional) and 1A4 b (residential) are combined. Reliable data about fuel consumption in these sectors are not available at the moment. Therefore, these sectors could not be disaggregated.

A third exception to the IPCC methodology is that all biomass for energy use is included in sectorial Standard Data Tables. Thus, there are no separate tables for ”Traditional Biomass Burned for Energy”. CO_2 emissions from biomass are excluded from totals, but other emissions are included in total emissions.

CARBON CONTENT OF FUELS

In the ILMARI model, the carbon contents of fuels are not used in calculations, because all forms of fuel consumption are expressed directly in terajoules. Instead, ILMARI uses emission factors (tonnes CO_2/TJ). These emission factors are mainly obtained from the report ”Greenhouse Gas Inventory Finland 1990”. Some corrections to these emission factors have been made.

There is one problem, however. National net calorific values of fuels seem to differ somewhat compared with those in the IPCC Reference Manual. Thus, it is not always clear whether these emission factors (per TJ) are correct.

For gasoline and diesel oil, such emission factors were used, which give the corresponding emissions calculated by the LIISA model.

FUGITIVE EMISSIONS FROM FUELS

The estimate on fugitive emissions from solid fuels is based on a previous report ”Greenhouse Gas Emissions Finland 1990”. Data from 1990 are adjusted to 1994 using the peat consumption quantity. The estimate is quite rough, because peat production and storages vary annually depending on the weather conditions. Peat consumption is more stable.

Fugitive emissions from liquid fuels are based on the report by Mroueh (1994).

4.2.2. EMISSIONS FROM OTHER SOURCES

Inventories of anthropogenic methane and nitrous oxide emissions in Finland for the years 1990 to 1995 by industrial processes, agriculture and waste were estimated in accordance with the IPCC Guidelines for National Greenhouse Gas Inventories (1995), with some deviations which are reported in the text.

The emissions inventories are based on a research project ”Potential and cost-effectiveness of reducing methane and nitrous oxide emissions in Finland” at VTT Energy (Pipatti 1997). Estimates given in the earlier national communications of Finland to FCCC have been updated.

The uncertainties associated with the methane and nitrous oxide emission estimates are largely due to the nature of the emission sources. Current statistics cannot provide all the input data needed in the estimates. This situation will improve within the coming years but will not reach the same level of reliability as input data used in the calculation of carbon dioxide emissions in the energy sector. The methodologies in the IPCC Guidelines (1995) are also still tentative and under development where methane and nitrous oxide inventories are concerned, and the results of more recent research data have therefore been used in the estimates when deemed essential.

EMISSIONS FROM INDUSTRIAL PROCESSES

As to the methane emissions, IPCC Guidelines (1995) give emission factors for coke, sinter, pig iron, carbon black, ethylene, dichloroethylene, styrene and methanol production. In Finland only methane emissions from the iron industry (coke, sinter, pig iron) are considered; the emissions from the other mentioned production processes are estimated to be insignificant. No data are available on how well the IPCC emission factors for CH_4 apply to the Finnish iron industry. The emission estimate is considered very uncertain.

As for the nitrous oxide emissions from the production of nitric acid, the mean value obtained using the emission factors (2–9 kg N_2O/tonne nitric acid) given in the IPCC Guidelines (1995) has been used. These emissions depend on technology and operating conditions. In Finland, nitric acid is produced in medium-pressure plants for which the IPCC/OECD/IEA Programme on National Greenhouse Gas Inventories, Phase II (1996) gives an emission factor range of 6–7.5 kg N_2O/tonne nitric acid. Use of this range would give slightly higher emissions than the values given in Table 4–4, but the emissions would still be within the estimated range of uncertainty, 1–5 Gg N_2O/a.

EMISSIONS FROM AGRICULTURE

Methane emissions from livestock digestion and manure were estimated in accordance with methods (Tier 2) in the IPCC Guidelines (1995), using the revised input data of Table 4–3.

The Finnish emission factors for enteric fermentation are very similar to the default values given in the Guidelines for Western Europe in cool temperature conditions. The Finnish emission factors for cattle manure, on the other hand, are lower than the corresponding default values given in the Guidelines. Different livestock breeds, nutrition and manure handling systems explain this difference. For the other animals, the calculated values are similar to those given in the Guidelines.

Soils can act both as a source and a sink for the important greenhouse gases carbon dioxide, methane and nitrous oxide. In agricultural soils, the mass balances of these gases are affected by climate, soil type, management system and fertilizer use. The methods for the estimation of the emissions or the sink strengths are still largely under development.

The Guidelines provide a method for estimation of nitrous oxide emissions from agricultural soils resulting from enhanced nitrogen input into the soils. The nitrous oxide emissions from unfertilized agricultural soils may also be enhanced compared with natural environments. As the available data on these emissions is scarce, the emissions are considered as background emissions in the current IPCC methodology.

In Finland, nitrous oxide emissions from agricultural soils were estimated according to the method given in the Guidelines. Only one set of emissions factors given in the Guidelines was used, namely the range derived from Mosier's (1994) work. In the summary table the mean value of the given range is used.

Nitrogen input to agricultural soils from the following sources was assessed:

- mineral nitrogen fertilization;
- organic nitrogen fertilization (animal excreta, crop residue and sludge); and
- biological fixation (legume cultivation).

Data on mineral fertilizer and sludge spreading were obtained from standard statistics. The amount of animal excreta spread on the fields was calculated with an ammonia emission model developed at VTT Energy. The nitrogen load from crop residues was calculated from the yearly grain harvest figures assuming 50% of the straw to be left in the soil. The nitrogen content in the straw was estimated to be approximately about 0.5%. The emissions from biological fixation of nitrogen were calculated multiplying the area of legumes cultivated with an emission factor of 4 kg N_2O–N/ha. Since the statistical data on the area of legumes cultivated are insufficient, these emissions could be somewhat underestimated.

The loss of nitrogen due to ammonia emissions after spreading of mineral and organic fertilizers was taken into account in the estimate. The values for the ammonia emissions were taken from the ammonia model.

Cultivation and fertilization of peatsoils increases the decomposition of the organic matter in the soils and also enhances nitrous oxide emissions. In the Finnish Climate Research Programme, the upper range for nitrous oxide emissions from Finnish cultivated peatlands was estimated to be around 4 Gg N_2O/a. This estimate is based on a limited number of field measurements and considered very unreliable.

EMISSIONS FROM WASTE MANAGEMENT

The estimates for CH_4 emissions from the landfills were updated with most recent data from the landfill registry of the Finnish Environment Institute and other recent research data. The landfill registry contains data on landfilled waste in Finland from the year 1992 onwards. At the moment, the newest data available are for the year 1994. The data are collected through questionnaires sent to landfill entrepreneurs in Finland. As weighing of landfilled waste is still rare at landfills, most of the quantitative data on the amounts of landfilled waste in the registry are still largely based on estimates.

The emissions from solid waste disposal on land were estimated in accordance with the methods given in the IPCC Guidelines (1995), but lower emission factors than those derived from the default values given in the Guidelines were used. The conditions in Finnish landfills are not optimal for methane generation. There are many small landfills in Finland, and the mean refuse depth is relatively low, only a few metres. The prevailing temperature in the landfills is estimated to be much lower (10 to 15°C) than the optimum temperature for methane generation (around 35°C). Some of the methane generated in the landfills will be oxidized by bacteria at the surface layers of the landfills. IPCC Guidelines (1995) give no default value for the oxidation. In the Finnish estimate, the impact of oxidation is incorporated in the emission factors used.

The methane emission factor used, 42 kg CH_4/tonne waste, can be derived from the following assumptions:

DOC	20%
DOC dissimilated	50%
Oxidation at landfill surface	10%
Methane in landfill gas	50%
MCF (methane correction factor)	70%

The methane correction factor (IPCC/OECD/IEA 1996) is derived from the assumption that half of the waste landfilled in Finland is taken to landfills with lower methane-generating potential (MCF = 40%) and half to landfills where the methane-generating potential corresponds to the default values (MCF = 100%).

The CH_4 emissions from landfills were estimated with the first order decay model. Values for the methane generation rate constant have varied from 0.02 (construction and demolition waste; wood waste) to 0.1 (community and industrial sludges). The first order dynamic model also requires data on historical solid waste disposal on land. As the data for this are mostly unavailable, the input values were estimated from data on population, GNP, industrial production and so on.

The emissions from the landfills were also calculated with the mass balance model for comparison. This simple model does not consider any time factors. The differences in the values derived from the two models are illustrated in Figure 4–2.

The emissions from wastewater treatment were estimated in accordance with the method in the IPCC Guidelines (1995). For community wastewaters, statistical data are collected on a yearly basis, whereas the data for industrial wastewaters are more irregular. Most community and industrial wastewaters are treated aerobically in Finland.

Nitrous oxide can also be produced during wastewater treatment but according to current knowledge these emissions are negligible in Finland.

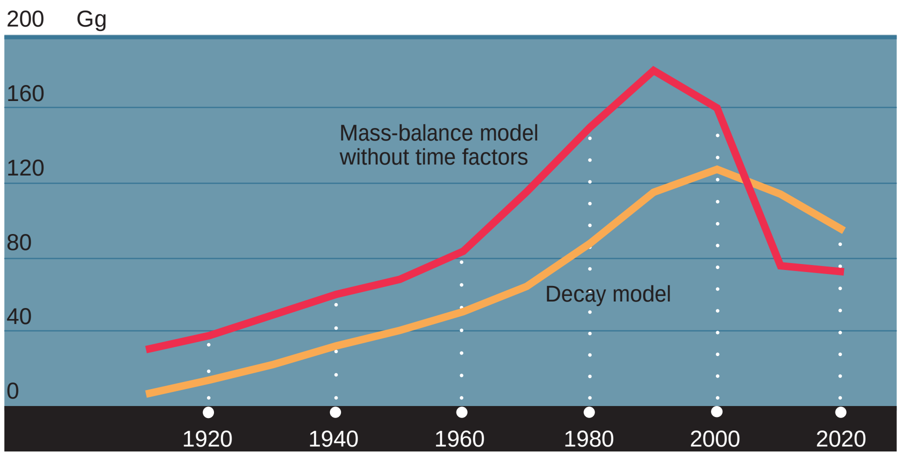


Figure 4–2. **Illustration of differences in values of methane emissions from landfills derived from the first order decay model and from the mass balance model (Pipatti 1997).**

4.3. FORESTRY AND CHANGES IN LAND USE

4.3.1. CARBON RESERVOIRS IN FOREST ECOSYSTEMS

Sustainable use of the Finnish forests is based on legislation, supervision, resource inventories, forestry plans and advisory services. Private individuals own about two-thirds of the forested land area. Regional forestry planning supports the management and use of these 430 000 private woodlots, and nowadays also in terms of the various objectives of environmental protection and multiple-use forestry. The new Forest Act, in force on 1 January 1997, e.g. prohibits timber cutting in areas classified valuable to forest biodiversity.

The total land area of Finland is 30.5 mill. ha, of which 26.3 mill. ha are classified as forestry land. The forestry land is grouped into three classes according to site productivity: 1) forest land, where the mean annual increment is at least 1 m^3/ha; 2) scrub land is mainly exposed bedrock and scree or mires, where the increment is 0.1...1.0 m^3/ha; 3) waste land, producing less than 0.1 m^3/ha.

The present area estimates are 20.03 mill. ha for forest land, 2.97 mill. ha for scrub land, and 3.1 mill. ha for waste land. Forest roads, timber depots etc. occupy 0.15 mill. ha of forestry land. These figures include nature conservation areas amounting to 2.9 mill. ha, which are situated almost entirely in northern Finland, above lat 66°N.

Systematic national forest inventories are carried out in Finland at 8 to 10 year intervals, and provide a detailed view about how the forests are developing. The forest inventory results and wood consumption statistics allow the calculation to be done at an accurate level as recommended in the IPCC methodology. Calculations can be done by tree species for the total tree biomass for the whole country. This biomass is obtained by multiplying four variables:

- growth, drain or stock of stemwood in m^3
- conversion factor (dry weight density) to dry matter in Mg
- expansion factor to expand stemwood to total tree biomass
- carbon content

Dry weight densities, expansion factors and carbon contents vary also within species, between regions and between age classes. Applied values are averages, but should be more precise than the default values provided in the inventory guidelines.

In 1995, the total growing stock volume was estimated to be 1980 mill. m^3; the average growing stock from the last forest inventory in 1989–94 was 1937 mill. m^3 (Table 3–2). The proportion of pine (Pinus sylvestris) was 46%, that of spruce (Picea abies) was 35%, and that of non-coniferous species (mostly Betula pendula and Betula pubescens) was 19%.

The present growing stock in Finnish forests is the largest since the first forest inventory in 1921–24, and the growth-boosting effect of efficient silviculture, drainage and forest improvement in areas of low yield will continue for a long time to come.

The carbon storage of the growing stock in 1995 was estimated to be 695 Tg. In addition, the forest ecosystem has other – and even bigger – carbon storages. The mineral soils of Finnish forests contain 1100–1300 Tg of carbon, even as much as 1500 Tg, if the organic material in deeper soil layers is included.

Over one-third of forested land in Finland are mires, which accumulate peat. Peat is incompletely decomposed plant matter with a high carbon concentration. The estimated amount of carbon in the peat of Finnish mires is 4500–5500 Tg. Even the mineral soils under the peat depositions may have considerable amounts of carbon.

There are still over four million hectares of mires in their natural state, and an estimated 4 Tg of carbon dioxide accumulates in them annually. On the other hand, methane is released into the atmosphere particularly from natural mires; a recent estimate on the amount is as high as 700 Gg per year (Roos 1996).

Drainage and forest improvement have affected the greenhouse balance of peatland forests. Since the beginning of the 1950s, about 5 million hectares of mires have been drained for forestry. As a result, tree growth has improved in most of the drained areas, thus increasing the amount of carbon stored in the trees, as can be seen in forestry statistics illustrating the development of the growing stock (Table 3–2). Contrary to earlier estimates, the accumulation of carbon in the peat layer seems to continue after drainage. In ombrotrophic mires in southern Finland, this process has even enhanced as compared with the natural state. Thus, the present estimate indicates an accumulation of about 5 Tg of carbon dioxide annually in drained peatlands (Laiho & al.1996).

Considering both virgin and drained peatlands, the estimated CO_2 uptake is thus 9 Tg per year. An average use of peat as a fuel is about 22 million m^3 per year, corresponding to CO_2 emissions of 7 Tg. The discontinued binding of carbon at the production mires, the release of CO_2 from stored peat stacks and the use of horticultural peat correspond to about 1 Tg emissions of CO_2 annually. According to these figures, the CO_2 sinks and sources of Finnish mires are near the balance at the present level of activity in the peat industry.

Although the lowering of the water table reduces anaerobic decomposition and thus the formation of methane, a considerable amount, about 150 Gg/a, of this greenhouse gas is estimated to be released from the drained peatlands in Finland.

About 0.7 million hectars of peatlands have been drained for agricultural purposes, mainly between 1900 and 1960. In these lands, the carbon emissions from decaying peat exceed the carbon uptake of the cultivated plants, resulting in carbon flow from the field into the atmosphere. The magnitude of this flow is very uncertain; an estimate of 2–5 Tg CO_2/a has been presented for 1995 with a decreasing trend (cf. Table 1–2).

Existing nature reserves and the areas in Lapland protected through the Act of Wilderness Reserves, which together cover about 8% of the country's land area, comprise a substantial volume of forest functioning as a stable carbon reservoir. True old-growth forests constitute a minority of the total protected area; thus the carbon uptake in bulk of these forests will continue for a long period, up to several centuries.

Forest fires are rare and very limited in Finland because of dense coverage by the forestry road network and efficient fire prevention. This implies that only small amounts of carbon are emitted from the forest ecosystem into the atmosphere through fires, in contrast to the situation in a large part of the boreal coniferous forest zone in general.

4.3.2. CARBON FLOWS AND STORAGES OF THE FINNISH FOREST SECTOR

The whole carbon cycle from atmosphere to forests, forest products, energy use of wood, management of wood waste and back to the atmosphere was studied in the Finnish Research Programme on Climate Change (Pingoud 1996). A summary of the results is shown in Fig. 4–3.

This study was made for the year 1990. In that year, the net anthropogenic removals of carbon from Finnish forests were 10.5 Tg. This was mainly stemwood; the other parts of the trees (including root systems), with a total carbon content of 7 Tg, were left in the forest. Besides, the natural processes (falling of needles and leaves, litter production of root systems etc.), increase the carbon storage of the forest floor.

About 40% of the wood removed from the forest was used in energy production; two-thirds of this was in the form of black liquor. More than 50 % of the utilized wood is remaining in the forest products, from which 2/3 are pulp and paper and 1/3 wood products. On the basis of their carbon content, about 80% of the forest products were exported, which means their decay mainly takes place abroad.

The carbon storage of forest products in use is approximately 15 Tg inside Finnish borders. The total carbon storage, including export products, is of the order of 45 Tg. The landfill storage accumulated since the beginning of the century was estimated to be 80 Tg, most of it abroad. Although these storages are small compared with the wood biomass in forests, their accumulation rates and greenhouse impacts can still be

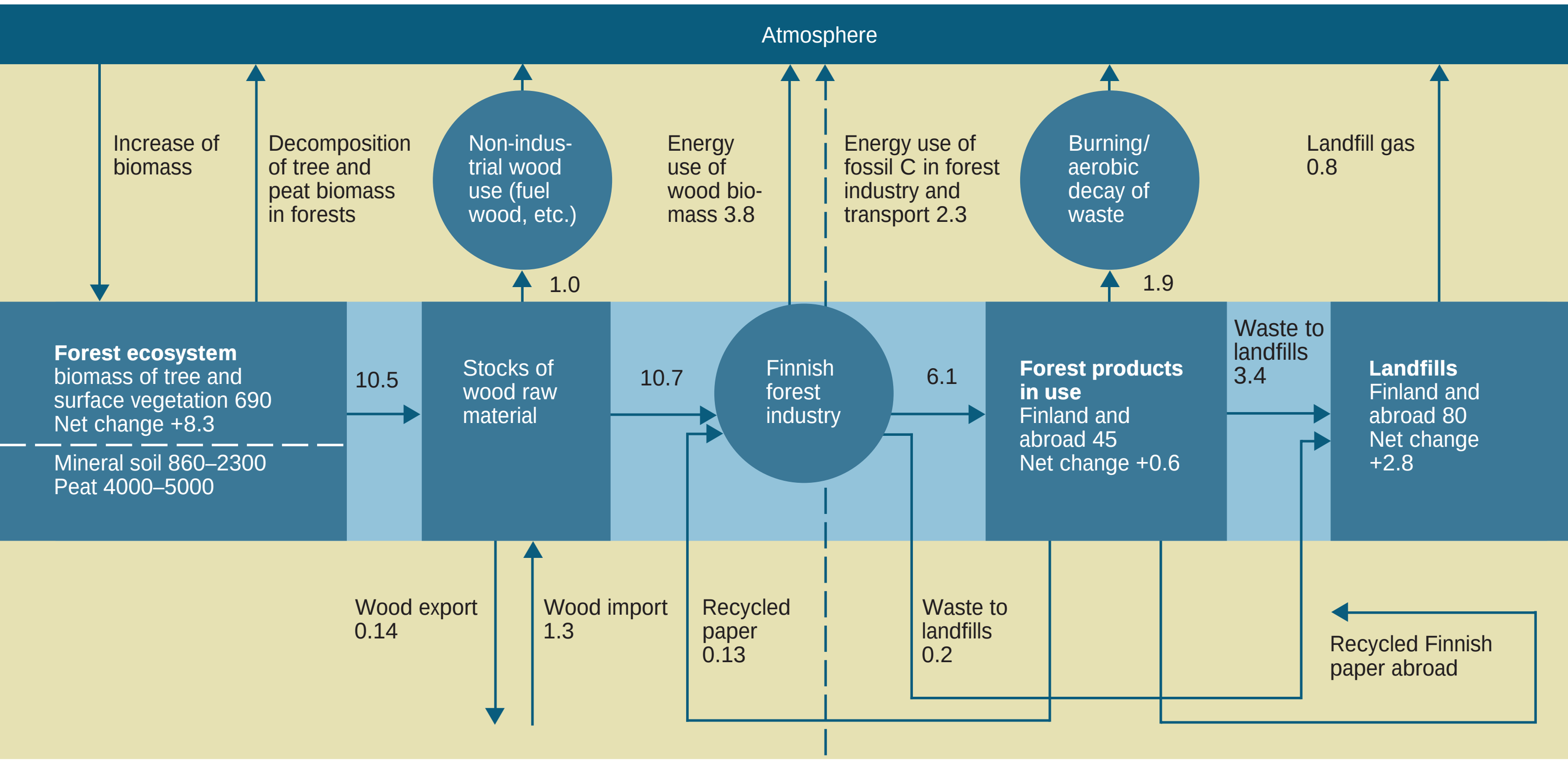


Figure 4–3. **Carbon reservoirs (Tg C) and fluxes (Tg C/a) if the Finnish forest sector in 1990 (Pingoud & al. 1996).**

important. For example the role of landfills is complicated. They act as carbon sinks, but emit methane, which is a powerful greenhouse gas. Thus, the waste management practices at landfills home and abroad may be an important factor in the overall greenhouse impacts of the Finnish forest sector.

A strictly national carbon and greenhouse gas balance of the Finnish forest sector would be considerably different. The export of forest products in 1990, about 5 Tg, represents in a way a sink in the carbon balance of Finland.

Import of roundwood to Finland in 1990 was approximately 6 million m^3 (1.4 Tg C). Mainly due to increased demand of birch pulpwood, import has increased to 9 million m^3 (2.1 Tg C) in 1995. Import of wood is sensitive to changes in domestic roundwood supply. Substitution of roundwood import with domestic wood would influence national forest carbon balance through increased fellings.

5. POLICIES AND MEASURES

5.1. ECONOMIC INSTRUMENTS

When Finland joined the European Union, the overall conditions for the use of economic instruments as a tool in environmental policy underwent a change. Basically, within the EU, individual member countries are entitled to formulate their own systems of guidance. Nevertheless, the real world brings about limitations.

For one thing, abolition of border controls is a precondition for an integrated free trade area. Secondly, the implementation of the environmental directives may, in specific cases, either favour or restrict the use of economic instruments. Thirdly, EU legislation on competition and legal praxis in the Court of the European Communities also entails specific limitations. Moreover, tax harmonization at the Union level, such as the harmonized minimum tax for fuels, makes it necessary for us to apply for an exception so that we can continue to favour low-sulphur fuels in our taxation.

Finland was the first country in the world to introduce a carbon dioxide tax in 1990. This tax was imposed on fossil fuels (except automotive fuels), at that time, according to carbon content.

5.1.1. VALUE ADDED TAX (VAT)

The VAT is a general, multi-stage non-cumulative tax on consumption. As a member of the EU, Finland has harmonized its VAT system entirely with the EU rules. The majority of the amendments came into force on 1 January 1995.

These amendments also removed the supports given to some energy forms through the VAT. In the former system, a special tax reduction was granted to wood and peat-based biomass; the primary energy component of biomass was thereby tax-exempt at all stages of production and use. A similar reduction also applied to natural gas. The removal of these supports was partly compensated for in the excise duties on energy. The additional duty on natural gas based on energy and carbon content of the fuel was reduced by 50% until 31 December 1997. An additional duty on carbon content was not levied in the case of peat up to the end of 1996.

The standard rate for the VAT levied on products and services is 22 per cent. A lower tax rate of 6% or 12% applies to certain commodities. Fuels, electricity and heat are subject to the full 22% tax. VAT is also levied on that part of the commodity's price made up of excise duty on fuels and energy sources.

5.1.2. EXCISE DUTY

The excise duty on liquid fuels is levied on car petrol, on diesel oil, as well as light fuel oil for commercial, industrial and heating purposes and heavy fuel oil. An excise duty on certain energy sources is levied on coal, milled peat, natural gas, electricity and pine oil. Additives and extenders in fuels are subject to the excise duty under the same principles as the fuel in question. Light fuel oil, vaporising oil and paraffin oil must contain a reactive reagent for revealing unauthorized use.

The excise duties were revised in 1993–94, in line with the EU regulation. The duty consists of a basic tax and an additional environmentally based tax. The basic duty is primarily a fiscal tax determined annually in the State budget proposal. The basic duty is, however, differentiated to promote environmental protection. In the case of motor petrol, there is a lower tax on unleaded and reformulated grades, and in the case of diesel oil on the desulphurized grade. The basic duty is also levied on light and heavy fuel oil, pine oil and nuclear power. Tax revenues derive primarily from liquid traffic fuels, however.

The additional environmentally based duty was determined in 1994–96 according to the energy and carbon content of the fuel or energy source. As a rule, the tax was imposed on primary energy inputs, thus encouraging improvements in energy efficiency and production techniques.

The yardstick when calculating the additional tax for the years 1994–96 was heavy fuel oil; 75% of the tax was based on the carbon content and 25% on the energy content. Therefore, the Finnish CO_2 tax system was often referred to as the ”75/25 model” as opposed to the ”50/50 model” proposed within the EU. In 1996, the tax component on carbon content was FIM 38.3 per tonne CO_2 and that on energy content FIM 3.5 per MWh. The additional taxes on all fuels are determined according to unit taxes worked out in this way.

For nuclear and hydropower, the additional environment tax was levied only on energy content. The energy duty component for nuclear power was the same as for electricity generated in coal-fired condensing plants, where the efficiency coefficient is about 38%. The duty on hydropower was worked out by applying the standard rate of energy content directly to the amount of electricity generated.

As a general rule, no additional tax is levied on renewable energy sources. Thus, for example, wind power and the use of waste and wood-based biomass are not taxed. Only the energy component of the duty applied to peat, as a consequence of the VAT reform.

The estimated revenues from the excise duty on fuels and energy products in 1996 were FIM 13.6 billion, representing 2% of GDP. The basic tax accounted for FIM 11 billion and the additional duty for FIM 2.6 billion. About 60% of additional duty revenues came from the carbon dioxide component and 40% from the energy component.

The problem with the system was that few countries have introduced corresponding taxes. Even those which have, have tried to safeguard the competitiveness of their industry either through low tax levels or by granting special concessions. This was especially the case with domestic electricity production, which was no longer competitive in the liberalized Nordic electricity market. The tax on imported electricity probably also went against the Treaty of Rome.

From the beginning of 1997, the energy tax system was reformed again. A uniform tax was imposed on all electricity generated and the taxes on input fuels of electricity production were removed. The electricity tax is differentiated between sectors. Industry and professional glasshouse growers are entitled to pay tax approximately at a rate equal to the one effective in the former system. For all other users of electricity, the rate was doubled in the reform. In the case of heat generation, the component based on energy content was removed, whereas the component based on the carbon content was approximately doubled to FIM 70 per tonne CO_2.

REFORM OF THE ENERGY MARKETS

In accordance with the international standards, the Finnish energy markets were liberalized by several step-by-step reforms already before the beginning of the 1990s. The aim in liberalization has been to make the functioning of the markets more effective and thus to cut the costs of energy users.

In 1995 a radical step towards free competition was taken. Thereafter Finland’s energy markets have been more open than the energy markets in almost any other country in the world. The electricity markets were liberalised by means of a new electricity market law enacted on 1 June 1995. Since November 1995, electricity distributors and large consumers have been entitled to buy electricity from any producer. Many buyers have negotiated their electricity supply contracts with new sellers. Two major industrial buyers agreed on long-term deliveries with a Swedish electricity producer – the first time industrial consumers in one EU country have bought electricity directly from a producer in another country.

In the second phase (beginning of 1997) the minor electricity users and producers also got the right to electricity sales with any partner with access to the national transmission or local delivery network. The transmission and delivery networks will remain natural monopolies, but they will have to serve all customers on an equal basis.

As a member of the EU, Finland supports the liberalization process of electricity markets and favours clear general rules on environmental protection. Finland sees that a certain harmonisation of the legislative framework and taxes on the electricity sector would improve the functioning of the internal markets of electricity in the EU.

The regulation on fuel imports was dismantled in Finland at the end of the 1980s. However, the number of suppliers in the Finnish fuel markets is, in practice, very limited. For example, in oil products the Neste Corporation is the only refiner in the country, and the Finnish distributors of international oil companies currently buy almost 90% of their fuel from Neste.

5.1.3. CHARGE FOR WASTE DISPOSAL AND MANAGEMENT

The municipalities charge users for sewerage and waste management. The sewerage charge is calculated according to the amount of water consumed (households) or on the amount and quality of waste water produced in the asset (industry). The waste management charge is normally determined on the basis of the nature, quality and quantity of the waste and the frequency of collection.

The rates are set according to the prime cost principle. The fee varies between municipalities and the revenue is used to finance collection of waste and treatment of sewage. On the average, for household waste the handling fee is FIM 150 per tonne and the transportation fee FIM 500 per tonne. Particularly the handling fee has increased considerably in recent years.

A new Waste Tax Act came into force on 1 September 1996. A waste tax is levied on waste delivered to public landfills and comparable sites set up for receiving wastes produced elsewhere. No tax is levied on wastes delivered to private landfills, primarily those set up by industry and production units for their own use, or to temporary deposition sites. Nor would landfills used exclusively for depositing soils be affected.

The tax is calculated on a per weight basis and set at FIM 90 per tonne of waste. The tax accrues to the State from those responsible for the upkeep of landfills; for this purpose, operators should be registered for taxation. They are to notify the authorities and pay the tax quarterly, based on the amount of waste delivered. Materials removed from the landfill are deductible from the landfill tax. Thus, only the net increase of waste in the landfill will be taxed.

5.1.4. OTHER CHARGES

CONTINGENCY RESERVE CHARGE

This charge is levied on certain commodities vital to maintaining supplies during an emergency, such as liquid fossil fuels. Revenues go into a special fund. The purpose of the charge is to transfer the costs accruing to the State from maintaining a contingency reserve for the economy as a whole to users of these commodities. The charge in 1996 was 4.3 pennies/l for gasoline, 2.3 pennies/l for diesel oil and light fuel oil and 1.9 pennies/kg for heavy fuel oil (100 pennies = 1 FIM).

OIL PROTECTION CHARGE

An oil protection charge is levied on imports of oil. The charge depends on the safety category of the transport tanker. The charge in 1996 was FIM 2.2 per tonne of oil if the tanker had a double bottom, but was doubled if the vessel had only a single bottom. The charges are paid into a special fund, which is used to provide oil damage prevention and to compensate for the cost of such damage.

5.1.5. ENVIRONMENTALLY MOTIVATED SUBSIDIES

The Ministry of Trade and Industry awards under its Energy Aid Scheme grants for development and investment projects which promote energy efficiency, the use of renewable energy or reduce environmental hazards associated with energy production. The grants can be awarded to enterprises and organizations. The amount of aid depends on the nature and purpose of the project. Development projects (so-called soft-aid projects) can receive grants up to 50% while the maximum for investment projects is 30%. The grants amounted to a total of FIM 198 million in 1996.

5.2. ENERGY EFFICIENCY MEASURES

The Government made in December 1995 a decision on the implementation of energy efficiency measures. The decision establishes a new energy efficiency programme with the aim to lower the total consumption of energy by 10 to 15% compared to the ”business as usual” development.

The energy efficiency programme is based on the current energy economic position and the forecasts concerning the development of energy prices. The programme takes account of the developments in the EU common energy policy. One basic assumption is that the promotion of energy efficiency cannot be built on increased State subsidies. Public financing should focus on developing and marketing new technologies. This means that research, product development and demonstration projects need to be subsidized. On the other hand, increased attention and efforts will have to be focused on energy efficiency throughout the public administration. The government has also decided to make Motiva, an information centre for energy efficiency a permanent body. Originally Motiva was started as a project organization for the period 1993–96.

The new programme is based on the implementation of various policy measures including the use of economic instruments, laws and regulations and voluntary agreements. For all the measures, preparations have been started during 1996. It should become possible for the government to submit the necessary bills to Parliament, and for the various other bodies to make their proposals, during 1997 at the latest.

Many of the suggested measures mark a mere beginning of the preparations. The proposals for the actual measures to be made as a result of the preparatory work will be discussed separately. The implementation of the programme shall be followed and reports prepared regularly.

Government policy in the industry and power sectors relies mainly on voluntary agreements. The government practice of concluding energy conservation agreements with producers, distributors and consumers of energy will be developed, with added emphasis on the goal-seeking and binding aspects of the agreements. Agreements with industry will be extended to involve individual industrial sectors and companies.

The agreements will reinforce several activities, in particular, monitoring energy efficiency, preparing conservation plans, auditing energy, carrying out energy efficiency investments, introducing new technologies, and providing the consumer with feedback data and guidance on their energy consumption. Efforts will be made to combine conservation agreements with, for example, fiscal incentives.

The Building Code will be revised with a view to reducing energy consumption in new buildings. Energy economy will be taken into account in subsidizing building renovations. In new buildings, each apartment will be equipped with a system permitting the metering of and charging for hot water and electricity consumed. For heat, metering will be required if warranted by the pilot projects and technological progress.

Energy auditing of commercial premises as well as public and residential buildings will be developed and the continuity of auditing will be ensured. Energy audits of residential buildings will be linked to the assessments administered by the Ministry of the Environment for checking the condition of buildings. For this purpose, a specific certificate will be prepared for use in judging the condition of properties. The new certificate will show the energy classification data for buildings, based on the EU’s SAVE directive.

In reforming the tax on automobiles, fuel consumption will be considered as one of the criteria on which the rate of the tax would depend. Measures shall be taken for the inclusion of energy-saving driver’s skills among the criteria to be applied in issuing driving licences.

Examination of the energy implications of any major decisions on land use and construction will be made compulsory. The laws and regulations concerning land use shall involve the obligation to promote integrated community structures in the territory and to improve the conditions under which collective transports and light traffic are carried out.

5.3. INCREASED USE OF BIOFUELS

In the utilization of bioenergy, Finland tops the statistics for the industrialized world. In 1995 bioenergy, including energy generated with peat and pulping black liquor, accounted for 21 per cent of the total energy consumption and for 17 per cent of electricity produced. It is the declared goal of the Government to increase the use of bioenergy by a minimum of 25 per cent (60 PJ) by the year 2005.

The biofuels concerned include wood, peat, agricultural biomass and biowaste. Various products can be made from these materials, such as charcoal, wood chips, sod peat, ethanol, rapeseed diesel oil and the gasoline additive ETBE.

Geologically, peat is not a fossil fuel, but rather a slowly renewable soil component made up of decomposed plants. Overall, more peat is produced in Finland than is used to produce energy.

Research and development play a central role in the promotion of expanded use of bioenergy in Finland. The aim is to identify and develop technologies for establishing and sustaining economically, environmentally and socially viable bioenergy niches in the energy system.

The forest industry is the largest consumer of wood-based energy in Finland. The chemical recovery boilers and industrial boilers for solid biomass required by the forest industry have laid the foundations for power boiler technology suited for various types of biomass and waste fuels.

Outside the forest industry, district and local heating plants constitute the main bioenergy segment in Finland. Peat is extensively used as a district heating fuel. Multi-fuel and co-firing combustion technologies extend the possibilities of utilizing biomass, which tends to be available in a limited supply within a feasible transport distance. The energy density of fresh biomass is typically less than one-tenth of that of coal, making it uneconomic to transport biomass over long distances.

The technology closely linked with cogeneration of heat and electricity in Finland is fluidised bed combustion (FBC). FBC boilers combust typically moist biomass and mixed fuels with high efficiency. The technology has been scaled down for application in small-scale biomass-fired CHP plants. Advanced grate combustion systems make it possible to utilize wet biomass, such as bark, sawdust and wood chips, in smaller boilers where FBC is not economic.

Gasification diesel technology is a promising

FLUIDIZED BED COMBUSTION IS A KEY ELEMENT IN BIOMASS UTILIZATION

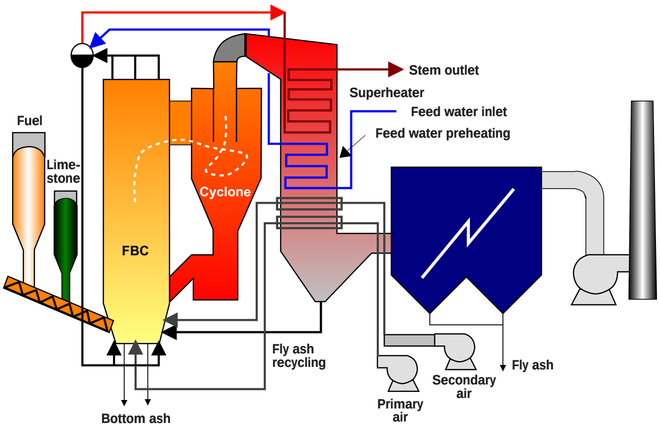
Fluidized bed combustion is a main technology for new biomass-fired plants. It has also made small sized power plants more cost-effective. With the fluidized bed technology, it is achievable to produce combined heat and power in smaller scale.

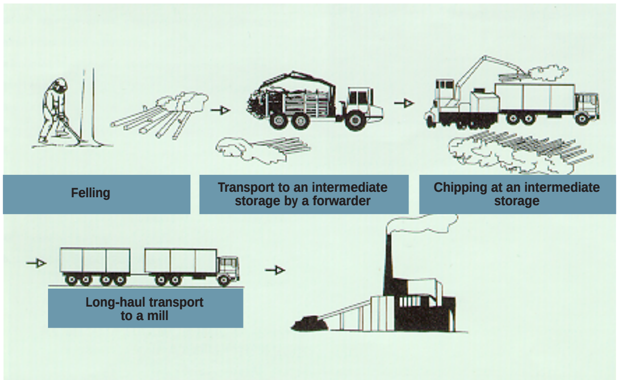
Fuels of different quality can easily be burnt in a fluidized bed because of its high heat capacity. Sulphur reduction is quite easy to carry out in fluidized bed combustion by adding limestone or dolomite into the bed.

Also NO_x emissions are low because of the low combustion temperature. The atmospheric fluidized bed technology can be classified into two different techniques; bubbling and circulating fluidized beds. The former is a more suitable alternative for big coal-fired boilers, the latter for smaller and midsize biomass-fired boilers.

In Finland, there are several fluidized bed boilers used for CHP production. They are usually suitable for many different fuels. There is also a lot of logging residue in Finnish forests to be used as fuel. Under these circumstances, there are good conditions for increasing the biomass utilization. However, the costs of introducing new biomass reserves may limit the increase of biomass utilization.

A lot of research and development work goes into developing the harvest technology for wood-based biomasses. This work is needed to integrate the harvesting of industrial wood material with that of logging residue. The Finnish government has set an objective to increase the biomass utilization by 25 per cent by the year 2005.





alternative for small-scale electricity production. Another area under research is the conversion of biomass into liquid fuels. Liquid biofuels could be used in diesel power plants and could replace fuel oil or motor fuels in various applications.

However, most types of biomass should be considered as difficult fuels. Wood can have a moisture content up to 60%. Straw and energy crops contain chlorides and alkals, which may cause corrosion at the power plant. Also, the combustion of some biomasses produces ash that melts in low temperatures leading to slagging and fouling problems.

It has been assessed that the untapped potential for biofuels in Finland is as high as 280–320 PJ per year. However, the chances of actually exploiting this potential are much more limited. Considering economic viability and real government potential for promoting use of biofuels, even the officially adopted target of an additional 60 PJ/a poses a challenge. To reach it would involve the correct allocation of government support, the efficient development of technology, more extensive advisory services and guidance, and changes in the legislation.

The conditions for wind power generation are favourable on the coasts, in the archipelagos and in the fell areas of Finland. About 7 MW of wind power has been erected, and about 11 GWh of wind energy were produced in 1995. The first Arctic wind park began operations in Lapland in September 1996.

The probably northernmost solar electric power plant in the world is located in Inkoo on the Gulf of Finland. It has a nominal output of 30 kW. A large potential for the solar energy market is provided by the 400 000 holiday cabins, half of which are located in remote, off-grid areas.

5.4. ENERGY TECHNOLOGY DEVELOPMENT PROGRAMMES

To maintain a diversified energy production structure, relying also on new technology and renewable energy sources, the Government promised in its report to Parliament to provide more funding for the development of Finnish energy technology by launching, financing and guiding research programmes and development and demonstration projects aimed at finding new solutions both for the home market and for export. Such programmes have actually been under way for several years now, and in 1993 the Ministry of Trade and Industry launched new energy technology development programmes for 1993–1998.

Eight national energy technology programmes for 1993–1998 are under way in cooperation with companies and other expert bodies (Table 5–1). The main emphasis in these research programmes is on environmentally sustainable technologies. Aspects covered include the development of new combustion techniques and research aimed at increasing use of biofuels and other renewable energy sources and raising the efficiency of energy production. The programmes involve considerable international collaboration. The total funding input is around FIM 1 500 million.

In the wind energy programmes, the goals are defined as

- 100 MW of wind power in Finland in 2005
- support the product development of industry

The test plant of Pyhätunturi in Lapland is a unique site to develop heating systems for the blades of wind power plants and to measure the efficiency and loading of wind power plants in freezing conditions.

5.5. INDUSTRIAL ADVANCES

Environmental considerations will change the industry in the future. Gradually, the market will come to demand products and services that promote sustainable development. National aspects such as our own know-how and natural resource base will, however, continue to constitute their own restraints. The environmental viewpoint will be integrated into all Finnish technological research and its funding and permeate all development.

New products and new production technology will, as a rule, be more environmentally acceptable than their predecessors, because being environmentally sound is known to be a crucial element in quality and competitiveness. As there has been more funding of technology in the last few decades, this has also meant faster technological advances, and hence the faster adoption of less polluting technologies.

Social choices concerning energy production, environmental regulations and the traffic infrastructure are also shaping the structure of industry. If industry’s investment choices are to be efficiently implemented, it is important for society’s administrative and economic control systems to be consistent and to disturb the markets as little as possible.

Natural resources will be used more economically once industry acts on its own initiative to take environmental considerations into account, for example through internal eco-auditing and eco-management. In product development and the renewal of production processes, life-cycle thinking and life-cycle analysis will promote more economical use of raw materials. On the same principles, use of renewable materials will increase. Use of harmful substances will decrease and harmful emissions and wastes will also decline in volume.

The Environmental Impact Assessment (EIA) Act, the revised Waste Act and the Eco-Audit system will work in practice to further the goals outlined above. Product life-cycle analyses, eco-labelling and voluntary eco-audits will all contribute to the same process. The aim is in fact to develop methods for reducing the environmental impact of industry and products on a basis of voluntary independent action.

5.6. REDUCING THE HARMFUL ENVIRONMENTAL EFFECTS OF TRAFFIC

Because of its small population and large area, Finland is a sparsely populated country with long distances from place to place. We are also rather far away from our main markets. These factors, combined with the distinctive structure of industry, tend to increase traffic volumes and thus greenhouse gas emissions from traffic. The distances driven annually by heavy goods traffic are about double the European average, and though the actual car density is around the European average, people drive about one and a half times more kilometres.

Traffic volumes are bound up with economic development. By themselves, the technical means normally

Table 5–1.

Energy-related RTD Programmes in Finland for the years 1993–1998.

Programme	Objectives
Energy Production	
LIEKKI 2 Combustion and gasification technology • Biomass combustion and gasification	To develop new production technology to reduce emissions and improve efficiency
BIOENERGIA Bioenergy • Wood fuel production and handling • Small-scale combustion of solid biomass • Peat production • Liquid biofuel production	To develop technologies to achieve a competitive price level for bioenergy and peat production
NEMO 2 Advanced energy systems and technologies • Solar and wind energy	To develop technologies for the use of wind and solar energy
FFUSION Finnish fusion energy research programme	To carry out high-level scientific and technological research in support of the European Fusion Programme and International Thermonuclear Experimental Reactor (ITER) project
The Environment	
SIHTI 2 Energy and environmental technology • Environmental research includes biomass and wastes	To develop technologies to reduce the emissions of harmful substances, to recycle raw materials and to limit the amount of wastes and utilize them in the energy sector
End-use of Energy	
MOBILE Energy and the environment in transportation • Utilization of liquid biofuels	To develop technologies to reduce emissions from the transport sector
SULA 2 Energy in steel and base metal production	Development of processes to achieve the world's lowest specific consumption of energy
SUSTAINABLE PAPER Energy in paper and board production	Development of processes to achieve the world's lowest specific consumption of energy
RAKET Energy use in buildings • Wood fuel utilization in space heating	To create technologies for halving the energy consumption of new buildings compared with present levels
EDISON Electric distribution automation	To develop an integrated distribution automation concept
TERMO District heating	To develop technologies to increase the effi-ciency and economy of district heating

resorted to in order to eliminate the causes of environmental pollution are insufficient to reduce greenhouse gas emissions from traffic.

Since 1990, a rapid decrease has been achieved in emissions of nitrogen oxide, hydrocarbons and carbon monoxide by traffic, thanks to technical improvements and tax reliefs on cars with catalytic converters. In 1992, Finland started applying US-standard exhaust gas limits to new cars, and since 1995 the EU-standard has been applied.

Exhaust gas emissions from lorries and buses have also been cut rapidly in the last five years, in line with EU directives. The maximum nitrogen oxide emission permitted for new heavy diesel engines is only half what it was at the end of the 1980s.

On the other hand, the adoption of catalytic converters in private cars increases nitrous oxide emissions from traffic. Lambda-regulated exhaust gas control based on a stoichiometric fuel mixture has also slightly reduced the potential for cutting fuel consumption.

Heavy lorries and buses are now required to have a speed limitation device which prevents them from travelling at very high speeds. This is expected to cut their fuel consumption by about one per cent.

The Finnish tax on new cars has always been rather high by international standards. It has also acted to discourage the purchase of high-powered cars, though this might otherwise have seemed natural considering the long distances that have to be travelled. The high car tax has also helped to restrain growth in the overall number of cars.

The Finnish tax on traffic fuels is a little higher than the average West European level. At the moment, the tax on gasoline is one of the highest in Europe, and that on diesel oil just above the EU minimum, though well below the average. The tax on both fuels has been raised sharply in recent years, and this, together with the recession in the early 1990s, has halted growth in traffic volumes.

The taxes on fuels are graduated according to environmental principles, and as a result reformulated gasoline has practically displaced the ’normal’ grades. Very low sulphur (max. 0.005% S) diesel oil is also widely used for the same tax reasons. The change-over to reformulated gasoline rapidly reduced total CO and hydrocarbon emissions from Finnish car traffic by 10–15%. The tax on fuel CO_2 and energy content is also levied on traffic fuels.

The other economic instruments used include a subsidy for public transport (though this has had to be cut sharply in recent years), investments in upgrading the rail network, a reduction in the tax deductibility of business travel expenses and a cut in the transport subsidy for industry in developing areas.

The use of alternative gas fuels containing less carbon, and the use of bioalcohols and rapeseed methyl esters as fuels has been studied and gas-powered lorries and buses have been developed as far as the production stage.

Emissions from trains have been reduced by electrifying rail traffic. This process and basic improvements continue.

In autumn 1994, the Ministry of Transport and Communications approved an action programme to reduce the harmful environmental effects of traffic. This programme is based on the recommendations of the Second Parliamentary Traffic Committee. The 1993 Council of State decision-in-principle on improving the safety of road traffic includes measures in line with this programme. The primary target – of restraining traffic growth – is common to both lines of action.

The action programme proposes long-range goals and targets up to the year 2000, plus measures to achieve these goals so that they are in harmony with Agenda 21, for instance. In the case of greenhouse gases, the aim is to promote attainment of the objectives of the Climate Convention.

Most of the measures in the programme concern road traffic, because its environmental impact is, on the whole, primary and more controllable than with other forms of transport. However, action is also proposed to reduce the environmental impact of rail, water and air traffic, and working machinery.

To ensure that traffic systems develop in a sustainable manner, it is proposed that traffic growth should be restrained through socially acceptable structural and financial means. Like the proposal of the Parliamentary Traffic Committee, this programme recommends that the necessary transportation should be provided efficiently and economically, while involving the minimal amount of traffic.

Economic controls will support the chosen social and traffic policy strategies. They will affect, for instance, trends in transport technology and fuels, use of means of transportation and location of functions. Planning of these measures will take the whole life cycle of traffic systems into account and the whole transportation chain, including related functions. The environmental impacts of building, managing and maintaining traffic systems will be assessed early enough in the planning system to allow the assessment to contribute to better solutions.

Cooperation between the various spheres of government will be increased, especially when measures are being harmonized, and in order to make research, monitoring, information and training more effective. Development of environmental technology in the traffic sector will be promoted.

The programme includes plenty of practical measures to reduce both greenhouse gas emissions and other environmental hazards. In terms of the FCCC, the most important measures are:

- maximum limits for greenhouse gases and other emissions coming into effect in the EU, or economic instruments will be adopted;
- measures to promote the sale of low-consumption cars and to restrain traffic growth will be worked out, together with the effects on community structure and transport needs of possible taxation practices promoting the use of environmentally more acceptable cars;
- operating potential of public transport and non-vehicular traffic will be improved, for instance by improving the price and service competitiveness of public transport;
- competitiveness of rail traffic will be improved through cooperation between the State Railways and other parties, for example, in physical planning, public transport system planning and improvement of the rail network;
- land use planning will pay special attention to changes in transport needs and choice of means of transport;
- pedestrian and cycle paths in town centres will be increased and parking arrangements planned so as to reduce traffic volumes;
- use of IT will be promoted as a replacement for physical traffic;
- projects promoting logistic efficiency will be supported in order to reduce traffic growth; and
- transit traffic through Finland into Russia will be examined so as to make the railways more competitive, for example, by adjusting freight rates.

The economic instruments included in the programme will restrain growth in car traffic and speed up the replacement of technology. The specific consumption of private cars can be cut about 20% by technical means, if their fuel economy is improved or people start using lighter, lower-powered cars.

Land use planning, economic controls to back it up and improvements in the operating potential of public transport could reduce energy consumption 5–15% over the next 10 years. Over the longer term, the effects would be much greater.

In 1995, in order to reduce particularly the emissions of nitrogen oxide and hydrocarbon from the traffic, inspection of exhaust emissions from motor vehicles was extended to include diesel-powered cars in addition to gasoline-powered cars. Research has been carried out to actively influence future EU rules on exhaust gases insofar as these deal with problems concerning cold starting and use.

Emissions from new working machinery and diesel trains will be reduced and electrification of rail traffic will continue. Efforts will be made to reduce nitrogen oxide emissions from ships' engines in international cooperation, so as to ensure that emissions from new engines are 30–40% lower than at present.

The future EU emission limits for aircraft will be put into effect. The adoption of landing charges graded according to the aircraft's environmental impact will be considered. In fuel distribution, recovery of VOCs in line with EU directives will be implemented. The use of cleaner fuels will be further promoted through economic instruments.

5.7. PROGRAMMES AFFECTING FORESTRY

5.7.1. THE FOREST 2000 PROGRAMME

Use of forests and the required forestry activities in Finland are outlined in the Forest 2000 Programme of the Ministry of Agriculture and Forestry. This programme assesses the development and use of forest resources and the factors affecting them, such as air pollution, the consideration of nature conservation objectives in forestry, and the multiple-use of forests. The Finnish Forest Research Institute has dated forest inventory results and estimated felling potentials and trends. If fellings remain at the level of the late 1980s, that is, about 50 million m^3 per year, Finland's forest resources could be doubled by 2030. This would gradually result in over-stocked and over-mature forests with degenerated growth.

According to the Forest 2000 Programme, fellings are most likely to increase up to 60 million m^3 by the year 2000 and up to 70 million m^3 by 2010. Despite this increase, forest resources could grow by a third by the year 2030. Using forest resources at this level allows to keep the forests in good productive condition under the concept of sustainable forestry. Nature conservation considerations can also be taken into account. The anticipated increase in the use of wood presupposes new investments in the forest industry or a substantial increase in the use of wood in energy production.

5.7.2. FORESTRY ENVIRONMENTAL PROGRAMME

In July 1994, the Ministry of Agriculture and Forestry and the Ministry of the Environment jointly confirmed the Forestry Environmental Programme as Finland's strategy for sustainable forestry for the near future. The programme especially emphasizes the protection of biodiversity in the forests, but the target state of the forests for 2005 also implies that they are managed and used as efficiently as possible, and that trees grow well, ensuring that the forest effectively sequestrates CO_2 from the atmosphere, mitigating climate change. The programme also acknowledges that maintaining tree growth and uptake of CO_2 is both a long- and a short-term prerequisite if Finland is to be able to fulfill its obligations under the FCCC.

The Forestry Environmental Programme, with its emphasis on nature-related, environmental and multiple-use considerations in managed forests, will mean that some 5–10 million m^3 of the total annual increment is left unused.

6. PROJECTIONS AND EFFECTS OF POLICIES AND MEASURES

6.1. CARBON DIOXIDE

6.1.1. EMISSION TRENDS ACCORDING TO DIFFERENT SCENARIOS

The scenarios presented here are not in themselves predictions or an attempt to project a balance sheet on energy consumption and supply possible that extends two or three decades into the future. The purpose of these calculations is to shed light on the dependency existing between energy economy and other development trends in society.

These scenarios, which differ in nature, have also been selected and presented with the purpose of specifying the broad spectrum of future trends that is at hand when examining the effects of energy production on carbon dioxide emissions in Finland.

The energy market scenario (EMS) analysis describes a situation where trends in energy economy are market-based without national or international measures influencing these trends in excess of the effects the market would otherwise have under present energy policy conditions. The departure point of the other scenario, the energy policy scenario (EPO), is that in order to curb CO_2 emissions, energy demand is reduced by strengthening current control measures. In addition, the energy production structure is steered, for example, by means of taxation, so that the energy supply balance would contain less coal. For the EPO scenario, two different trends are examined; one in which the use of wood and natural gas is increased to meet the additional demand for energy (EPO1); and one in which more nuclear power is built (EPO2).

ENERGY DEMAND INCREASES IN STEP WITH THE ECONOMY – ALTHOUGH AT A SLOWER PACE

Consumption and generation of energy are tightly bound with other activities of society. The central factors affecting demand for energy are economic growth and the pattern of growth, available technology, relative price of energy, and consumers' habits and attitudes. The population size and structure also affect energy consumption.

Similarly, the methods used for the energy supply to meet the demand is influenced by several factors; the country's geographical location and natural resources, technology, taxation and relative prices of various fuels and energy production methods, and the current energy policy.

As to the economy, the departure point in the EMS and EPO scenarios is that total production of the Finnish national economy would roughly double by the mid-2020s, in which case the average annual growth rate would be 2.5%. During a period of corresponding length, from 1965 to 1995, the Finnish economic growth rate was approximately 3% per annum.

Economic growth or normal development of the economy have not been assumed to be regulated by the availability or price of energy.

The calculations indicate that economic growth is a key factor explaining energy consumption; when the economy expands, the demand for energy also increases. In the future, however, energy consumption will no longer grow at the same pace as the economy. This result is explained not only by structural changes in the economy but also by the fact that, in many sectors, the period of most rapid growth of factors influencing energy consumption – such as the number of motor vehicles, households' acquisition of appliances and equipment, and the building stock – has already passed.

Ageing of the population and the decline in the population size in the 2010s are also explanatory factors contributing to a slowing down of the increase in energy consumption.

Overall, in the energy market scenario (EMS), by 2025 total energy consumption would be 1.4 times the amount consumed in the mid-1990s (Fig. 6–1). The corresponding figure for electricity consumption would be a 1.7-fold increase. In addition to the assumptions concerning the population and the economy, the result is based on the assumptions that consumer prices for energy products would rise owing to higher import prices; that the use of energy is not restricted or steered more than at present; and that the technology for energy use develops steadily.

If the price of energy should increase over time, as a consequence of rising world market prices and rising energy taxes, such a trend would have a slowing effect on the rise in energy consumption as compared with the energy market scenario (EMS) described above. Economical use of energy and an energy-saving motivation based on environmental values would be mutually supportive. The EPO scenario includes an assumption of this kind, that is, that energy taxation would increase considerably in the coming decades.

If additionally it is assumed that conditions involving rising world market prices and higher energy taxes lead to the prerequisites for commercialisation of new energy technology and for the introduction of norms influencing consumption, one arrives at results according to which both total energy consumption and total electricity consumption would increase at a substantially slower rate than in the trend arrived at in the energy market scenario (Fig. 6–1).

A trend in accordance with the EPO scenario, however, cannot be achieved by means of Finnish energy policy decisions only. A precondition of the trend indicated by the EPO scenario is that widespread and

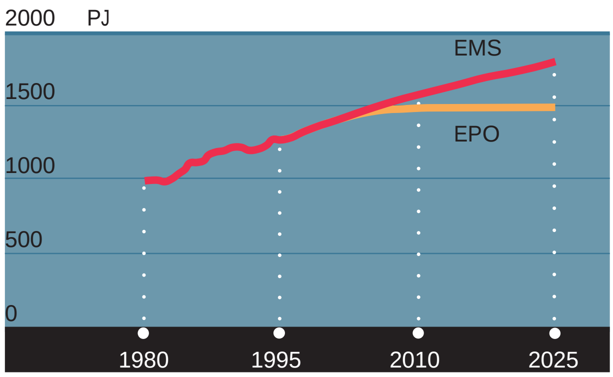


Figure 6–1. **Total energy consumption in the energy market (EMS) and energy policy (EPO) scenarios (Ministry of Trade and Industry 1997).**

international agreements are made concerning several norms affecting energy consumption; examples include norms for vehicle fuel consumption, norms for the electricity consumption of household appliances and norms for industrial energy audits. The trend should also be supported by the extensive introduction of higher energy taxes. Moreover, investment in development and commercialisation of energy-efficient technology should be substantially greater than at present.

INCREASED CARBON DIOXIDE EMISSIONS

A slowing down of the increase in energy consumption, caused by structural factors in the economy, already means considerable reductions in CO_2 emissions from the levels they would have reached with a doubling of the national economy. It is also assumed that a rise in the world market prices of fuels and technological development will have similar effects on the trend in CO_2 emissions. The joint impact of these factors, however, is not enough to accomplish major reductions in CO_2 emissions.

In the energy market scenario (EMS), it is assumed that – for economic, technological or other reasons – hydropower, nuclear power or other CO_2 emission-free forms of energy generation cannot be increased in Finland, that the efficiency of energy use improves at most at the present pace, and that energy technology develops in trends. In such a situation, we arrive at the conclusion that CO_2 emissions will increase substantially. They may rise from 55 Tg in 1995 to as much as 79 Tg by 2020 (Fig. 6–2). This would conflict clearly with the internationally agreed objectives intended to prevent climate change.

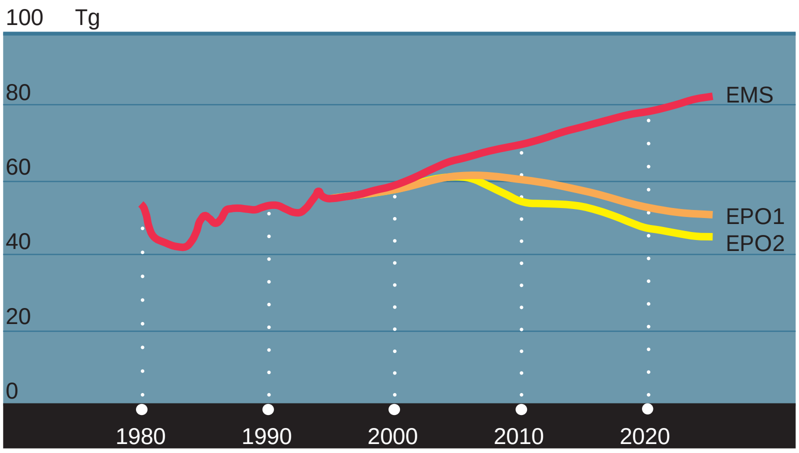


Figure 6–2. **Carbon dioxide emissions in the energy market (EMS) and energy policy (EPO1 and EPO2) scenarios (Ministry of Trade and Industry 1997).**

Importation of electricity affects domestic CO_2 emissions. In all scenarios, import has been taken into account in more or less the same amount as at present. Finland has in recent years imported 10–15% of its electricity needs from neighbouring countries. In 1995, net imports of electricity accounted for 12% of total consumption of electricity, which would have caused some 8 Tg of CO_2 emissions if it had been generated by Finnish condensing power.

PRODUCTION CONCEPTS PLAY A KEY ROLE IN CO_2 EMISSIONS

If the departure points of the EMS scenario are considered a reality with regard to nuclear power and hydropower, essential cuts in CO_2 emissions can be achieved only through major improvement in the competitiveness of bioenergy and substantial increase in import and use of natural gas. Both of these conditions incorporate a wide range of open questions and problems.

As technology develops, the competitiveness of bioenergy will also improve. The role of bioenergy, however, cannot increase significantly without intense investment. If the competitive situation of bioenergy could be improved by special measures, changes in market shares would take place slowly.

In the long-term, a precondition for increasing the use of natural gas, especially in generating electricity, is to link Finland’s natural gas network to the European natural gas network. If implemented, the project would provide electricity producers with a base, more secure than the present one, for building condensing power plants relying on natural gas. Even in the best of cases, however, it would take years to carry out the natural gas pipe project.

In order for CO_2 emissions to follow the EPO1 trend (Fig. 6–2), besides the fairly tight departure points concerning energy consumption, it would be necessary to use considerably more wood as an energy source, to increase importation of natural gas fourfold, and to continue importation of electricity at least to the same extent as it is now imported. In this context, wood would have to replace half the peat consumption by 2025, and use of coal as fuel for condensing power plants would have to cease altogether.

Construction of additional nuclear power would have a clear impact on CO_2 emissions. Nuclear power could replace fossil fuels – especially coal – in the generation of electricity.

The lowest CO_2 emission trend illustrated in Fig. 6–2, the EPO2 trend, could be the result if nuclear power would be used to generate about an additional 2000 MW, and if this replaced energy will be generated by coal. In this alternative, use of natural gas to generate electricity would remain smaller than in EPO1. For all other uses, except condensing power plants, however, natural gas would continue to replace coal, and wood would continue to replace peat. In EPO2, imports of natural gas could be more than double the amount at present; this amount would also require ensuring the availability of natural gas different from the current means.

Table 6–1

Summary of implemented policies and measures to reduce carbon dioxide emissions. These reductions are already included in the EMS scenario.

Policy/measure	Type of instrument	Objective
Fuel switching	Market liberalisation Energy taxation	Efficiency in energy markets
Renewable energy	R&D of new technology Market liberalisation Energy taxation	Diversity and sustainability of electricity supply
Energy Efficiency Programme	Savings target Information and incentives Voluntary agreements Regulations, advice, grants, labelling R&D of new technology	Energy efficiency
Total		

6.1.2. EFFECT OF VARIOUS POLICIES AND MEASURES

Assessments of future energy consumption and emission trends are usually based on detailed economic and other social goals, and analysis of the subsequent energy demand. Assumptions also have to be drawn regarding energy production and consumption technology, the price of energy, and the quality and effectiveness of energy policy measures. The following presents an assessment of trends in energy sector CO_2 emissions up to the year 2020, based on general assumptions about economic and social development and taking into account the potential effect of the emission reduction programmes outlined earlier.

EFFECT OF ACTION PROGRAMMES ON CARBON DIOXIDE EMISSIONS

The effect of the measures outlined above on CO_2 emissions from energy production and consumption up to the year 2010 are shoun in Table 6–1. In the most likely policy option, emissions would be 60 Tg in 2000 and between 60–70 Tg in 2010. This option takes into account cuts brought about by energy taxation, energy conservation, increased use of bioenergy and the adoption of new technology. Depending on arrangements concerning the base-load capacity and the amount of electricity imported, annual CO_2 emissions could well decline from the upper level, reaching some 65 Tg or perhaps returning to earlier levels in 2010.

EFFECT OF ENERGY TAXATION ON CO_2 EMISSIONS

Boosting the price of carbon-based fuels by raising the tax on them will make them less competitive and encourage the energy industry to develop new production methods based on renewable fuels. Because the energy industry is rather slow to change, taxation will take effect gradually, and it will only be possible to point to distinct effects over a 10–20 year period.

Energy taxation also means that rising energy prices will be a stimulus for more efficient use of energy and make previously non-viable energy conservation investments more attractive. Thus, the total amount of energy used would be lower than in a situation without taxation.

The effects of the CO_2 tax depend on several component factors, which may not materialize. They include the overall scale on which an energy tax is adopted internationally and how the tax revenues in different countries are used or consumers compensated, and also whether the system allows for many exceptions. The question of whether more nuclear power plants are built will also greatly influence what happens.

The CO_2-based energy tax currently levied in Finland is expected to reduce CO_2 emissions about 4–5% by

Sector	Status	Estimate of mitigation impact ($TgCO_2$) 2000	2010
Electricity generation	Implemented	1	2–5
Electricity generation	Implemented	3	3–5
Public Residential Industrial Transport Commercial	Implemented	2	2–5
		6	7–15

2000 compared with the 1990 level, that is, by 2 Tg, if it proves possible to pursue this policy consistently. In 2010 the reduction would already be around 10%. This estimate is based on a substantial increase in the price of carbon-based fuels by 2000 through a tax applied internationally.

EFFECT OF THE ENERGY CONSERVATION PROGRAMME ON CO_2 EMISSIONS

The aims of the energy conservation programme up to 2005 are to reduce electricity consumption by 5.2 TWh and consumption of primary energy by 110 PJ, compared with a no-action alternative. This would mean a cut of some 6–8 Tg of CO_2 by the year 2000, though with the provision of a gradually rising energy tax. By 2005, the effect of the present programme would be a cut of around 9 Tg.

The additional investments in the energy economy called for by the most efficient modern technology would be a good FIM 2 billion a year. If more efficient techniques were also adopted in space heating, the annual additional investment would be close to FIM 8 billion. This comes pretty close to Finland's annual bill for imported energy (FIM 11 billion). It is therefore obvious that these investments cannot be carried out very rapidly, and time must be allowed for creating the technical potential for emission cuts.

The estimates made of the reductions in emissions that can be achieved through energy taxation and energy conservation overlap to some extent.

EFFECT OF WIDER USE OF BIOENERGY ON CO_2 EMISSIONS

More extensive use of wood under the programme to promote use of biofuels will help to achieve the CO_2 reduction targets. By 2000, it would cut about 3 Tg (6–7%) off total emissions at installations where wood will replace coal.

Further use of peat, where emissions are already included in the total, will also replace coal, so here the effect will be unchanged. Emissions from peat extraction can be reduced through careful choice and post-management of extraction sites.

MORE ADVANCED TECHNOLOGY TO REDUCE CO_2 EMISSIONS

Intensive investment in research, development and demonstration projects concerning new technologies has already yielded solutions, some of which are already commercially competitive, and will continue to do so. As energy taxation gradually alters relative fuel prices, new techniques will come onto the market.

Natural gas is already utilized in CHP production. This is economically viable where gas remains available at the current price. Achieving real potential for emission cuts would mean extending the natural gas network.

A large proportion of the as yet unbuilt hydropower potential cannot be commercially exploited for environmental reasons. It is, however, to some extent possible to build small hydropower plants, and to modernize or add generating units to existing ones.

The biggest potential user of bioenergy is the forest industry, which already accounts for the bulk of total bioenergy consumption. The preconditions for more extensive use are competitively priced wood, integrated harvesting methods for both wood raw material and firewood, and new power plant technologies. If the new techniques work in practice, they will reduce emissions substantially, but not until around 2010. The plants are combination utilities based on pressurized gasification, using waste wood as the energy source. The first power plants based on gasification of black liquor could well go on line after 2005, when their heat load would be utilized by solid fuel gasification plants.

Coal gasification techniques are also being developed to increase electricity generation at CHP plants even if no additional heat is needed. The same amount of fuel would then yield more energy.

Overall, the cut in emissions permitted by new technologies ranges from 1 Tg to 5 Tg of CO_2 in 2005, while the variation in 2010 could be as great as 5–15 Tg, or even higher. Some of the technology development measures are the same as have been adopted under the bioenergy promotion programme and the energy conservation programme.

Of all the individual technical means available, more use of nuclear power in separate electricity production would actually be the most effective means of reducing CO_2 emissions. However, as Parliament has decided against a fifth nuclear power plant, no additional nuclear power is likely to be generated in Finland on a time scale that would influence the situation in 2000 or 2005.

ELECTRICITY PRODUCTION CAPACITY CHOICES AND THE IMPORTANCE OF IMPORTED ELECTRICITY FOR CO_2 EMISSIONS

In the next few years, Finland must decide how it is going to produce the base-load capacity needed. Some of the capacity needed up to 2000 will possibly be covered with CHP production in towns and industry, a small amount by more hydropower, and some by wind power. The rest will be covered by wider use of bioenergy and natural gas, and possibly through coal-fired utilities. Depending on the choices, CO_2 emissions in 2000 will vary by some 3–4 Tg.

Finland's Electricity Markets Act is designed to improve the functioning of the electricity market, ensuring that the overall system of Finnish electricity generation, transmission and distribution remains efficient and competitive in future. It also aims to prepare the Finnish electricity market for integrating into Nordic markets and any European markets that may open up. The reform would reduce obstacles to competition and eliminate unnecessary regulation in that part of the market where competition is possible, that is, in the production and sale of and foreign trade in electricity.

The reform would improve market access in the case of renewable energy. It is difficult to estimate exactly what the structure of our electricity production capacity will be in future, or the amount of electricity that will be imported.

Finland has consistently imported over 10% of the electricity it needs from Russia, Sweden and Norway. In 1990, the figure was 17% of the total, and if this had been produced in Finland, resulting CO_2emissions would have been 11 Tg. There are major uncertainties and conditions attached to merely continuing with the present level of imports, not to mention raising it. As a result, the calculations allow for the expansion of Finnish electricity production capacity to replace current imports. This also results in some uncertainty about CO_2 emission trends.

6.2. METHANE AND NITROUS OXIDE

6.2.1. ENERGY SECTOR

The future emissions of these gases from different energy sources are based on the projections on primary energy demand (EMS and EPO scenarios) and expected changes in energy production.

The methane emission estimates for the years 2000 to 2020 take into account the projected increase in total primary energy consumption by energy source. No increase in the use of small-scale combustion of firewood is assumed and the projected increase in fuel wood consumption is assumed to be used totally in large-scale facilities. The growing use of catalytic converters in cars will decrease the future methane emissions even if the vehicle mileage is predicted to increase.

The energy sector is a significant source of nitrous oxide emissions in Finland and in the future the importance of the energy sector as a source of this gas is predicted to grow. The emission estimates for the years 2000 to 2020 take into account the projected increase in total primary energy consumption and also a predicted increase in the use of fluidized bed combustion and use of catalytic converters in cars. The fluidized bed technique is estimated to be used in all new coal-fired CHP power plants and in 80% of the new power plants using other solid fuels. The yearly renewal of power plants is estimated to be 3% of the existing capacity.

Tighter regulations on NO_x emissions will slightly decrease the N_2O emissions caused by nitrogen deposition.

6.2.2. INDUSTRIAL PROCESSES

Methane emissions are expected to increase according to the projections for growth in industrial production (Table 4–3). No significant changes in nitric acid production in Finland are expected in the near future. Nitric acid is used mostly in production of nitrogen fertilizers. The domestic use of nitrogen fertilizers is expected to decrease in Finland but this is not expected to have a major impact on the production of nitric acid.

6.2.3. AGRICULTURE

Membership in the European Union has changed the economy of agriculture in Finland. Many smaller farms have stopped production and the mean size of farms has grown. This trend is expected to continue. The total livestock numbers and the use of fertilizers are expected to decrease somewhat. The impact on production volume will be smaller because of improved production efficiencies.

In agriculture, environmental protection has focused on water protection. Most of the environmental protection measures have been voluntary. With membership in the European Union, a new agri-environmental programme has been introduced in Finland. Most of the farmers have joined the programme through basic and special subsidies that are paid to the farmer for actions that benefit the environment. The goals of the environmental programme are to decrease the pollutant load to the environment, to increase biodiversity and to protect the landscapes. Reductions in over-fertilization and improved livestock waste management practices are goals which will also benefit the reduction of greenhouse gas emissions from agriculture.

The number of dairy cattle has declined steadily since the 1980s and this trend is assumed to continue (Table 4–3). The slaughtering of surplus dairy cows will affect the need for other cattle, which will also be reduced in numbers. The volume of pig husbandry is expected to remain at the current level. The predicted changes in the numbers of other livestock will have a smaller impact on the emissions, which are expected to decrease a little more than 10%. The reduction in future methane emissions is attributed mainly to lower emissions from enteric fermentation because there will be less dairy cows. Emissions from manure management will remain almost constant since the volume of pig manure, the major source of these emissions in Finland, is not expected to undergo any major changes.

The emissions of N_2O from nitrogen deposition caused by ammonia emissions from agriculture are expected to decline somewhat as tighter regulations come into force.

6.2.4. WASTE MANAGEMENT

The waste sector will undergo large changes in the coming years as a result of already existing and planned legislation. Waste reduction, increased recycling and alternative treatment techniques as substitutions for landfilling are encouraged. The long-term target is that no organic waste should be taken to landfills.

The present impact of methane emissions because of landfill gas recovery is small, estimated to be less than 5 Gg CH_4 in 1995. In the forthcoming years, this activity is going to become more significant.

Anaerobic wastewater treatment is likely to be more common in the future, but it will be combined with methane recovery. In the projections no changes in the emissions are anticipated.

6.2.5. SUMMARY

Anthropogenic methane emissions in Finland are declining (Table 6–2). The waste management sector faces large structural changes. Government bodies are preparing regulations to decrease the amount of organic matter taken to landfills. Landfill gas recovery will also be mandatory in the future. The effect of the planned regulation is incorporated in the projected emission estimates. In agriculture the predicted decline in methane emissions is due to lower numbers of livestock, mainly dairy cows.

The decline in total methane emissions by 2010 is estimated to be about 20% and by 2020 nearly 30%. It takes a long time for a significant reduction in emissions to become apparent, after a decrease in the volume of landfilled waste. Potential methane emissions are even less than these figures imply.

Anthropogenic nitrous oxide emissions in Finland show a rising trend (Table 6–3). In the agricultural sector, the amount of nitrogen fertilization used is expected to decrease and the emissions to decline. However, the importance of the energy sector is expected to grow with greater energy production and use, and more fluidized bed combustors and cars with catalytic converters, all of which add to the emissions.

If the assumptions of the EPO scenarios are used instead of Table 4–3, the methane emissions from fuel combustion would become 5–10% smaller throughout the period 2000–2020. The nitrous oxide emissions from fuel combustion would decrease more; in 2020 they would be 11 Gg, while the level is 14 Gg with the assumptions of Table 4–3.

New promising techniques conducted under laboratory conditions, which have been published in literature, show abatement of nitrous oxide emissions from fluidized bed combustion and nitric acid production of up to 99%. Measures to reduce the emissions from cars with catalytic converters are still in the planning stage and no easy solutions to problem are in sight. If the abatement measures developed for fluidized bed combustion and nitric acid production work in practice, a reduction of about 20% in the projected anthropogenic nitrous oxide emissions in Finland seems feasible. These measures have not been included in the projections given in Table 6–3.

Table 6–2

Summary of projections of anthropogenic emissions of CH_4 (Gg).

	1990	1995	2000	2005	2010	2020
Fuel combustion	15	16	16	17	17	18
Fugitive emissions from fuels	<1	<1	<1	<1	<1	<1
Industrial processes	4	4	5	6	6	7
Enteric fermentation	90	78	71	68	68	68
Animal wastes	11	10	10	10	10	10
Waste	126	133	124	105	90	76
Other						
Total	246	241	226	206	191	179

Table 6–3

Summary of projections of anthropogenic emissions of N_2O (Gg).

	1990	1995	2000	2005	2010	2020
Fuel combustion	5	6	8–9	10–12	12–13	11–14
Stationary sources	3	4	6	7–9	8–10	7–10
Transportation	3	2	3	3	3–4	3–4
Industrial processes	3	3	3	3	3	3
Agriculture		9				
Nitrogen load	6	5	4	4	4	4
Peatlands	NE	4	NE	NE	NE	NE
Total*	18	18	19–20	21–23	23–24	22–25

* The emissions from peatlands are assumed to be 4 Gg N_2O/a for the whole period.

6.3. OTHER GASES

In 1989, a commission set up by the Ministry of the Environment prepared a Finnish programme for reducing nitrogen oxide emissions. The commission stated that a 15% reduction on the 1980 emission level could be achieved by 2000, if new combustion technology was adopted in new and existing plants, if flue gas scrubbing was installed in new plants, if new techniques were designed for heavy diesel engines, and if catalytic converters were required in new gasoline engines. These measures would make it possible to cut emissions down to 224 Gg by 2000 and to 200 Gg by 2010 (Table 6–4).

As a result of these measures, carbon monoxide emissions from traffic will take a downward turn during the 1990s. The estimate is that carbon monoxide emissions from road traffic will fall to 220 Gg by 2000 and to 190 Gg by 2010. CO emissions from energy production and industry may remain at their present level.

A reduction of about 35% in NMVOC emissions will be achieved as a consequence of decisions already taken or measures most probably to be implemented, including tighter limits for emissions from petrol-driven cars, further reductions at plants required to report their emissions, and the adoption of more environmentally sound products to replace the more harmful ones. The recovery of gasoline vapours from distribution systems has also begun. Compared with the 1988 level, emissions from stationary sources will decrease by about 25% and those from traffic by about 40% by 2000. Total emissions of NMVOCs at that time would thus be 140 000 tonnes.

The Second Agreement on the reduction of sulphur dioxide emissions was undersigned by 28 countries in Oslo in June 1994. Finland's target is to reduce SO_2 emissions to one-fifth of the 1980 level, that is, to 116 Gg by 2000. According to the scenarios for energy production, industry and traffic, this target looks realistic for the whole period 2000–2020.

Emissions in Finland of sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are relatively small (Table 6–5). Over 90% of SF_6 is used by the electric industry and a slight increase in its use can be anticipated. The used of HFCs will probably increase as a replacement for CFCs and HCFCs, although the high cost of HFCs is likely to restrict their use.

Table 6–4.

Summary of projections of anthropogenic emissions of precursors and SO_2 (Gg).

	1990	1995	2000	2005	2010	2020
NO_x	295	259	224	212	200	200
CO	487	434	395	352	309	309
NMVOCs	213	182	151	108	108	108
SO_2	260	96	116	116	116	116

Table 6–5.

Summary of projections of anthropogenic emissions of other greenhouse gases (Mg).

	1995	2000	2005	2010	2020
SF_6	4	5	6	6	6
HFCs	61	100	120	150	150
PFCs	0.04	0.05	0.05	0.10	0.10

Table 6–6.

Carbon uptake, removal, net biomass change and stock of the tree biomass in Finnish forests in 1970–2020 (Yearbook of Forest Statistics 1992; Statistical Yearbook of Forestry 1996; Karjalainen 1997).

	1970	1980	1990	1995	2000		2005		2010		2020	
					A	B	A	B	A	B	A	B
Carbon uptake (Tg C/a)	20.6	24.8	28.0	26.6	29.3	29.3	30.2	30.1	31.2	30.6	34.0	31.1
Carbon removal (Tg C/a)	20.0	17.6	19.6	22.7	24.8	24.8	24.8	26.0	24.8	27.3	24.8	29.9
Net biomass change (Tg C/a)	0.5	7.2	8.3	3.9	4.5	4.5	5.3	4.0	6.4	3.4	9.2	1.1
Net biomass change (Tg CO_2/a)	2.0	26.3	30.6	14.3	16.4	16.4	19.5	14.8	23.4	12.4	33.6	4.2
Carbon stock (Tg C)	529	584	660	695	720	720	745	741	774	759	853	782

6.4. SCENARIOS FOR THE FOREST CARBON BALANCE

Two different scenarios concerning the development of forest resources have been made for the years 2000–2020. In both scenarios the wood demand is assumed to increase by 2% per year until 2000; this is based on recent trends and reletively large new investments by the forest industry. Thereafter the demand is assumed to level off in the first scenario, while in the second scenario it increases by 1% per year.

In both scenarios, annual growth is assumed to remain at 3.9% of the growing stemwood stock. Although the growth has considerably increased in the last decades, this trend might level off. In spruce stands in southern Finland, some decline in growth in recent years has been observed.

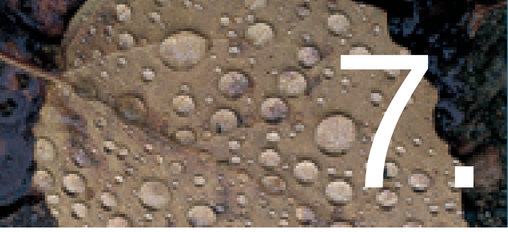
Table 6–6 summarizes the results. According to scenario A, the carbon stock of the Finnish forests would increase by 158 Pg or 23% by 2020. According to scenario B, the corresponding values would be 87 Pg or 13%.

The possible effects of climate change have been excluded here. According to the results of the national research programme on climate change, forest growth would be enhanced during the next few decades all over the country. In the long run (after 40–50 years), however, growth of spruce and pine may decrease at least in the southern part of the country, if the increase in temperatures exceeds 0.4°C per decade.

From the point of view of preventing climate change, the possibilities of utilizing forests for mitigation have been discussed in Finland. If logging would be reduced, obviously the carbon storage of forests would increase during the next 20–50 years, but on the other hand, carbon uptake would decrease in the long run. This method would, however, be disasterous to the Finnish economy. Extensions of existing nature reserves cannot be considered a realistic alternative, either. Besides, both these methods would be unsustainable in the long run; they would become ineffective within half a century.

Reforestation of, for example, 0.1 mill. ha of agricultural lands (5% of the total in Finland) would create a carbon storage of 7–8 Tg within 50 years. In the first 15 years, the sequestration of carbon would be small.

The carbon storage of mineral soils in forested lands is very large, and its growth could possibly be enhanced. The upper limit of this storage and harmful side effects have not been studied.



7. EXPECTED IMPACTS OF CLIMATE CHANGE AND VULNERABILITY ASSESSMENT

7.1. RESULTS OF SILMU

7.1.1. FUTURE CLIMATE OF FINLAND

Climatological observations have been made in Finland for about 150 years. Proxy data on climate can also be obtained for much longer periods. In SILMU (The Finnish Research Programme on Climate Change; cf. section 10.2), for example, the annual growth of pine trees in Lapland was used as a proxy indicator of summer temperatures during several thousand years.

In many areas of Europe a warming trend has been observed during this century. On the other hand, temperatures in the North Atlantic have declined. In Finland the changes have not been very clear. Annual averages based on eight representative weather stations indicate a statistically significant warming of about half a degree during this century, but variations from year to year are large.

It is generally difficult to detect statistically significant long-term trends in climate over northern Europe because of the high interannual variability of climate. This high variability may also affect people’s attitudes and perceptions of the climate change issue.

Three scenarios of temperature and precipitation change were developed for SILMU, based on GCM results over Finland: a central ”best guess” scenario and lower and upper estimates representing an uncertainty range (Fig. 7–1).

The central temperature scenario gives a mean

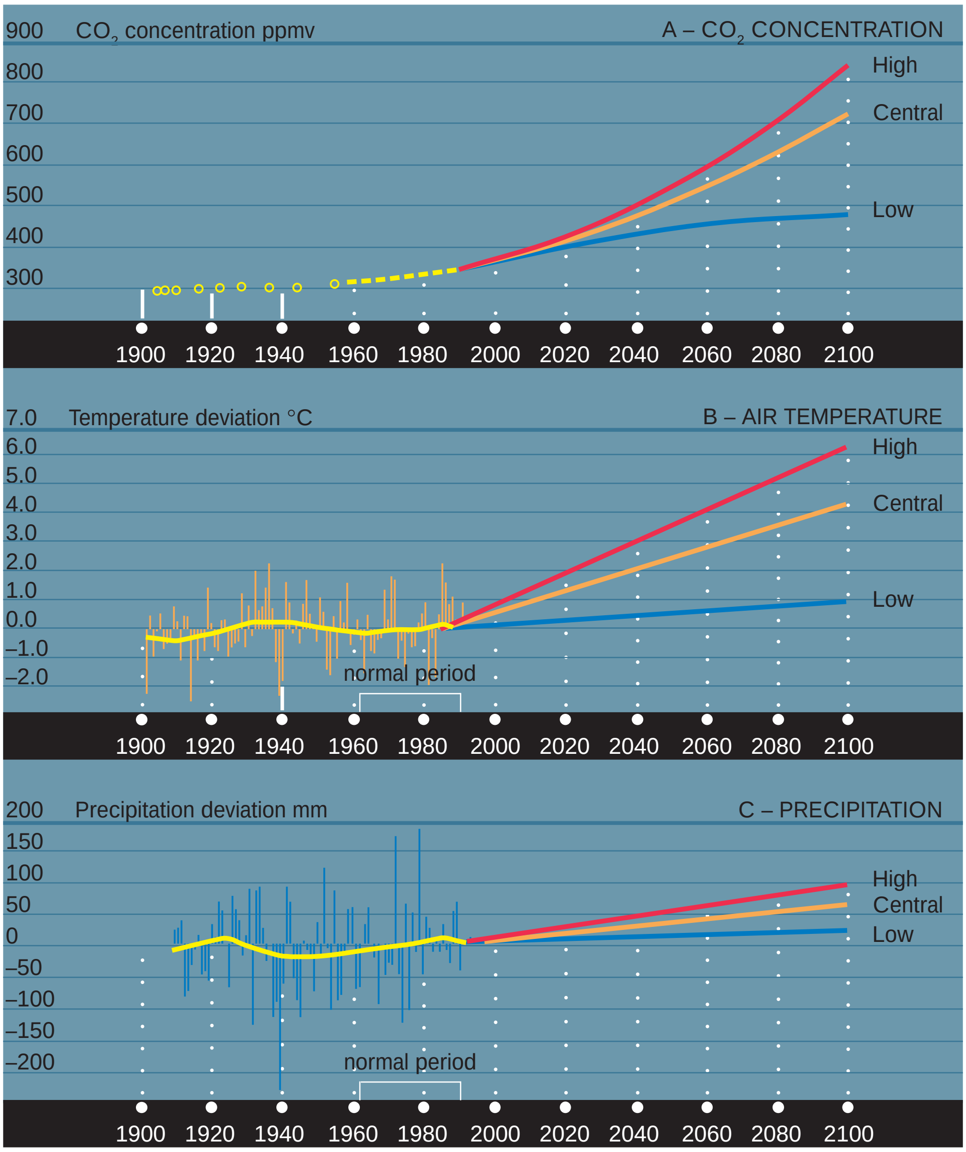


Figure 7–1.
The central, low and high SILMU scenarios of carbon dioxide (absolute), air temperature and precipitation (relative to the 1961–90 mean) for the period 1991–2100. These scenarios were used in all SILMU projects to estimate the effects of climate change in Finland. Also shown are the historical values from 1900 of CO_2 (global), air temperature (mean of eight stations in Finland) and precipitation (mean of 24 stations).

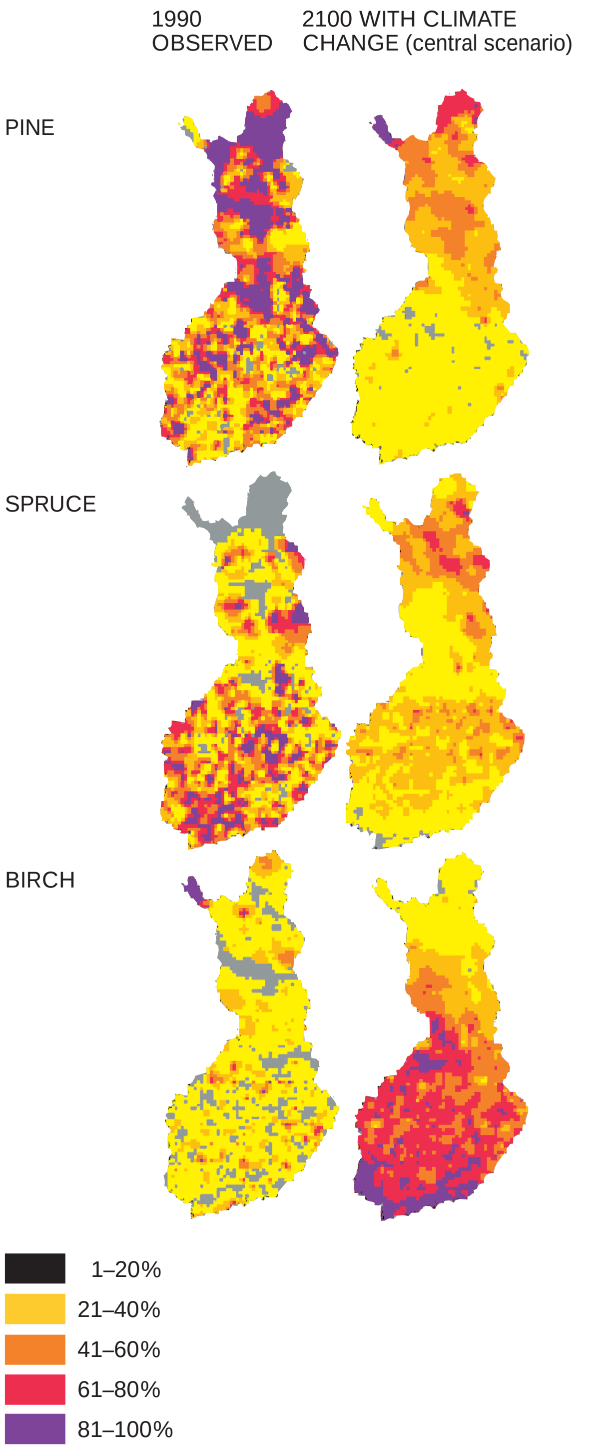


Figure 7–2. **The estimated volume of pine, spruce and birch as a proportion of growing stock in 1990 (observed) and by 2100 under the SILMU central scenario. The birch category comprises the two common species, Pendula birch and Pubescent birch.**

annual warming of 2.4°C by 2050 and 4.4°C by 2100. This is about one and a half times greater than the average global warming expected over the same period. Under the low scenario the corresponding values are 0.6°C and 1.1°C, and under the high scenario, 3.6°C and 6.6°C, respectively. Warming is expected to be greater in winter than in summer.

Predictions of precipitation are much more uncertain than those of temperature. The SILMU central scenario for annual precipitation is an increase of 1% per decade (2% per decade in winter and 0.5% per decade in summer). This represents an annual increase of about 30–40 mm by 2050 and 60–70 mm by 2100 in southern Finland. Under the low scenario the increase is 0.5% per decade and under the high scenario, 1.5% per decade. Because these scenarios are scaled relative to the temperature scenarios, they do not reflect all of the uncertainties in GCM estimates.

Scenarios of future atmospheric carbon dioxide concentrations were also provided, since CO_2 is known to affect plant growth and water use. The central scenario gives concentrations of 523 ppm by 2050 and 733 ppm by 2100. The corresponding values are 456 ppm and 485 ppm for the low scenario and 555 ppm and 848 ppm for the high scenario.

The potential effects of the SILMU scenarios on natural ecosystems and economic activities in Finland were evaluated using a range of approaches, including experimentation, mathematical modelling and expert judgement. The main focus of studies was on land ecosystems, including forests, peatlands and agriculture, and aquatic ecosystems, including inland waters and the Baltic Sea.

7.1.2. FORESTS

Annual growth of Finnish forests is expected to increase by over a third within a few decades. Part of this increase will be due to improved forestry, and part will be caused by higher atmospheric CO_2 content, higher temperatures and longer growing seasons.

The enhancement of growth will be most pronounced in northern Finland. If the species composition of trees is managed to make optimal use of the changed conditions, 60–80% of the forests in southern Finland may consist of birch (mainly Pendula) by the year 2100. Norway spruce will decline in the south, but benefit in the north. The warming may also decrease the amount of Scots pine in southern Finland (Fig. 7–2).

Several broad-leaved species will extend their range northwards; for example oak could grow at lat 65°N by the year 2100. However, natural expansion of the range of a tree species is usually very slow.

Milder winters may increase the risk of damage caused by insect pests overwintering as eggs in tree canopies. However, there might be some counteracting effects, especially through changes in the activity of natural enemies. Moreover, the risk of damages from fungi, fire and wind may be greater as a result of milder winters, less snow and shorter periods of frozen soil, and possibly drier summers.

7.1.3. AGRICULTURE

Under the central SILMU temperature scenario, the length of the growing season in 2050 would be extended by about 3–5 weeks relative to the present day. Cereal production could expand 250–500 km northwards. The yields of adapted spring cereals will increase, these new longer-season cultivars benefitting from both higher temperatures and elevated CO_2. Higher-yielding winter-sown cereals could be cultivated over much larger areas than today. There would also be potential for the successful cultivation of new crops like maize in southern Finland.

Grass yields are also expected to increase considerably as a result of a longer growing season and the beneficial effects of elevated CO_2. This assumes that water and nutrient limitations remain minor and that grass cultivars do not become more prone to winter damage because of lower tolerances to winter conditions resulting from higher autumn temperatures.

Thus, the productivity of Finnish agriculture can be assumed to increase under future climate change. However, there is also an increased potential for losses because of damage from crop pests and diseases. The range of many harmful organisms is expected to expand northwards at about the same rate as the northward shift in crop suitability. Additional generations of some species would develop successfully and new species may become established in Finland.

7.1.4. INLAND WATERS

The Finnish winter may not endure in the southern parts of the country; the present accumulation of seasonal snow cover is likely to be an exception in the mid-21st century. Snowmelt and rainfall may cause winter floods, warning signs of which have already been observed in recent years.

In small catchments of central Finland, the spring flood will attenuate and occur earlier (Fig. 7–3). In the large basins of the Lake District, the abundant winter flows will raise the levels of major downstream lakes to flood stages in spring; for example, increasing the outflow from Lake Saimaa by 15–20% in April–May by the year 2050.

In northern Finland the spring flood will also occur earlier and the peak will usually be lower than under the present climate. However, the risk of large spring floods is still obvious, because winter precipitation may increase and it mainly falls as snow.

Winter floods and the lack of snow cover will make the agricultural soils of southern Finland susceptible to increased leaching of nutrients. However, according to modelling results, this increase will be relatively small and can be controlled with proper protective measures.

Nitrate leaching from forest areas may increase significantly. Total nitrogen deposition in the boreal forest is large. With the high scenario of SILMU, the simulated nitrogen leaching would double before the year 2050, but the effects of enhanced forest growth can balance this increase.

The duration of ice cover in lakes will become shorter. In some of the larger lakes of southern Finland the ice cover may even disappear in midwinter during the latter half of next century. In summer, the surface water temperatures will increase about as much as air temperatures.

The spring peak of phytoplankton will occur earlier and become clearly greater than today. The littoral zone is likely to be more sensitive to the effects of climate change than the pelagic ecosystem. A doubling of atmospheric CO_2 content and an increase of 2–3 °C in water temperatures more than doubled the growth of some littoral macrophytes in an artificial greenhouse lake.

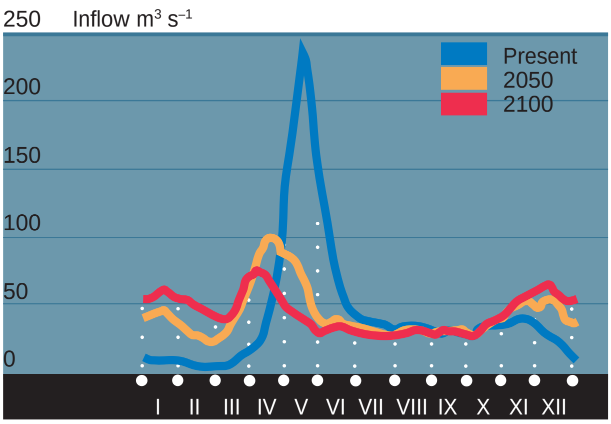


Figure 7–3. **The mean annual inflow hydrograph of Lake Porovesi in the northern part of the Lake District at present, in 2050 and in 2100 (central SILMU scenario).**

The habitats of many warmwater fish species are likely to expand, especially in northern Finland. Unfortunately, most of these species have little or no commercial or recreational value. Many coldwater species will suffer from warming, for example, salmon, brown trout, arctic char and whitefish. However, the larvae and juveniles of most Finnish fish species will grow faster.

7.1.5. THE BALTIC SEA

The ice season in the Finnish waters of the Baltic Sea normally lasts 5–7 months. According to the central SILMU scenario, ice cover would appear about 20 days later in 2050 and melt 10 days earlier than today. The maximum ice thickness is estimated to decrease by 20 cm. In 2100, only the Bothnian Bay will have an ice cover in a normal winter and ice thickness may be about 30 cm.

The input of nitrogen to the coastal waters is expected to increase in winter. Before the onset of spring, nutrients will be transported further from the coast, with a consequent risk of eutrophication over a large area. The reduction of nitrogen loading will obviously be one of the crucial measures required to prevent harmful effects of climate change in the Baltic.

7.1.6. ECONOMIC EFFECTS

Because of the long time periods and many uncertainties involved, estimation of the economic effects of climate change is very difficult. In SILMU, some estimates were made on a sector by sector basis. These estimates indicated that the Finnish economy might benefit by about one per cent of GNP by 2050. However, it should be noted that detailed evaluations could not be made for all sectors, and many effects cannot easily be valued in economic terms.

Moreover, international agreements and responsibilities as well as negative effects of climate change in other parts of the world may result in significant costs for Finland. Thus, even if we may see no emergency coming in Finland, as a small and open economy we are very dependent on nations more vulnerable to a changing climate.

7.2. VULNERABILITY ASSESSMENT

Considering the implications of climate change in Finland, no systematic vulnerability assessment has been made. Some preliminary research has been made and estimates presented, particularly in those sectors where harmful consequences are potentially high.

Silviculture is a very important climate sensitive part of the Finnish economy. Finnish forestry researchers say that the genetic ability of our most important tree species – pine, spruce and birch – is exceptionally good, because Finland is located between continental and maritime climates. However, the risk of new pests and insects in a warmer climate should be considered. Similar risks will occur in agriculture, although this sector may otherwise benefit considerably because of longer growing seasons and higher temperatures.

The vulnerability of the Finnish coastline to sea level rise is essentially cancelled out by land uplift, which more than compensates for the IPCC forecasts along most of our coastlines during the next century. More severe storms or other direct climate hazards are not considered serious in Finland.

Of all the risks involved with climate change in Finland, those caused by detrimental changes elsewhere in the world are considered the most serious ones. Soaring food prices, malnutrition and other health hazards could require immense international efforts with high costs to all well-to-do countries.

8. ADAPTATION MEASURES

Adaptation offers a means to reduce the possible effects of future climate change. Measures to adjust to climate change can be taken both on an individual level and by society as a whole.

In the SILMU program, some possible means of adaptation to climate change in Finland were studied. They were mainly related to forestry and agriculture (Table 8–1). For issues such as extreme weather events, water supply, sea level rise, biodiversity or human health very little discussion of the need for adaptation has thus far taken place.

The Finnish economy is deeply dependent on the forest sector. Because of the long time periods involved, the forest might be more sensitive to climate change than other sectors or agriculture. Over the next few decades warming could enhance forest growth. However, Finland should also be prepared for a greater risk of forest damage.

The adaptation of agriculture to climate change depends – in addition to the farmer – on technological progress and agricultural policies at the regional, national and international level. One challenge will be the development of new crop varieties, which are able to exploit the future conditions optimally. Maintaining soil properties suitable for crops might also require considerable efforts in the future.

As for water resources, changes in hydrological regimes and leaching should be anticipated. An increase of winter flows can also alter considerably the conditions for hydropower production.

Table 8–1.

Some means of adaptation to climate change in Finland.

Forest:
- Preparedness for increased damage
- Preparedness for changes in soil moisture and leaching
- Maintainance of biodiversity
- Changes in the proportions of tree species
- Introduction of new species
- Improved risk control in forestry

Agriculture:
- Plant breeding, changes in crop species and varieties
- Timing of cultivation practices
- Maintainance and improvement of soil properties
- Lengthening of the grazing season
- Modified and improved pest/disease control

Watercourses:
- Preparedness for changes in precipitation and runoff
- Preparedness for changes in leaching and eutrophication

Energy sector:
- Preparedness for changes in hydropower production

9. FINANCIAL ASSISTANCE AND TECHNOLOGY TRANSFER

9.1. DEVELOPING COUNTRIES

Development cooperation is one of the major tools Finland can provide to assist developing countries to enhance the objectives of the FCCC. In bilateral development cooperation, Finland has traditionally been involved especially with two sectors which relate to the Convention, that is, the energy and forest sectors (Table 9–1). In multilateral cooperation, Finland has resolutely pursued environmental aspects of development (Table 9–2).

Finland has actively participated in the UNCED process and supported the implementation of Agenda 21 through various channels.

With new and additional resources available for solving global environmental problems, Finland has contributed to the first phase of the GEF. Finland is also among the major donors to UNEP and firmly supports

Table 9–1.

Bilateral financial contributions to sectors related to the implementation of the climate change convention (USD thousand).

Recipient country	Category	1994	1995	1996
Energy:				
Zambia	1	2 545	45	
Tanzania	2	11 664		915
Ethiopia	2	368	339	95
Ghana	2	118	530	313
Kenya	1	313	247	80
China	1	308	1 343	1 263
Thailand	1	1 262	974	887
Total		16 578	3 478	3 553
Forest:				
Kenya	3,4,5	1 209	936	174
Namibia	3,4,5	236	487	1 046
Senegal	3	631	434	305
Tanzania	3,4,5	1 816	1 581	2 179
Indonesia	3	801	548	65
Laos	4	36	533	1 220
Vietnam	3,4	17	67	545
Central America	3,4	3 945	4 898	2 876
Total		8 691	9 484	8 410

Categories:
1. Energy efficiency and energy conservation projects
2. Developing the use of renewable energy resources
3. Forest conservation and reforestation activities
4. Forest management and forest industries planning
5. Research, institutional support and development activities

the role of UNEP in implementing Agenda 21.

The Government made, in September 1996, a Decision-in-Principle of Future Strategies for Finland's Development Cooperation. This decision has a strong emphasis on the protection of the environment, which is reflected in all levels of aid interventions, from the policy level to the grass-root project level. The Decision also emphasizes the role of development aid in supporting developing countries to fulfil their international environmental obligations. Thus Finland will, in the future, increase support to activities that promote the objectives of the international environmental conventions.

9.1.1. TRANSFER OF TECHNOLOGY

Finland has specific programmes and financial arrangements for transferring environmentally sound technology. Finland also supports cleaner power and heat generation options with grants, concessional credits and development credit financing.

Although energy-related pollution is still rather minor in many parts of the developing world, it is rapidly increasing. Thus, a great deal of attention must be paid to counteract this development. To this effect Finland has supported energy efficiency and conservation projects related to the problems of power transmission and distribution. Finland has also supported national

Table 9–2.

Financial contributions to the operating entity or entities of the financial mechanism, regional and other multilateral institutions and programs.

	Contributions (USD thousand)		
	1994	1995	1996
Global Environment Facility			218
Multilateral Institutions[1]:			
World Bank/IDA	2 360	33 810	13 314
World Bank/IDA XI		19 020	
AfDf	11 230		20 043
AsDB and AsD	1 920	5 020	447
IDB	1 790	1 854	
UNDP	5 170	12 600	13 943
UNSO		218	
UNEP	3 258	5 860	3 704
IUCN	580	985	218
EU's aid programmes		42 300	43 573
NDF (Nordic Development Fund)	2 890	6 590	6 298
Multilateral Scientific Programmes[2]:			
CGIAR	920	1 098	436
WIDER	259	366	349
Total	28 587	110 419	123 635
New and additional resources:			
GEF	7 921	9 458	9 005

[1] General support to institutions that may have activities which promote partly, although mostly indirectly, the Climate Change Convention

[2] General support to institutions that may have research programmes related to the Climate Change Convention

policies that promote energy conservation and efficiency.

Greater efficiency in the use of coal and other fossil fuels has been achieved by introducing and developing new technologies in electricity generation and combined heat and power generation. These include the circulating fluidized bed boiler, district heating and advanced diesel power plant technologies, which all help reduce carbon dioxide and sulphur dioxide emissions.

9.1.2. RENEWABLE ENERGY RESOURCES

Over the long term, it is important to gradually introduce renewable energy sources. Finland's work with renewable energy has mostly been directed at developing the use of hydropower and biomass. Finland has also supported the establishment of appropriate data records for wind and solar energy through the meteorological development programmes.

With regard to the use of biomass, an increase in fuel wood production is currently emphasized in a number of forestry projects. In future, emphasis will be on comprehensive schemes, such as agroforestry programmes. Innovative ways of using biomass have been developed through research.

9.1.3. GREENHOUSE GAS SINKS

In order to enhance the objectives of the FCCC, Finland has provided assistance to promote sustainable management of forests, that is, greenhouse gas sinks and reservoirs. These activities include afforestation and community forestry programmes, adoption of sustainable agricultural practices, comprehensive forestry planning and watershed management.

9.1.4. RESEARCH AND CAPACITY BUILDING

Since the early 1970s, Finland has actively participated in the building up of a global meteorological network to observe and monitor the physical and chemical elements of the atmosphere by providing systems for measuring the basic variables. Major programmes have been launched in cooperation with WMO. These programmes produce data on climate change, ozone depletion and transboundary dispersion of pollutants relevant to the implementation of UN global conventions. The programmes do not only accumulate information but also contribute to the preparedness for the prevention of natural disasters.

In November 1996, as a cooperative venture between Finland and Nicaragua, a programme called ”Finalization of National Programme for Implementation of International Convention on Climate Change and Montreal Protocol” was initiated.

Furthermore, Finland has provided funding for CGIAR institutions that could play an important role in assisting agriculture in developing countries to adapt to the effects of climate change. Finland has supported a number of training programmes in the forestry sector to promote sustainable forest management.

Cross-sectoral linkages between forestry and climate change require a lot of further study and research. Finland is one of the major donors to the UN WIDER Institute, which has, in cooperation with the European Forestry Institute, carried out research projects on the role of forests in the implementation of international conventions of climate change and biological diversity.

The valuable role of national and international nongovernmental organizations in the debate on strategy and policy orientation in reconciling environmental and development objectives has also been acknowledged.

9.2. NEIGHBOURING REGIONS

Finland has promoted and supported joint environmental programmes in neighbouring regions since 1991. The focal areas are the southern neighbours – Estonia, Latvia and Lithuania – and northwestern Russia, particularly the St. Petersburg region, the Republic of Karelia and the Murmansk area. One additional component of the cooperation has been debt-for-nature swaps comprising the conversion of payments on Poland's outstanding loans into environmental investments in Poland.

The primary aim of the cooperation is to prevent transboundary air and water pollution. Relative to the costs involved, cooperation with the neighbouring regions is a very efficient way of protecting the Finnish environment.

The local partner – that is, the recipient of the support for the project – has the main responsibility for the financing and implementation of the project. For example, the Finnish Ministry of the Environment's grant aid can cover at most 50% of the value of Finnish work in each project.

Over the first five years the Ministry of the Environment has issued nearly USD 50 million in grants for a total of 140 investment projects. Furthermore, 430 joint technical aid projects have been given assistance totalling USD 17 million to promote training and education, research, institutional strengthening and environmental monitoring.

Some of the joint projects aim at or have already resulted in significant reductions of sulphur emissions.

- In northwestern Russia, the emissions from Kostamuksha iron pellet combine, and the Svetogorsk and Segezha pulp and paper combines will be significantly reduced.
- In Estonia, Finland has supported the restructuring of the Narva power plants and oil-shale mining in Estonia, installed a pilot-scale sulphur reduction device in the Narva power plant and modernized several power plants so that they can use gas as a fuel instead of heavy oil. In Tallinn, the Iru power plant has been converted to burn natural gas; this change will result in a 100 000 tonnes annual reduction in CO_2 emissions.
- In Poland, Finland has assisted modernization, reduction of sulphur emissions, and improvement of energy efficiency in altogether 15 power or industrial plants, of which Jaworzno's power plant has great regional significance. Distrect heating systems have also been upgraded and modernized at some locations with Finland's support, resulting in noticeable decreases in air emissions.

10. RESEARCH AND SYSTEMATIC OBSERVATIONS

10.1. CLIMATE OBSERVATIONS

In Finland, meteorological observations have been made at several stations for more than a hundred years now. At the moment, observations are made at three meteorological observatory stations, 46 synoptic stations, 87 climatological stations and 57 automatic stations. Long-term climatological time series form a necessary basis not only for the actual climatological research but also for estimates on the effects of climate change. Finnish climate observations have been included in the international North Atlantic Climatological Data Set (NACD) database, which is a collection of reliable long-term climatic observations for climate change research.

Finland also participates in the Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO). The GAW observes greenhouse gas concentrations and long-range transport of pollutants in the atmosphere. In 1994, the WMO accepted the Pallas-Sodankylä station in Finnish Lapland as a part of the global GAW network. The station measures air composition and measurable meteorological quantities, focusing on greenhouse gases such as CO_2, CH_4, N_2O and O_3. Furthermore, pollutants conventionally associated with regional air pollution are measured continuously in Finland at 20 background stations in different locations.

The Finnish Meteorological Institute is also involved in various development cooperation projects in meteorology, the most important ones being regional projects with the African SADCC countries and with the Central American isthmus. During the last ten years, Finland's total contribution to cooperation projects concerning meteorological technology has totalled about USD 30 million. Projects have been carried out in some 40 countries all over the world.

10.2. FINNISH RESEARCH PROGRAMME ON CLIMATE CHANGE

The first research projects on climate change were started in Finland at the beginning of the 1980s as individual projects carried out by universities and research institutions. By the end of the decade, research on climate change had gained an important standing in the activities of international communities, and Finland also acknowledged the need to put effort into the study of climate change and the development of alternative models for adaptation and prevention.

An interdisciplinary research programme called the Finnish Research Programme on Climate Change (SILMU) was initiated in 1990 to coordinate the majority of all climate change research in Finland. The principal goals of SILMU were to increase our knowledge about climate change, its causes, mechanisms and results; to promote research on climate change; to further opportunities for Finnish scientists to participate in international research projects; and to prepare and disseminate information to form a basis for decisions on adaptation to and prevention of climate changes.

The key research areas in the programme were the climate changes anticipated in Finland, estimation of the effects of changing climate on ecosystems, and the development of adaptation and prevention strategies.

The programme was scheduled to take six years (1990–95), and the annual budget was FIM 12–15 million. Altogether, the programme comprised over 80 research projects and involved some 200 researchers. The research had been grouped into four sub-groups: atmosphere, water bodies, terrestrial ecosystems and human actions.

The central aim of atmospheric research was to determine the magnitude of past and future climate changes, with a special focus on northern Europe. In addition, research was conducted on air chemistry and physics.

Research concerning water ecosystems focused on the effects of climate change on the hydrology and ecology of Finnish lake, river and marine ecosystems, and also covered interaction between the atmosphere, hydrosphere and biosphere.

Terrestrial ecosystems research involved studies on the effects of climate change on agriculture and forestry, and on the biochemical cycling of carbon in peatlands.

Studies on the social and economic impacts of climate change were also carried out, and assessments on how to limit greenhouse gas emissions and how to reduce or adapt to the effects of climate change were made.

Some research projects under SILMU were included in international research programmes on climate change, such as the World Climate Change Programme (WCRP) and the International Geosphere-Biosphere Programme (IGBP).

The SILMU Programme was evaluated by an international committee in autumn 1996 (Hordijk & al. 1996). In general, the committee found the research performed in SILMU of high quality and relevance. Critical remarks were mainly presented concerning the insufficient integration of subprogrammes.

As for the continuation of climate change studies in Finland, the committee identified five important areas of SILMU research:

1. Continuation of work establishing past and existing climate variability, and climate analysis/modelling studies which make contributions to understanding the underlying processes of climate variability and change.
2. Further work on aerosols, aimed at understanding the role which they play in the climate system.
3. Integrated assessment studies. The committee sees the need for a continuing effort in assessing the results of ongoing climate change research in Finland. This is important because from 1996 on there will be no integrated program like SILMU and research will continue unconnected. One might hope that collaboration will continue to exist in areas covered by the SILMU subprograms.
4. In view of Finland's northerly position, continuing work on ozone/UV exposure, ensuring that the most northerly latitudes are not neglected.
5. Sociology and socio-economic studies on climate change.

The committee also recommended some new research areas:

1. Impact of climate change on high latitude areas. Almost all research on climate change in Finland is focusing on the areas in southern and central parts of the country. Until now potential effects on the lives of the people in the sparsely populated northern Finland have not been studied.
2. Agriculture economics.
3. Mitigation options and costs.

To further advance the understanding of climate change effects on forests and peatlands requires work in the following areas:

1. A physical, chemical and biologically determined process model for peat soils.
2. Development of a theory for allocation processes within trees and how they may change under different environmental conditions, that is, acclimatization of growth processes as well as photosynthetic rate.

The committee also gave recommendations concerning organization and administration of future multidisciplinary climate change programs. At the moment, such a program is not under consideration.

11. EDUCATION, TRAINING AND PUBLIC AWARENESS

Climate change issues have been extensively dealt with in the Finnish media in the last few years. A considerable part of this discussion was initiated by SILMU, the Finnish Research Programme on Climate Change. By approaching directly the media professionals, SILMU administrators and scientists have provided information for television and radio programs and for a number of newspaper articles.

A book about SILMU's activities and results was published in Finnish after the project (Kuusisto & al. 1996). This comprehensive review of SILMU's results was aimed at the general public with particular interest in climate change issues. This book also received an award in the annual Science Book Competition.

A climate change exhibition was arranged at the Finnish Science Centre Heureka near Helsinki in 1996. This impressive demonstration was circulated to other venues in Finland in 1997.

One of the aims of SILMU was to produce information for decision-makers and for the general public. An integrative project for this purpose was PAATE, an inquiry into the present state and future possibilities of interaction between researchers and decision-makers. This project started with a survey among more than one hundred people; researchers, officials of various ministries, politicians, representatives of the economy and nongovernmental organizations.

The viewpoints of the respondents regarding climate change in the next 20 years varied considerably. A small majority believed that significant changes would occur during that period. When asked to estimate climate changes during a longer period of time (100 years), almost all respondents were convinced that anthropogenic changes would occur to some extent.

When the respondents were asked to consider possible effects of climate change, they emphasized that these effects will be both negative and positive in Finland. The negative effects mentioned included, for example, the adaptibility of forests to rapidly changing conditions and the disappearance of "real winters". Possible positive effects included increased forest growth and savings in heating energy. On the other hand, it was recognized that the situation in Finland is affected critically by the global effects of climate change. The greatest cause of concern was the general increase of risks, as reflected, for example, in changed conditions affecting the cultivation of land or in people's migrations induced by environmental changes.

In the discussions between researchers and policy makers several alternatives emerged for slowing down the increasing emissions in Finland. These included, first and foremost, investing in research and technology, joint implementation, technology transfer, and measures that also serve other social purposes. More disputable measures include energy and carbon taxes, the selection of appropriate forms of energy production, the preservation of carbon sinks and reservoirs, and solutions involving community planning and transport policy.

Ordinary citizens have also been interviewed in Finland on climate change issues. In general, they emphasized local environmental risks such as air and water pollution. The most serious consequences of climate change were thought likely to occur elsewhere than in Finland. Most interviewees believed that global warming could lead to, for example, desertification and rising sea levels. Additionally, the number of environmental refugees was assumed to increase.

Who is guilty of causing climate change? This was not explicitly specified by the interviewees, but was connected to main stream industrialization and to the modern way of living, which consumes a lot of energy.

From the standpoint of the public in Finland, climate change is an integrated part of overall ecological issues in the modern world. People anticipate that the pursuit of material well-being will lead to an accelerating decline in the quality of life in the future, unless strong protective measures are applied now.

There was a broad consensus for the need to work together to reduce environmental hazards. International climate agreements were supported. The public also claimed to be more actively engaged in everyday actions to protect the environment than the opinion formers assumed.

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