ESTONIAN SECOND NATIONAL REPORT

under the United Nation`s

Framework Convention on Climate Change

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1.1 National circumstances

1.1.1 Basic

Estonia is situated in north-western part of the flat East-European plain, remaining entirely within the drainage area of the Baltic Sea. The total area of Estonia is 45,216 km^2, of which 4,132 km^2 (9.2%) is made up of more than 1,500 islands and islets. Of the total population of 1,575,000 inhabitants (1990 Population Census), 71.4% live in urban areas. The population density is 35 persons/km^2.

Geologically the country is located on the southern slope of the Baltic Shield which is undergoing isostatic land uplift extending 2.8 mm/year on the north-western coast and 1.0 mm/year in the south-west. Only comparatively small south-eastern part of its territory is slightly subsiding. Isostatic land uplift is a reason why the number of small isalnds is increasing as well potential reducer of sea-level rise impact on the Estonian coasts but it does not compensate latter.

1.1.2 Economy

The most important branch of industry in Estonia is energy production. The total power yield of the Estonian and Baltic Thermal Power Plants in NE Estonia is about 3,000 MW. About half of the energy produced in 1990 was exported to Russia and Latvia. Approximately 75% of pollutants (CO_2, SO_2, NO_X, fly-ash) was emitted by the Baltic and Estonian TPP, which rank among the ten biggest sources of air pollution in Europe. Since 1990 the total primary energy supply decreased continuously and in 1996 it was about half of that in 1990. Oil shale constituted 50–60% of the energy balance.

Estonia is quite rich in renewable natural resources. During the last half-century the area of forest stands has more than doubled compiling in 1990 about 19,200 km^2 of the Estonian territory. Despite the small area of the territory of Estonia, the forests growing here are rather diverse. The great variability brought about by natural conditions (parent material of soil, relief, climatical differences) is in its turn increased by the circumstance that the majority of the forests of Estonia have been affected by human activities in various degrees and ways (cutting, drainage, fires, etc.).

The area of arable land in Estonia is 1.3 million ha, the total sown area is 1.11 million ha. Estonian agriculture has specialized in livestock breeding of which cattle-breeding is most important. Grasslands make up 55% of the total arable land of Estonia and grain fields 38%. The share main cereal – barley – provides over 60% of the total sowing area of cereals. Some of the vegetation types most characteristic to Estonia are grasslands, meadows and natural or seminatural pastures.

The peatlands area is approximately 10,000 km^2, corresponding to 22% of the territory (partly coinciding with forest areas) and their contribution to the balance of GHG is significant as the changes in the hydrological regime contribute to the increase in the emissions of CO_2 and CH_4. During the last decades Estonian peatlands have been heavily influenced by the amelioration for agricultural, forestry and peat industry concerning purposes.

Unique landscapes and numerous species included into Red Data Book demonstrate that Estonian ecosystems have importance in European and worldwide aspect and therefore it is nessessary to pay special attention to the vulnerability of ecosystems and landscapes in the course of global warming.

Estonia is overcoming the economic restructuring with a notably changed economic structure. The shares of trade, transportation and service sector have increased rapidly. The share of manufacturing was 35.1% and that of agriculture (together with hunting and forestry) 21.5% in GDP in 1989. In 1994 the shares of these branches were respectively 16.7% and 8.3% and in 1995 14.9% and 6.7% . At the same time the share of trade in GDP increased from 7.0% in 1989 to 15.8% in 1994 and to 16.4% in 1995, the share of transportation from 6.9% to 8.2% and 8.9%, the share of financial institutions and insurance from 0.9% to 2.8% and 3.1%, respectively. The structure of the Estonian GDP has become rather close to the structure of GDP of developed countries, but these structural shifts happened during restructuring of economy, which was more complicated for industrial enterprises. Some restoration of the role of these industries should be expected during the next years.

1.1.3 GHG Budget 1990–1996

During 1994–1996 the GHG inventory was compiled for the baseline year 1990 using the IPCC Guidelines for National GHG Inventories. Later same methodology was applied to compile GHG inventories for 1991–1996. The results reflect a great decrease in the GHG emissions during these years in Estonia. GHG Inventory for Estonia was compiled for energy, industry, transport, agriculture, forestry, land-use sectors: that is for all activities related with emission of greenhouse gases in Estonia.

The recovery of political and economic independence in 1991 brought about drastic changes in the structure of fuel consumption. Transition from a centrally planned economy to a market economy resulted in a sharp increase in fuel prices, and raw materials as well as in an abrupt decline of the Eastern market.

In 1990 the total CO_2 emissions from the consumption of fossil fuels were 37,184 Gg, but in 1996 only 21,216 Gg. This means that during these years the total emission of CO_2 from *energy production and use* decreased 43%. In the decrease of CO_2 emission the reduction of fossil fuel consumption, especially that of imported fuels, was the major factor. So the CO_2 emissions according to fuel types decreased as follows: natural gas 47%, coal 74%, gasoline 56%, kerosene 59%, heavy fuel oil 78% and diesel oil 45%. The decrease of CO_2 from domestic fuels was not so high. For example, the decrease of CO_2 from oil shale consumption was 34%, from peat 3%. The total emissions from solid biomass increased 203%. Overall, the decrease of CO_2 emission was especially high in the years 1991–1992. The major part of primary energy in Estonia is converted to electricity and heat or refined to peat briquettes and shale oil.

In Estonian *industry* greenhouse gases are produced mainly by cement and lime production. By thermal processing of calcium carbonate ($CaCO_3$) from limestone, chalk or other calcium-rich materials calcium oxide (CaO) and carbon dioxide (CO_2) are formed. Total CO_2 emissions from cement and lime production in Estonia were 613 Gg in 1990 and 206 Gg in 1996.

Restructuring of *agricultural* production, development of the private sector, partial loss of the traditional eastern market and search for new ones, and a rise in prices for fuel and fertilizers have influenced immensely the total agricultural sector. In 1995 the total sown area has shrunk to 925.4 thousand hectares, the area sown to cereals and legumes was 302 thousand hectares, and potatoes were cultivated on 37.6 thousand hectares.

The use of fertilizers and pesticides has also decreased. In the 1980s 110–130 kg of nitrogen from mineral fertilizers, and 60–70 kg from organic fertilizers was used per hectare of arable land. In comparison with 1987, the use of mineral fertilizers and manure in agriculture decreased 7 and 4 times, respectively for 1995.

Forests, which cover about 47% of Estonian land area, are an important terrestrial sink for carbon dioxide (CO_2). Because approximately half the dry mass of wood is carbon, as trees add mass to their stems, branches and roots, more carbon is accumulated and stored in the trees than is released to the atmosphere through respiration and decay. Soils and vegetative cover in forest also provide a potential sink for carbon emissions.

As a result of the drainage of virgin *peatlands*, the accumulation of organic matter has ceased, and due to intensive decay processes the mineralization of organic matter has increased. For several decades the breakdown of peat resources and peat losses on the minerotrophic fens that have been ameliorated for agricultural purposes has been monitored in Estonia. It is shown that the mineralization of organic matter is about 15 to 20 tons per hectare per year during the first decade after the establishment of an amelioration system. The calculations indicate that human activities have most drastically affected the carbon budget in fens, swamps and floodplains where the CO_2 accumulation has decreased from 638 to 169, from 378 to 37 and from 117 to 22 Gg y^{-1}, respectively In total the CO_2 emission has increased about 1.8 times during the period of 20 years (from 1970 to 1990).

The values for methane emissions are an order of magnitude lower and their changes are not so substantial. The methane emission from peatlands has decreased about 2.2 times (from 18 to 8.1 Gg y^{-1}). The CO_2 emissions from 1990 to 1996 are assumed to be constant, decrease of CH_4 emissions are not included in GHG inventory.

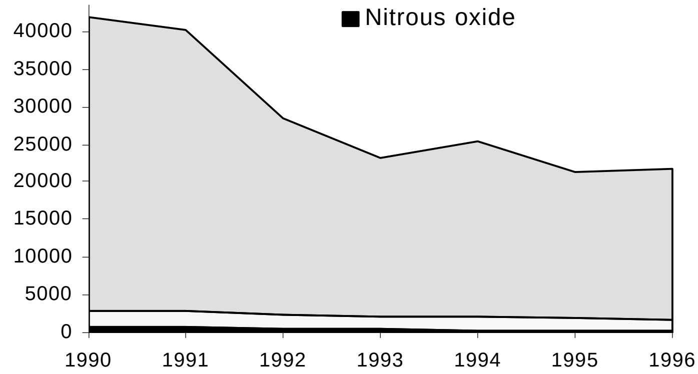

Figure 1.1.1. Emission of GHGs in Estonia according to global warming potentials (GWP) of different gases

The Figure 1.1.1. demonstrates that the total amount of emitted GHG in Estonia decreased from 1990 to 1996 by about 49%. It must be mentioned that besides direct dropping GHG the emission of other pollutants like SO_2, fly ash, aromatic chemical etc. has also decreased.

Table 1.1.1. Changes in GHG emissions in Estonia, Gg

Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996
Carbon dioxide	**36251**	**35189**	**25136**	**19597**	**21527**	**17363**	**18549**
Energy and Transformation	34528	33957	26030	20179	20882	18938	19682
Transport	2656	2386	1423	1607	1786	1700	1534
Industrial Processes	613	614	313	193	215	222	206
Land-Use Change and Forestry*	-1545	-1767	-2630	-2382	-1355	-3496	-2874
Methane	**105.2**	**102.1**	**91.3**	**79.7**	**79.5**	**67.7**	**63.2**
Fuel Combustion	2.6	2.5	1.9	1.6	1.8	1.7	1.8
Agriculture	60.2	60	54.7	47	46.4	34.3	30.2
Waste Management	42.4	38.6	34.7	31.1	31.3	31.7	31.2
Nitrous oxide	**2.3**	**2.3**	**1.7**	**1.4**	**1.3**	**1.2**	**1.2**
Fuel Combustion	1.4	1.4	1	0.9	0.8	0.8	0.8
Agriculture	0.9	0.9	0.7	0.5	0.5	0.4	0.4

* includes emissions from wetland drainage

1.1.4 Actions and programs to reduce emissions

The National Environment Strategy, approved by Estonian Parliament on 12 March 1997, envisages as one of the priorities reduction of negative effects of the energy sector and improvement of air quality. The following goals are fixed:

"To reduce the environmental impact of the energy sector, to direct energy policies towards energy efficiency technology development programmes, more extensive use of renewable energy resources and reduction of greenhouse gas emissions, to include all environment-related costs of energy consumption in the energy price.

To reduce emissions of air pollutants, focusing primarily on substances causing climate change and ozone depletion, and on pollution originating from transport".

The legislation concerning the air protection in Estonia consists of several acts and regulations both of the Government and the Minister of the Environment. Most part of these legislative acts include also towards a gradual reduction of greenhouse gases emissions. Some standards for ambient air quality established during the Soviet period and were set mainly to protect human health are still in force. The long-term goal in Estonia will be the full implementation of the European Union (EU) environmental legislation in Estonia. Co-operation in the field of environment and nature conservation, with the purpose to solve serious regional as well as pan-European environmental problems is one of priorities. As a result, the overall objective of an ecologically sustainable development will be promoted.

In 1994–1997, the number of acts and regulations, regulating the air protection, were passed, approved or drafted in Estonia. Estonia has signed several international conventions in the field of reducing air pollution.

1.1.5 Projections of CO_2 emissions

Energy consumption projections were derived from two different economic growth scenarios. Both scenarios assume that global political and economic development has a strong influence on economic development in Estonia. The moderate growth scenario called West-West (WW) assumes Estonia's close integration with western political and economic structures, especially with EU, but relations with Russia and other CIS countries are relatively weak. The high growth scenario called West-East (WE) assumes that Estonia's market is oriented towards both the west and the east and Estonia could become a transit country. Estonian energy system was modelled with MARKAL model basing on 1995 data.

In the WW scenario, an average annual GDP growth 2.5% during 1995–2035 was foreseen. In the WE scenario corresponding figure was 5.3%. In developing useful energy demand projections, an average annual energy intensity improvements 1.4% and 2.9%, respectively, were assumed. In other words, useful energy demand per capita is expected to grow from 76 MJ/capita in 1995 to 121 MJ/capita and 168 MJ/capita in the year 2030 in the WW and WE scenario, respectively. It was assumed that population of Estonia will not grow during the whole planning horizon, but will even decrease in the first decade.

CO_2 emission projections for both WW and WE corresponding to the Base-Case assumptions. In all cases the useful energy demand projections did not change. Energy intensity improvements and basic conservation measures were already considered in these forecasts. CO_2 reduction will be achieved by changing the fuel and technology mix. It became also clear that introduction of wind generators in a large scale and small biomass cogeneration plants needs economic measures.

Considering that Estonia’s actual economic growth during 1996–97 have exceeded even the optimistic WE scenario assumptions and significant changes in the energy conversion sector have not taken place yet, the CO_2 emissions will hardly be lower than the WE Base-Case projection in the near future.

1.1.6 Effects of climate change in Estonia

The provided study concentrated on the influence of global climate change on four main socio-economic sectors: agriculture, forestry, water resources, and coastal resources.

The impact of a 1.0 m sea level rise on the economy of Estonia is also taken into account. The future forecasts do not include the shifts in economy caused by socio-political changes (membership of the EU) and the possible shifts in migration due to the climate change. All the studies are based on the present socio-economic structure influenced by the future climate change.

Global climate change will have the most significant effect on agriculture, forestry, and coastal resources. The changes in agriculture will accordingly influence the whole structure of Estonian economy. In the assessment of Estonian agriculture the emphasis was laid on the cultivation of crops. The results showed that due to the climate change the barley yield decreased 17–18% and the potato yield became unstable. The weather conditions were more favourable only for herbage cultivation.

The total effect of the climate change is probably not damaging to agriculture. Moderate rise of temperature and stability of moisture will favour agricultural production, although some restructing activities will be needed: breeding new cultivars as well as changes in planting dates, fertilization, irrigation, and land usage. An increse in the biomass of grasslands and more mild winters will result in the development of dairy-farming, which in its turn would support the production of one of the traditional export articles – foodstuffs.

The effects of the climate change on Estonian forest resources can’t be defined so accurately. A summary of the different sample plots shows that the total biomass of forests may decrease 21–35%. The migration of species was not taken into account in the models used in this study. A logical consequence of the climate warming would be the replacement of the present species in forest ecosystems by those of more southern distribution. In this case the results of productivity and economic assessment could be completely different.

The total economic loss because of the sea level rise would be considerable, especially in the storm surge zone. A 1.0 m sea level rise would risk several natural values, but would not cause particular mobility of the population because of relatively sparce settlements and low density of population in the coastal zone. As a result of the sea level rise scenario, about 3% of the territory of Estonia would be inundated or temporarily damaged. As the economic losses are distributed between different owners and take place during a comparatively long period, the activities to protect the seashore are unrealistic in general. The exceptions could be the seaside cities and some beaches of high recreational value.

The climate warming would not cause any problems with water supply. The results of water supply and demand analysis indicate that possible climate change has no particular effect on water management in Estonia. The positive effect may be in lower energy consumption because of milder winters, but also in better navigation conditions because of longer ice free periods in our harbors.

Climate warming will probably cause some changes in the life style and cultural habits (no snow any more), but the shifts because of temperature rise will be less important than those because of cultural contacts.

Finally, we can conclude that the climate change will not have catastrophic effect on Estonian economy. Vice versa, the summary of changes will be even favourable from the economic point of view. It will increase the producers (food manufacturing) surplus and decrease the consumers (heating) surplus in Estonia.

2 National Circumstances

2.1 Introduction

On November 16, 1988, the Declaration of the Sovereignty of the Estonian SSR was passed, which marked the beginning of the “new awakening”, a peaceful struggle to regain independence. In May 1989, the country declared economic independence. On August 20, 1991, the Supreme Council of the Republic of Estonia approved a resolution in which it affirmed national independence. The Republic of Estonia is a member of the United Nations since September 17, 1991.

After the re-establishment of independence Estonia has experienced a difficult political and economic adjustment period, resulting in a drop in domestic agricultural and industrial trade relations – especially with the republics of the former USSR – and restructuring of the national economy. However, several political, institutional, legal, and economic changes have recently been successfully implemented and thus conditions for future development have improved.

Further structural reforms and major investments are required to ensure environmentally sound economic development. The energy sector is in this respect a priority area. The legislation in force in Estonia consists of a great variety of legislative acts with different origins and backgrounds. The framework for environmental legislation is provided by the:

- Law on the Protection of Nature in Estonia,
- Law on Protecting Nature Objects,
- Pollution Charge Law,
- Act of Suistanable Development etc.
- Since 1990, 12 acts, 24 regulations of the Government of the Republic and 61 regulations of the Ministry of the Environment have been worked out and adopted. During the same period numerous conventions having importance from the point of view of Global Climate Change have been ratified by the Parliament.

Some important documents like energy law, long-term plans of energy use and agricultural development as well as macroeconomic forecasts are still in the preparation. Therefore the projection of greenhouse gas emissions and working out the mitigation options are rather difficult.

2.2 Basic facts about Estonia

Estonia is the northernmost Baltic country (between 57.30^o and 59.49^{o}N and 21.46^o and 28.13^{o}E). Its total area is 45,216 km^2. Over 1,500 islands and islets account for 9.2% of the territory. Estonia is a seaside country, and entirely within the drainage area of the Baltic Sea (Figure 2.2.1.). Its total coastline length, including the mainland and islands and islets, is 3,794 km. The coastline is characterized by numerous bays, peninsulas, and straits between islands. The coastal sea is shallow and full of shoals.

Figure 2.2.1. Location of Estonia

Situated in the northwestern part of the East-European Plain, Estonia is characterized by a flat topography. The average elevation is about 50 m, and the highest point is 318 m above sea level. The country can be divided into two regions: Lower Estonia and Upper Estonia. Upper Estonia comprises the more elevated areas in the central and southern parts, which were not flooded by the sea and ice lakes during early stages of the Holocene Epoch. The soils in Upper Estonia are more fertile and the rural population is denser than in Lower Estonia.

Geologically, the country is located on the southern slope of the Baltic Shield, which is undergoing an isostatic land uplift; Estonia is being lifted 2.8 mm/year on the northwestern coast and 1.0 mm/year in the southwest. Only a comparatively small southeastern part of its territory is subsiding slightly. Isostatic land uplift could potentially reduce, but not alleviate, the impact of sea-level rise on the Estonian coast.

Estonia belongs to the Atlantic continental region of the temperate zone. Its territory lies in a transitional belt with the maritime type of climate in the West-Estonian Archipelago and the continental one in eastern Estonia. Therefore, a remarkable spatial variability can be observed within the limits of the country. Summers are moderately warm (mean air temperature in July is 16–17^{o}C) and winters are moderately cold (mean air temperature in February lies between -3.5^{o}C and -7.5^{o}C). In autumn and winter, coastal regions are much warmer than inland.

The climate of Estonia is humid because precipitation exceeds evapotranspiration. Nevertheless, there are often droughts during the summer period. Mean annual precipitation ranges from 550 to 750 mm. Stronger rainfalls occur during the period from July to November. It must be emphasized that the precipitation in Estonia has a high temporal variability; variation coefficients of monthly values being over 0.50.

Mean annual total of solar radiation in Estonia is 1.300–1.400 W/m^2. Due to a very intense cyclonic activity in Northern Europe, the mean wind speed is comparatively high 5–7 m/s in the coastal zone.

Today 47.6% of the country, approximately 2.02 million ha, is covered with forest. The total area of stands is 1.82 million ha, and there are 53,500 ha of young cultivated forests and forest nurseries. Forests with conifers as the dominant tree species make up 63% of the total forest and 66% of total forest yield; forests with deciduous trees as dominant species constitute 37% of the forest and 34% of the forest yield. Forestry and the forest industry have been and still are important contributions to the economy and employment of Estonia, constituting together with agriculture 11% of the labor force and 10% of the GDP.

The peatland area of Estonia is approximately 10,000 km^2, or 22% of the territory (partly coinciding with forest areas).

Estonia is one of the smallest and least populated countries of Europe – its total population is 1,574,955 inhabitants (1990 Population Census). The population density is 35 inhabitants/km^2. About 71% live in urban areas, and 51% live in five largest cities:

Tallinn (484,400); Tartu (115,400); Narva (82,300); Kohtla-Järve (76,800); and Pärnu (54,200).

Although small in area, Estonia is relatively rich in natural resources, both mineral and biological, which have been the basis of the economy, and particularly of industry. The most important natural resource is oil shale. Other natural resources worth mentioning include phosphorite, dolomite, sand, gravel, peat, curative mud, and mineral water. The main industrial sector in Estonia is energy. Both the energy and chemical industries are based on oil shale.

Estonian agriculture specializes in livestock breeding, which provides 65–70% of agricultural production. When Estonia was part of the Soviet Union, agricultural production was based on state and collective farms. Animal husbandry was strongly dependent on imported fodder, and preference was given to pig husbandry and pork production. Most of the meat and dairy products were exported to the other republics of the Soviet Union.

Since the transition process began, the former state and collective farms have been replaced by private farms, which today number over 14,000. The end of state and collective farms, the development of private farms, the loss of previous market, and high prices for fuel and fertilizers are the primary agents affecting the agricultural sector today. A decrease in farmed land (from 1.11 million ha in 1990 to 925 thousand ha in 1995) as well as in the number of cattle (1.9 times) is evidence of the changes in the sector. The projection for 1996 is for further decrease in sown area, but yield quality and the main animal husbandry products should increase compared to the 1990–1991 level.

The production and processing of mineral resources give a considerable share of the gross national product (Table 2.2.1.).

Table 2.2.1. Active deposits of Estonian mineral resources

Resource	Amount	Unit
Oil shale	3,800	million tons
Phosphorite	260	million tons
Limestone, dolomite	300	million m^3
Sand, gravel	180	million m^3
Peat	560	million tons
Lake mud	120	million tons
Curative mud	4	million tons

2.3 Energy and industry

Estonia's energy sector is totally dependent on fossil fuels, their substantial part being imported. The mining and power generation equipment as well as heat distribution and electrical networks are outdated and depreciated while the abatement technology is poor or absent. Since 1992 the fuel and raw materials' prices have risen sharply.

Estonia's domestic fuels are oil shale, peat and wood. Their share in the energy balance is approximately 70%. The actual hydropower potential makes up less than 1% of the present power generation capacity, whereas nuclear power is not used. Although the wind potential is quite substantial, in particular on islands, both technical and economic conditions for its utilization are non-existent today.

The main fuel used in Estonia is *oil shale*: 99% of electricity generation and ca 25% of heat production are based on its combustion. The Estonian oil shale as a fuel is characterized by a high ash content (45–50%), a moderate moisture (11–13%) and sulphur content (1.4–1.8%), a low net caloric value (8.5–9 MJ), and a high content of volatile matter in the combustible part (up to 90%). In 1990, the production of oil shale was 22.5 million tons and in 1996, 14.7 million tons. Oil shale is produced in two quality categories: with the grain size of 0–25 and 25–125 mm. Enriched lumpy oil shale (25–125 mm) with the calorific value of 11–13 MJ/kg is used in the oil shale industry for the production of shale oil and as a fuel in cement kilns. Of the minable oil shale (grain size 0–25 mm) with the calorific value of 8.5–9 MJ/kg 80% can be used as a boiler fuel in large power plants. The net calorific value of oil shale varies, showing a decreasing trend, since the best quality oil shale layers have mostly been exhausted already.

Oil shale mining and burning put severe strains on the environment, giving 80% of the total harmful emissions in Estonia. As to GHG emissions, it is important to note that during the combustion of pulverized oil shale, CO_2 is formed not as a burning product of organic carbon only, but also as a decomposition product of the mineral part of fuel. The oil shale carbon emission factor (CEF) with taking into account the decomposition of its mineral carbonate part is 29.1 tC/TJ. Without the decomposition of mineral carbon part, oil shale could be qualified as a fuel with medium CEF = 22 tC/TJ.

Among imported fuels, the share of *heavy fuel oil* (HFO) is the largest. In 1996, 15.753 PJ of HFO and 1.958 PJ of *light fuel oil* (LFO) were used. The consumption of *natural gas* in 1996 was 26.895 PJ. In Estonia *coal* is used in small boilers up to 1 MW where fuel handling and ash removal are performed manually. In 1996, 2.38 PJ of coal was used in Estonia. The Estonian road, railway, air and water transport are dependent on imported *motor fuels* (gasoline, diesel oil, and jet kerosene). In 1996, the consumption of motor fuels was at 25.72 TJ.

The data on the primary energy supply, final energy consumption and generating capacities are presented in Table 2.3.1, Table 2.3.2, Table 2.3.3 and Table 2.3.4.

Table 2.3.1. Estonian primary energy supply and final energy consumption

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Total supply, PJ	**416.6**	**390.6**	**277.3**	**224.2**	**238.7**	**221.6**	**226.3**
Oil shale, %	54	53	63	61	60	57	57
Fuel oil, %	18	16	11	14	12	10	10
Motor fuels, %	11	11	8	11	12	13	12
Gas, %	10	11	9	6	7	9	10
Coal, %	2	3	3	2	2	2	2
Wood & peat, %	4	4	6	6	7	8	9
Electricity, %	1	2	0	0	0	1	0
Final consumption, PJ	**213.4**	**208.9**	**136.9**	**114.0**	**114.9**	**106.3**	**108.2**

Table 2.3.2. Primary energy use in 1996

Category	Share in total resources, %
Electricity generation	35.1
District heat production	22.1
Oil shale processing	11.6
Direct use of fuels	3.7
Non-energy use	2.9
Fuel losses	5.1
Export	7.7
Stockpiles	11.8

Table 2.3.3. Structure of final energy consumption in 1996, PJ

Sector	Electricity	Heat	Fuels	**Total**
Industry	6.9	12.8	9.1	28.8
Agriculture	1.2	0.9	1.9	4.0
Transport	0.4	0.5	15.3	16.2
Households	4.4	20.9	19.6	44.9
Other economy	0.3	0.0	0.0	0.3
Public services	4.1	4.5	0.4	9.0
Total	**19.0**	**42.2**	**47.0**	**108.2**
Losses	0.6	2.6	0.7	

Two large power plants fired by oil shale – the Baltic Power Plant and the Estonian Power Plant – are located near Narva (Table 2.3.4). These plants produce over 95% of the total electricity consumpted in Estonia. The efficiency of the Baltic Power Plant is 27% and that of the Estonian Power Plant forms 29%. The efficiencies of the Kohtla-

Järve and the Ahtme Central Heating Power (CHP) Plants are 25–28%. The efficiency of conventional pulverized coal-fired power plants is about 33% and that of advanced pulverized coal-fired power plants about 38. A comparison of the efficiencies of oil shale-fired power plants with those of conventional and advanced coal-fired power plants shows that CO_2 emissions per MWh electricity generated in oil shale-fired power plants are much higher than those in coal-fired power plants. Low efficiency of oil shale-fired power plants can be explained by the specifics of burnt oil shale (such as high ash content, low net caloric value), but the main reason is that oil shale power plants are technologically out of date. The Estonian Power Plant is over twenty and the Baltic Power Plant thirty years old. These power plants were designed to supply the North-West Region of the former Soviet Union, nearly neglecting the environmental impact. During the Soviet regime approximately 50% of electricity was exported (Figure 2.3.1).

Table 2.3.4. Installed generating capacity of power plants

Power Plants	Commissioned in years	Electricity, MW	Heat, MW	Efficiency, %	Fuel
Eesti PP	1969–73	1610	84	29	oil shale
Balti PP	1959–66	1390	690	27	oil shale
Iru PP	1980–82	190	825	49	oil, gas
Kohtla-Järve PP	1948–58	39	534	28	oil shale
Ahtme PP	1951–53	20	335	25	oil shale
Diesel plants		8	0		Diesel
TOTAL		3257	2468		

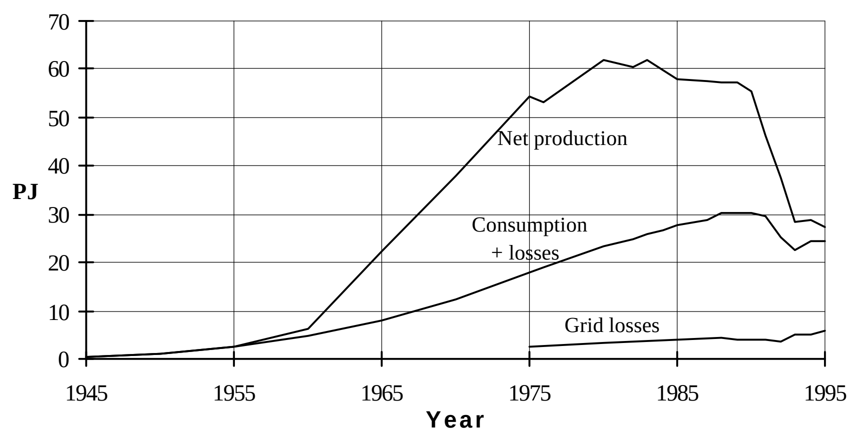

Figure 2.3.1. Net production and consumption of electricity (incl. losses) and grid losses in 1945–1995

Heat is produced by power and co-generation plants in district heating boiler houses and industrial enterprises. About 77% of the district heating boilers are small with the capacity up to 1 MW. Their total share in heat production was 16% in 1996. Of total heat 84% was produced by hot water and steam boilers with the capacity of 2–116 MW. As the technical equipment is thirty years old, the boiler efficiency and its availability are low, heat losses are high, and repairs are frequent. Heat production efficiency of oil shale-based boilers is 62–70%. Of the plants and boiler houses 70–85% are operating on heavy fuel oil and natural gas, and 50–70% of boiler houses on coal. The efficiency of wood- and peat-fired boilers is 65–80%.

District heating, which is well developed in Estonia, supplies most towns and small towns with heat and steam. The system is also well developed in rural areas. The total length of heat pipelines is about 2,200 km. Total heat losses through leakage at the transport from the heat source to the end consumer are up to 30%.

Data on atmospheric emissions are presented in Table 2.3.5.

Table 2.3.5. Emissions from power plants in 1990–1996, Gg

Year	Solids	SO_2	CO	NO_X	CO_2
1990	269	239	60	23	37,184
1991	278	233	57	21	36,342
1992	241	179	33	15	27,453
1993	189	145	28	12	20,656
1994	161	141	32	15	21,413
1995	113	110	27	15	20,495
1996	99	117	30	16	21,898

According to international agreements Estonia must reduce its SO_2 emissions by 50% to the year 1997 and by 80% to the year 2005 from the level of 1980. The NO_X emissions cannot exceed the level of 1987 (Co-operation Agreement on Air Protection between the Governments of the Estonian Republic and the Finnish Republic, signed on July 2, 1993).

2.4 Land Use

Estonia is quite rich in renewable natural resources. During the past half-century the area of forest stands has more than doubled and the growing stock on it has increased 2.7 times. In the beginning of 1995, the area of managed forest land in Estonia was 2.02 million ha, making up 47.6% of the land area of Estonia. Compared with 1990, the area increased 0.1 million ha, mainly due to the abandonment of agricultural lands. As a result of Estonian forest policy the area of managed forest land will continue to grow and it is projected to reach to 2.2 million ha for 2020, making up 51% of the land area of Estonia. The Estonian forests belong to the zone of mixed and coniferous forests with relatively favourable growth conditions. The main tree species in Estonian forests are Scotch pine, Norway spruce and birch.

Despite the small area of Estonia, the forests growing here are rather diverse. The variability brought about by natural conditions (parent material of soil, relief, climatical differences) is in its turn increased by the circumstance that the majority of the forests of Estonia have been affected by human activities in various degrees and ways (cutting, drainage, fires, etc.).

The area of arable land in Estonia is 1.3 million ha, the total sown area is 1.11 million ha. Estonian agriculture specializes in livestock breeding of which cattle-breeding is the most important. Loop production yields about one third of the gross agricultural product – as of 1 January 1990 the overwhelming majority of arable land belonged to collective and state farms. Since that the large farms began to break into private farms and now there is a transitional period in full restructuring of agriculture.

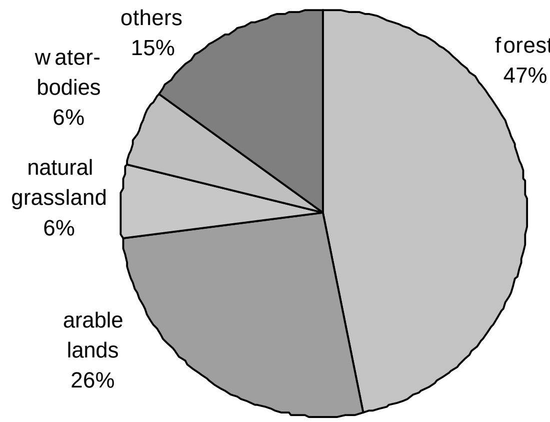

Figure 2.4.1. The structure of land-use by the end of 1996

Grasslands make up 55% of the total arable land of Estonia and grain fields 38%. The main cereal is barley, the share of which constitutes over 60% of the total area sown to cereals. Some of the vegetation types most characteristic to Estonia are grasslands, meadows and natural or seminatural pastures. Meadow communities, often rich in species, are beautiful patterns in Estonian landscapes.

The peatland area is approximately 10,000 km^2, corresponding to 22% of the territory (partly coinciding with forest areas) and their contribution to the balance of GHG is significant. The calculations demonstrate that changes in the hydrological regime contribute to the increase in the emissions of CO_2 and CH_4. During the last decades Estonian peatlands have been strongly influenced by the amelioration for agricultural, forestry and peat industry concerning purposes. According to official data about 34% of Estonian peatlands are affected by drainage activities, but the real value is higher due to the insufficient statistical data as well as to the influence of drainage on the surrounding areas. Most drastically affected are fens, swamps and floodplains of which only about 10% has not been subject to human impact (Figure 2.4.2).

Thanks to the variety of landscapes, differences in climate conditions at different distances from the sea, different types of bedrock, and the resulting high variety of soil types, the biological diversity is high. At present 8,814 species of flora and 12,070 species of fauna are already known in the territory of 45,215 km^2; the probable number is estimated at about 35,000. Unique landscapes and numerous species included into Red Data Book demonstrate that Estonian ecosystems have importance in European and worldwide aspect and therefore it is nessessary to pay special attention to the vulnerability and adaptation assessment of ecosystems and landscapes on the Global Climate Change.

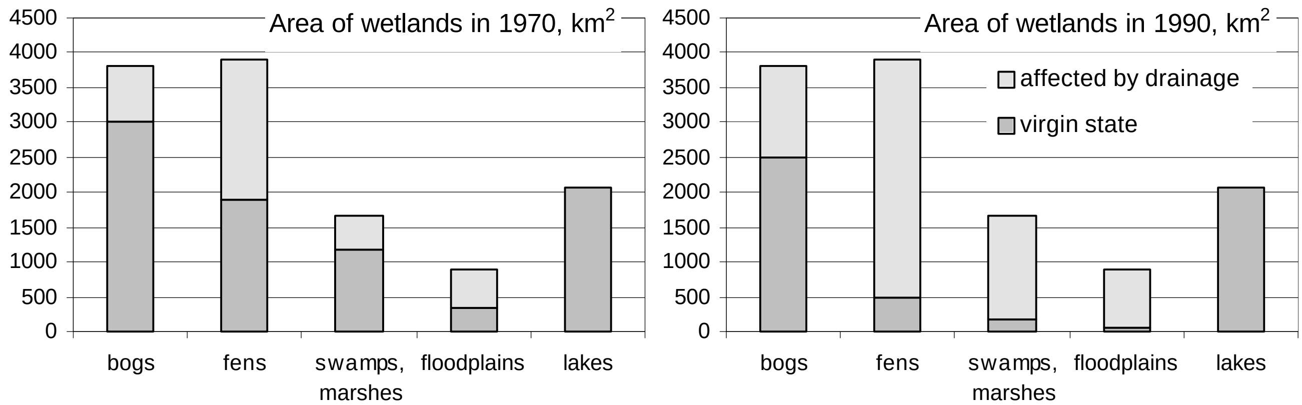

Figure 2.4.2. Area of main peatland types in Estonia in 1970 and 1990 with the area affected by amelioration

Today there are 4 state nature reserves, 4 national parks, 1 biosphere reserve and 479 various protected areas in Estonia. Most of them will be under the direct influence of climate change processes.

Environmental and nature protection have long traditions in Estonia. In 1910 a bird sanctuary was established on the Vaika islets in the West-Estonian Archipelago and the first nature protection law in Estonia was passed in 1935.

2.5 Economy

2.5.1 Changes in the economic structure

It has been characteristic of the Estonian economic reform that no branch of economy has been preferred, practically the single determining factor in the restructuring has been the ability of an enterprise to adapt itself to the economic conditions, especially the ability to orientate itself to the Western market. It is due to the vague economic situation, drastic changes in prices, rapid decrease in the availability of the Eastern market. But it is also due to the conviction that the strict monetary policy used by different governments and the determining effects of the market-oriented economic environment created by it are efficient. The most direct consequence of the changed economic environment has been the sharp decline of production in all branches of economy. Economic changes were very much forced by the prices and foreign economic shock. As a result, the GDP fell 3.6% in 1990, 13.6% in 1991, 14.2% in 1992, 8.6% in 1993 and 3.2% in 1994. The cumulative decline of GDP during the period 1990–94 was 36%. The decline of industrial production began in 1991 and was 10% then. A further decline of 38.9% followed in 1992, a 27% decline occurred in 1993 and 6.7% in 1994.

During the second half of 1994 some stabilization seems to have started in the economy. The GDP increased 2.9% and the industrial output 3.7% in 1995. The Bank of Estonia estimated some economic growth also in 1994. Statistical Office has changed the methodology of calculating several indicators, which complicates the comparing of figures for different years.

Estonia is overcoming the economic restructuring with a notably changed economic structure. The shares of trade, transportation and service sector have increased rapidly. The share of manufacturing was 35.1% and that of agriculture (together with hunting and forestry) 21.5% in the GDP in 1989. In 1994 the shares of these branches were respectively 16.7 and 8.3% and in 1995 14.9% and 6.7% . At the same time the share of trade in the GDP increased from 7.0 per cent in 1989 to 15.8% in 1994 and to 16.4% in 1995, the share of transportation from 6.9% to 8.2% and 8.9%, the share of financial institutions and insurance from 0.9% to 2.8% and 3.1%, respectively. The structure of the Estonian GDP has become rather close to the structure of GDP of developed countries.

The growth in 1995 occurred for two reasons. First, in 1995 large-scale privatization in the Estonian industry was close to its end, and the private sector had the dominant role. This clarification of ownership relations was a very important starting point for future economic growth. And secondly, there had been decline in the Estonian industry, and growth would be possible mainly on the basis of the already existing production capacities. Foreign and domestic investments in certain branches and access to new markets are factors supporting this growth. Estonia is a very small country and one large investment by some big international corporation in the cement industry or in manufacturing of wood and paper could change the growth rates and the structure of the whole economy.

2.5.2 Factors promoting Estonian economic development

The small size of the Estonian market and the need to export a great proportion of its production require concentration of production. To satisfy the demand of the domestic economy a small country has to import a larger share of products than do medium size or large countries. Due to these circumstances, integration into the World Economy is a critical issue for Estonia. The first positive effects of economic reform were achieved by the liberalization of foreign trade and introduction of a convertible currency. This created local access to high-quality consumer goods and services (such as tourism). This change had also a very strong political effect, helping substitute for the former shortage economy, and it was some counterweight to the temporary decrease in real wages in the process of economic stabilization. The need of most enterprises for very substantial restructuring was one reason for the increase in import of capital goods. On the other hand, partly just to widen their markets, partly to gain access to wealthier markets, enterprises are increasing exports.

Table 2.5.1. Estonian Economic Indicators[1] (after A. Purju)

	1990	1991	1992	1993	1994	1995
GDP (mln. EEK)	798	1832	13054	21918	30103	41503
GDP (%, real growth)	-3.6	-13.6	-14.2	-8.5	-2.7	2.9
Industrial output (%)	0	-10.0	-38.9	-27.0	-6.7	1.1
Inflation (%)	60	303	952	35.6	41.7	28.9
Unemployment (%)[2]	0	0.1	1.9	2.6	2.2	1.8
Average wage (EEK)[3]		115	802	1165	2096	2697
Exchange rate/DEM			8	8	8	8
Exports (mln. kroons)	262	510	5425	10632	16947	21177
Imports (mln. kroons)	342	445	5069	11891	21535	29109
Foreign trade balance (mln. Kroons)	-80	65	356	-1259	-4588	-7932
Foreign trade (surplus/deficit)/GDP (%)	-10.0	3.6	2.5	-5.5	-15.2	-19.1
Exports/GDP (%)	42.9	29.8	38.0	46.5	56.1	51.0
Current account balance (mln. kroons)			430.2	300.5	-3195.6	-2123.7
Capital account balance (mln. kroons)			628.1	2952.9	2274.1	2992.8
Foreign currency reserves (mln. kroons)			2370.4	4488.9	5341.1	6541.5

[1] GDP, industrial output, average wages, export, import and balance of payments indicators are in current prices. Recalculation of indicators from the pre-kroon period (this is, for the period 1989–1991) is based on the exchange rate 1 EEK = 10 SUR .

[2] The number of persons receiving unemployment benefits in comparison with the total number of employed and unemployed persons, at the end of year.

[3] Average monthly wage in the fourth quarter of year.

Estonia has a relatively high educational level, rather close to EU standards. However, to use this advantage for producing and exporting more sophisticated products requires large investments and further integration with other developed countries in the framework of international organizations, and on the level of firms. Estonia is managing to realize rather successfully the creation of basic conditions for future economic growth (a stabilized monetary environment, a dominant private sector in business, introduction of institutions typical for developed countries), which should also guarantee realization of other advantages like educational level and geographical position.

3 GHG Budget 1990–1996

3.1 Introduction

During 1994–1996 a GHG inventory was compiled for the baseline year 1990 in the framework of U.S. Country Study Program by Estonian Country Study Team using the IPCC Guidelines for National GHG Inventories. Later the same methodology was applied to compile GHG inventories for 1991–1996. The results of the study reflect a great decrease in the GHG emissions during these years in Estonia.

GHG Inventory for Estonia was compiled for energy, industry, transport, agriculture, forestry, land-use sectors; that is for all activities related with emission of greenhouse gases in Estonia.

Uncertainty

Unfortunately, the availability and reliability of data from different sectors differ. During these years great changes took place in statistical data collection and processing methods in Estonian government institutions. Also it must be pointed out that there is lack of scientific base for the separation of natural and man-made part of GHG emissions and removals from wetlands.

By expert opinion the uncertainty of activity data could differ from 10% to 25% on dependance of the sector and years, in the beginning of 1990s uncertainties were much higher than in recent years.

3.2 Energy

Energy-related activities are the most significant contributor to Estonian greenhouse gas emissions (see Table 3.2.1.). The production, transmission, storage and distribution of fossil fuels also serve as sources for greenhouse gases, as do primary fugitive emissions from natural gas systems, oil shale mining and shale oil production.

During the last fifty years Estonia was a part of the integrated national economic complex of the former Soviet Union. The national economy was developed considering the interest of the USSR and neglecting local conditions and peculiarities. According to the planned economy, power-intensive and materials-consuming industries were developed in Estonia. At the same time, the price of fuels was abnormally low and they were easily available. Such a situation did not encourage anyone to economize on energy.

Estonia satisfies most of its energy demand by fossil fuels and approximately 68% of the CO_2 emissions in Estonia are released by the combustion of oil shale. The remaining 32% comes from heavy fuel oil, natural gas, coal, light fuel oil and other fuels. From the point of view of greenhouse gas emissions it is important that during combustion of oil shale CO_2 is formed not only as a burning product of organic carbon, but also as a decomposition product of mineral carbon. Therefore the total quantity of carbon dioxide increases up to 25% in flue gases from oil shale burning.

A formula compiled by A. Martins for calculation of Estonian oil shale carbon emission factor, taking in consideration the decomposition of its carbonate part, is as follow:

$$\mathbf{CEF_{oil\ shale} = 10\ \frac{C^r_t + k(CO_2)^r_M\ 12/44}{Q^r_i}} \quad \mathbf{(tC/TJ)}$$

where Q^r_i - net caloric value oil shale at combustion, MJ/kg;

C^r_t - carbon content of oil shale at combustion, %;

$(CO_2)^r_M$ - mineral carbon dioxide content of oil shale at combustion, %;

k - decomposition rate of ash carbon part (k = 0.95-1.0 for pulverized combustion of oil shale).

Net calorific value of oil shale is changeable, showing decrease tendency, because the oil shale layers with best quality are mostly exhausted already. In 1990 the average net caloric value of oil shale, burned in power plants, was 8.6 MJ/kg (data from Estonian Energy).

Calculation of oil shale carbon emission factor:

$$\mathbf{CEF_{oil\ shale} = 10\ (20.6 + 0.95 \times 17.0 \times 12/44) / 8.6 = 29.1, \quad (tC/TJ)}$$

Table 3.2.1. CO_2 and non- CO_2 emissions from energy use and transport in 1990, Gg

Sector	CO_2	CH_4	N_2O	NO_X	CO	NMVOC
Energy conversion	28 461	0.05	0.002	35.78	7.33	NA
Residential	1 588	0.46	0.425	3.04	0.97	NA
Commercial	1 581	0.12	0.954	3.13	1.62	NA
Industrial	2 897	0.05	NA	4.81	1.67	NA
Transport	2 656	1.93	0.036	32.64	171.95	22.92
Total	37 184	2.61	1.417	79.41	183.54	22.92

Note: The totals provided here do not reflect emissions from bunker fuels used in international transport activities

The regaining of political and economic independence in 1991 brought about drastic changes in the structure of fuel consumption. Transition from a centrally planned economy to a market economy resulted in a sharp increase in fuel prices, and raw materials as well as in a decline of the Eastern market.

Table 3.2.2. shows the price increase for different fuels in the period 1991–1993, when the increase of prices was extremely high, especially for imported fuels. For example, the price of natural gas rose more than 700 times, that of heavy fuel oil about 450 times while the prices of gasoline and diesel oil increased 150 times within one and half years. Naturally, these increases brought about significant changes in the structure of fuel consumption.

Table 3.2.2. Fuel prices (incl. VAT) in Estonia

	Price EEK / t		(1 DEM = 8 EEK)			Price increase (times)
Fuels	Before 1991	Jan. 1991	Apr. 1992	July 1992	Sept. 1992	Jan.1991- Sept. 1992
1. Oil shale	0.42	1.67	24.7	24.7	24.7	59
2. Coal	4.25	6.7	411.0	350.0	350.0	82
3. Heavy fuel oil	3.05	8.0	825.0	885.0	1,381.0	453
4. Nat. gas, EEK/10^3m^3	1.85	6.1	539.0	1,321.6	1,321.6	714
5. Diesel oil	13.90	-	1,590.8	2,039.0	2,188.0	157
6. Gasoline	26.00	-	3,144.8	3,905.0	3,905.0	150

In 1990 the total CO_2 emissions from the consumption of fossil fuels were 37,184 Gg, but in 1996 the emission was only 21,216 Gg. This means that during these years the total emission of CO_2 from energy production and use decreased by 43% (Table 3.2.3.). In the decrease of CO_2 emission the reduction of fossil fuel consumption, especially that of imported fuels, was the major factor. So the CO_2 emissions according to fuel types decreased as follows: natural gas 47%, coal 74%, petrol 56%, kerosene 59%, heavy fuel oil 78% and diesel oil 45%.

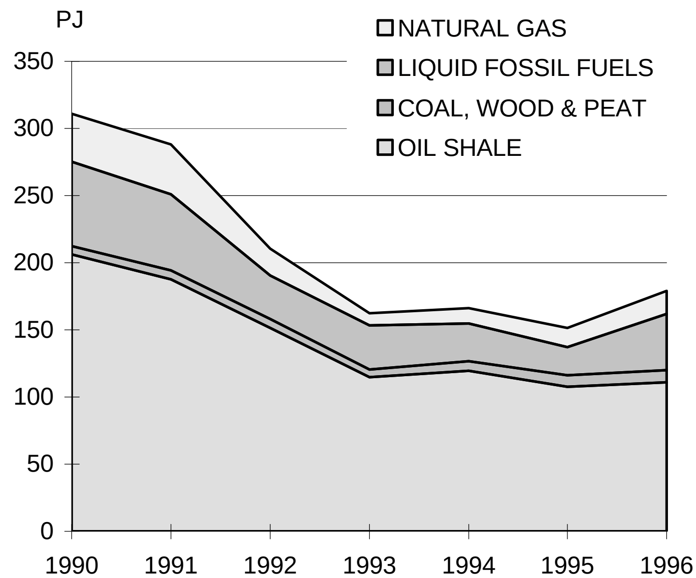

Figure 3.2.1. Changes in the structure of fuel supply in Estonia

The decrease of CO_2 from domestic fuels was not so high. For example, the decrease of CO_2 from oil shale consumption was 34%, from peat 3%. The total emissions from solid biomass increased 203%. Overall, the decrease of CO_2 emission was especially high in the years 1991–1992 (24%).

The major part of primary energy in Estonia is converted to electricity and heat or refined to peat briquettes and shale oil. CO_2 emissions for years 1990 and 1996 according to sources are given in Table 3.2.3.

In 1996, 156 PJ of primary energy was produced in Estonia of which oil shale formed 86% (Energy Balance 1996, 1997). The remaining 14% comes from heavy fuel oil, natural gas, or other energy sources such as coal and light fuel oil. The energy conversion sector accounts for 87.8% of the Estonian emissions from fossil fuel consumption, making it the largest source of CO_2 emissions.

Table 3.2.3. Sources of fossil fuel CO_2 emissions by sector, Gg

Source	**1990**	**1996**
Total fossil fuel consumption	37184	21216
Energy conversion	28461	18635
Residential	1581	756
Commercial	1589	20
Industrial	2898	710
Transport	2656	1095

Oil shale across all sectors of the economy was responsible for about 71.6% of total Estonian energy related CO_2 emissions (Table 3.2.4.).

Table 3.2.4. CO_2 from energy sources, Gg

Fuel Types	1990	1991	1992	1993	1994	1995	1996
Fossil fuels total *	**37183.8**	**36342.2**	**27453.3**	**21786.0**	**22667.5**	**20637.6**	**21216.2**
Liquid fossil fuels	**9734.4**	**8566.6**	**5023.4**	**5191.38**	**4782.3**	**3721.6**	**3647.2**
Natural gas liquids	95.6	91.9	40.4	21.6	30.3	21.2	14.2
Gasoline	1688.4	1417.3	681.4	694.6	858.1	649.6	740.8
Kerosene	335.7	262.7	68.8	157.6	147.2	70.4	139.3
Jet kerosene	112.1	109.9	37.3	57.4	47.4	52.5	49.0
Diesel oil	1887.0	1826.2	1198.9	1280.1	1174.7	1100.0	1043.4
Heavy fuel oil	5500.2	4700.0	2921.2	3229.2	1975.0	1247.5	1194.4
Other oil	115.4	158.6	75.4	525.3	549.6	580.5	466.1
Solid fossil fuels	**24595.4**	**24908.6**	**20753.5**	**15761.6**	**16690.2**	**15549.9**	**16064.7**
Oil shale	23051.4	23011.7	19347.8	14854.9	15867.1	14727.1	15196.7
Coal	880.1	863.4	536.3	282.4	211.6	201.1	229.2
Peat and peat briquette	653.7	1024.1	861.3	615.9	605.3	615.6	635.6
Coke	10.2	9.4	8.1	8.4	6.3	6.2	3.1
Gaseous fossil	2854.0	2867.0	1676.4	833.1	1193.8	1366.1	1504.4
Natural gas	2854.0	2867.0	1676.4	833.1	1194.9	1366.1	1504.4
Biomass total	1074.0	796.5	843.7	793.4	1289.3	1445.9	1613.5
Solid biomass	1074.0	796.5	843.7	793.4	1289.3	1445.9	1613.5

* biomass is not included into fossil fuels total

3.3 Transport

Emissions from transport sector are estimated by major transportation activity (passenger cars, lorries, special vehicles, motorcycles, tractors, small excavators, diesel locomotives, air transport), where several major fuel types, including gasoline, diesel fuel, jet kerosene, natural gas liquids, other kerosene and LPG are considered. Road transportation accounts for the majority of mobile source fuel consumption, and the majority of mobile source emissions.

In 1996 the CO_2 emission from the transport sector made 1534.1 Gg making 42% less than in 1990 (2655.6 Gg).As we can see in Table 3.3.1, in the period of 1990-1996 the number of passenger cars in Estonia increased about 69% (240.9 thousand in 1990 and 406.6 thousand in 1996, respectively). At the same time the use of motor fuels in the transport sector has decreased (in 1990 it was 37.3 PJ and in 1996 21.6 PJ, respectively) due to the decline in the freight traffic, both of the goods and the passengers, but also due to the increasing share of new and more economic vehicles in the transportation (in the beginning of 1998 less than 10 year old passenger cars made 30% of the total number of these vehicles).

Table 3.3.1. Vehicles, 1990–1996 (thousands)

	1990	1991	1992	1993	1994	1995	1996
Passenger cars	240.9	261.1	283.4	317.4	337.8	383.4	406.6
Buses	7.9	8.6	8.4	8.7	6.3	7.0	6.7
Lorries and special vehicles	67.7	77.1	74.6	74.1	53.7	65.6	71.3
Motorcycles	105.7	100.2	100.0	97.14	2.2	3.3	4.7
Tractors	45.2	48.6	50.8	48.4	48.8	49.4	50.4
Small excavators	1.7	1.7	1.6	1.9	2.1	2.1	2.3

Table 3.3.2. Total fuel consumption and CO_2 emissions from mobile combustion, Gg

	1990	1991	1992	1993	1994	1995	1996
Total fuel consumption in transport sector, PJ	37.3	33.5	20.0	22.6	25.2	23.9	21.6
CO2 emissions, Gg	2655.6	2385.5	1423.4	1607.2	1786.0	1700.1	1534.1

3.4 Industrial processes

In Estonian industry greenhouse gases are produced mainly by cement and lime production. By thermal processing of calcium carbonate ($CaCO_3$) from limestone, chalk or other calcium-rich materials calcium oxide (CaO) and carbon dioxide (CO_2) are formed. Total CO_2 emissions from cement and lime production in Estonia were 613 Gg in 1990 and 206 Gg in 1996 (Table 3.4.1.).

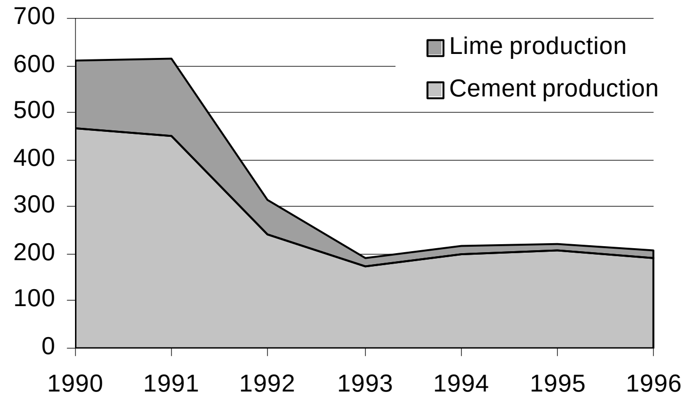

Figure 3.4.1. CO_2 emissions from industry, Gg

Table 3.4.1. Sources of CO_2 emissions from industrial processes, Gg

Source	1990	1991	1992	1993	1994	1995	1996
Cement production	467.6	451.2	240.8	176.5	200.7	208.3	192.9
Lime production	145.3	162.6	72.3	16.5	14.1	13.2	13.5
Total	612.9	613.8	313.1	193	214.8	221.5	206.4

3.5 Wastes

In Estonia methane emissions from waste come mainly from landfills, domestic and commercial wastewater treatment, and industrial wastewater (Table 3.5.1.). Organic landfill materials such as municipal waste, including waste food and waste paper, may decompose and produce methane by anaerobic decomposition.

Table 3.5.1. CH_4 emissions from waste management, Gg

Source	1990	1991	1992	1993	1994	1995	1996
Municipal landfills	26.3	26.2	25.9	25.4	25.1	24.8	24.6
Municipal wastewater	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Industrial wastewater	15.2	11.5	7.9	4.8	5.3	6.0	5.7
Total	42.4	38.6	34.7	31.1	31.3	31.7	31.2

Methane production usually begins in 1-2 years after the waste delivery to the landfill and lasts for a long time (over 50 years).

3.6 Agriculture

In 1990 the total sown area was 1100 thousand hectares whereas the forage crops covered 665.4 thousand hectares, cereals and legumes 397.1 thousand hectares and potatoes, vegetables and industrial crops 4.1, 0.5 and 0.3% of the total sown area, respectively. Restructuring of agricultural production, development of the private sector, partial loss of the traditional eastern market and search for new ones, and a rise in prices for fuel and fertilizers have influenced immensely the whole agricultural sector. In 1995 the total sown area shrank to 925.4 thousand hectares, the area sown to cereals and legumes was 302 thousand hectares, and potatoes were cultivated on 37.6 thousand hectares.

The use of fertilizers and pesticides has also decreased. In the 1980s 110–130 kg of nitrogen from mineral fertilizers, and 60–70 kg from organic fertilizers was used per hectare of arable land. In comparison with 1987, the use of mineral fertilizers and manure in agriculture decreased 7 and 4 times, respectively for 1995 (Figure 3.6.1.).

Figure 3.6.1In 1983, when animal husbandry was at its highest level, methane emission from enteric fermentation and livestock manure management was 68.2 Gg. By 1990 it had decreased to 64.1 Gg and in 1995 it was only 35.5 Gg. Ruminants, which include cattle, sheep and goats, are the largest producers of CH_4. Of CH_4 emissions 88% was from cattle raising, and 8.7% from pig husbandry. Methane emission from enteric fermentation formed 87% of the total CH_4 emissions in agriculture (Figure 3.6.2.).

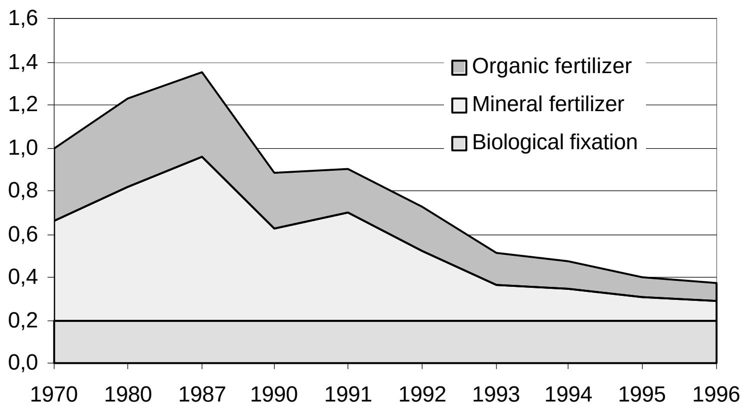

Figure 3.6.1. Nitrous oxide emissions from fertilizers ($C = N_2O_{emitted} / N_{applied} = 0.0036$).

According to the IPCC methodology more attention has been paid to CH_4 and N_2O emissions, as the main GHG sources in the Estonian agriculture are animal husbandry and the use of nitrogen fertilizers. Emissions from burning straw and other plant residues have not been considered, as burning of plant residues is not crucial to estimating GHG emission in our conditions. Methane emissions from enteric fermentation and manure management are calculated according to IPCC methodology, where different emission coefficients were applied to different animal types.

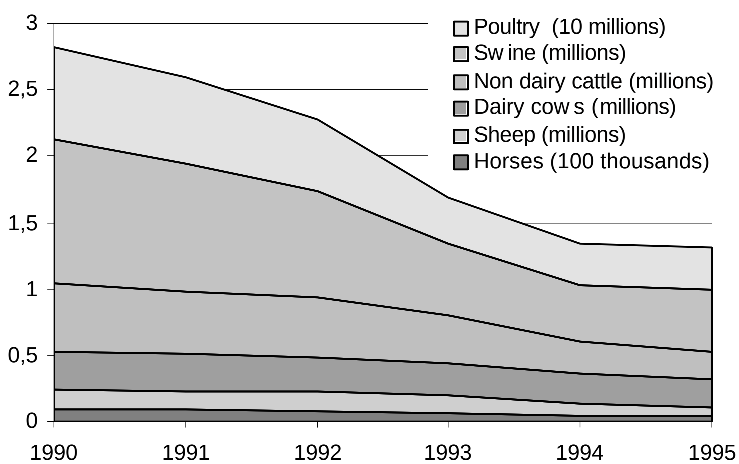

Figure 3.6.2. Number of animals in Estonia

The amount of methane produced during the decomposition of manure depends on the type and population of animals, and manure management methods. Swine manure is the greatest emission source, making up about 48% of the total methane emissions from livestock manure.

Nitrous oxide production and emissions from soils are influenced by soil properties, crop type, management regime, amount of nitrogen fertilizers and organic manure used, biological fixation of nitrogen, etc. For the year 1995 nitrous oxide emissions were 3 times lower than in the 1980s when relatively large amounts of fertilizers were used.

3.7 Forestry

3.7.1 Forestry and land-use change

Forests, which cover about 47% of Estonian land area, are an important terrestrial sink for carbon dioxide (CO_2). Because approximately half the dry mass of wood is carbon, as trees add mass to their stems, branches and roots more carbon is accumulated and stored in the trees than is released to the atmosphere through respiration and decay. Soils and vegetative cover in forest also provide a potential sink for carbon emissions. When humans use and alter the functions of forest ecosystem through land use change and forest management activities, the natural balance of CO_2 and other GHG-s emissions and uptake may be disbalanced and their atmospheric concentrations adjust.

CO_2 removals and emissions

Atmospheric CO_2 concentrations are the net results of continuous emissions and sequestration that occur through natural processes and human activities. Plants and soils absorb and store CO_2 from the atmosphere and use it in their functional processes. CO_2 emissions occur when the carbon stored in these sinks is released due to forest harvested and wood is burned for energy.

The estimation of CO_2 emissions from forestry and land use change requires consideration of events over a long period of time. When forests are cleared or agricultural lands abandoned, the biological responses result in “commitments” of fluxes of carbon to or from the atmosphere for many years after the land use change.

The basec calculations focus primarily forest conversion processes and abandonment of managed lands. In the calculations the processes of CO_2 removals or emissions of forests alterations of areas and aboveground biomass changes due to management of forest have been taken into account. Annual removal of CO_2 from Estonian forests was during the base year 14,873 Gg. This figure includes 12,446 Gg CO_2 due to accumulation by total growth increment of managed forests and 2427 Gg CO_2 due to accumulation by abandonment of managed lands over the previous 20 years. In the processes of forest management a portion of wood may be removed from the conversion site and used as firewood or for making products, a portion may be burned on site or converted to slash and decay to carbon dioxide step by step. In 1990 the total CO_2 emission from forest ecosystem was 3556 Gg CO_2 (Table 3.7.1.). The calculations using the IPCC methodology show that from 1990 to 1995 both emissions and removals of

CO_2 have increased (Figure 3.7.1.). The annual removal increased by 1% for 1994 and by 16% for 1995. The annual emission increased by 10% for 1994 and by 13% for 1995. The increase of emission is a result of enlarged harvest activity in Estonian forests. The net CO_2 uptake by Estonian forests in 1990 was estimated at 11,317 Gg, 11,125 Gg in 1994 and 13,266 Gg in 1995. In 1990–1995 the net CO_2 uptake by Estonian forests decreased by 2% for 1994 but increased by 17% for 1995. The decrease was mainly caused by lower extent of afforestation of abandoned managed lands. The afforestation activity was very intensive in 1995.

Table 3.7.1. Removals (-) and emissions (+) of CO_2 due to forestry and land use change in 1990, 1994 and 1995, Gg

Activity	1990	1994	1995
Forest management			
Biomass growth increment	-12,446	-13,229	-14,833
Harvest	3,018	3,465	3,658
Forest conversion			
On- and off-site burning	128	49	4
Decay	48	39	25
Soil	362	352	336
Abandoned managed lands			
Aboveground biomass	-1,474	-1,093	-1,580
Soil	-953	-708	-876
Total	**-11,317**	**-11,125**	**-13,266**

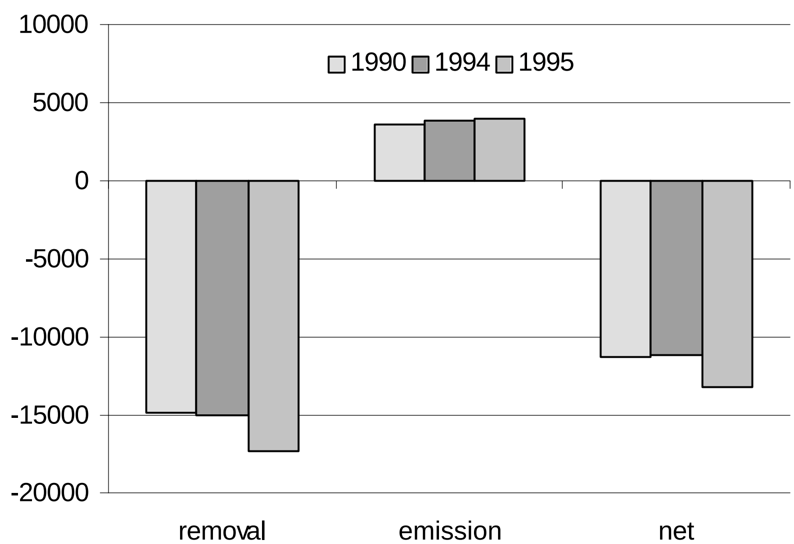

Figure 3.7.1. CO_2 emissions and removals, Gg

Non-CO_2 GHG emissions

Forest management activities may also result in fluxes of other greenhouse and radiatively important gases balance in the atmosphere. Open burning associated with forest clearing or other land use change may of disbalance the normal situation of non-CO_2 trace gases in the atmosphere. Inventories of methane (CH_4), carbon monoxide (CO), nitrous oxide (N_2O) and oxides of nitrogen (NO_x, i.e. NO and NO_2) emissions have been carried out in case of open burning associated with forest conversion in Estonia. Gross emissions of non-CO_2 trace gases due to biomass burning are also net emissions and are generally produced immediately, while gross emissions of CO_2 may or may not be balanced by the uptake of CO_2 and may occur over immediate or delayed time frames.

Although the effects of forestry activities on fluxes of these gases are not finally understood and highly uncertain, the data calculated by using the methods recommended in IPCC Guidelines (1994) are presented for Estonia in Table 3.7.2. As it can be seen the emission of all non-CO_2 trace gases has decreased. The main reason of the decrease is that the drainage and road building in forests have stopped. There is no need for new ditches in Estonia and it is planned to keep the existing drainage network in good order.

Table 3.7.2. Emissions of non-CO_2 trace gases in Estonian forests, Gg

Years	CH_4	CO	N_2O	NO_x
1990	0.31	2.72	0.002	0.077
1994	0.12	1.04	0.001	0.029
1995	0.01	0.08	0.000	0.002

Wetlands

The total area of wetlands reaches ca 1,231,700 ha. Of this area the lakes cover about 207,000 ha, marshes some 5000 ha, and the rest (ca 83%) is covered with peatlands. During the last decades Estonian peatlands have been significantly influenced by amelioration activities, mostly for agricultural and forestry purposes. The role of peat industry is considered to be somewhat less important.

No up-to-date assessment of the ecological state of peatlands in Estonia has been made. According to the expert assessment, about 120,000 ha of peatlands have been drained for agricultural purposes, some 180,000 ha for the needs in the forestry, and ca 38 000 ha to satisfy the demand of industry. The total value of about 340 000 ha of drained peatlands does not correspond to the actual area of affected by drainage peatlands, since the data show only the area of immediate amelioration systems. Also, the outflow ditches and other facilities outside the systems greatly expand the affected area and have not been taken into account.

It has been estimated that for the drainage by peat harvesting the drainage impact on the area outside the edge ditches may range from 50 to 130% while the average value of the drainage impact on the harvested area of the same size is 90%. Consequently, by multiplying the official drainage value by a factor of 2, we should reach a more realistic estimate of the area of peatlands affected by drainage. Most drastic has been the impact on fens, swamps and floodplains, since only about 10% of them are still in the virgin state. Less important is the influence of drainage on the *Sphagnum* dominated bogs. The anthropogenic impact on the state of lakes and marshes has resulted in the drop of water level only in very exceptional cases.

Our data indicate that the peat accumulation in different types of peatland does not vary widely and ranges between 1.5 and 1.9 t $ha^{-1}y^{-1}$, and we base our calculations on a mean value of 1.7 t $ha^{-1}y^{-1}$. In lakes the accumulation of organic sediments (mud) is highly variable, from 1 to 100 mg $cm^{-2}y^{-1}$, and we take a representative value of 10 mg $cm^{-2}y^{-1}$ or 1 t $ha^{-1}y^{-1}$. Considering the carbon content of 54% in the dry matter, both in peat and lake sediments, the mean accumulation of CO_2 in the virgin peatlands is about 3.37 t $ha^{-1}y^{-1}$. The corresponding value in lakes is ca 1.19 t $ha^{-1}y^{-1}$ as the ash content in Estonian lake muds is about 40%.

As a result of the drainage of virgin peatlands, the accumulation of organic matter has ceased, and due to intensive decay processes the mineralization of organic matter has increased. For several decades the breakdown of peat resources and peat losses on the minerotrophic fens that have been ameliorated for agricultural purposes has been monitored in Estonia. It is shown that the mineralization of organic matter is about 15 to 20 tons per hectare per year during the first decade after the establishment of an amelioration system. Later, the process stabilizes and, depending on the character of exploitation (crop field, grassland, pasture), may remain between 5 and 15 tons per hectare per year, depending somewhat on management method. The possible average level may be about 8 tons per hectare per year, or 15.8 t of CO_2. After drainage the annual amount of peat decomposition remains within the range of 15 to 124 times the mean annual peat accumulation. It has also been shown that the rate of peat mineralization in bogs and swamps is quite probably about the same level as in fenlands.

The calculations indicate that human activities have most drastically affected the carbon budget in fens, swamps and floodplains where the CO_2 accumulation has decreased from 638 to 169, from 378 to 37 and from 117 to 22 Gg y^{-1}, respectively. The CO_2 emission has increased per year from 3153 to 5350 Gg in fens, from 920 to 2391 Gg in swamps and from 836 to 1294 Gg in floodplains. The values for raised bogs, lakes and marshes have not changed significantly. In total the CO_2 emission increased about 1.8 times during the period of 20 years (from 1970 to 1990).

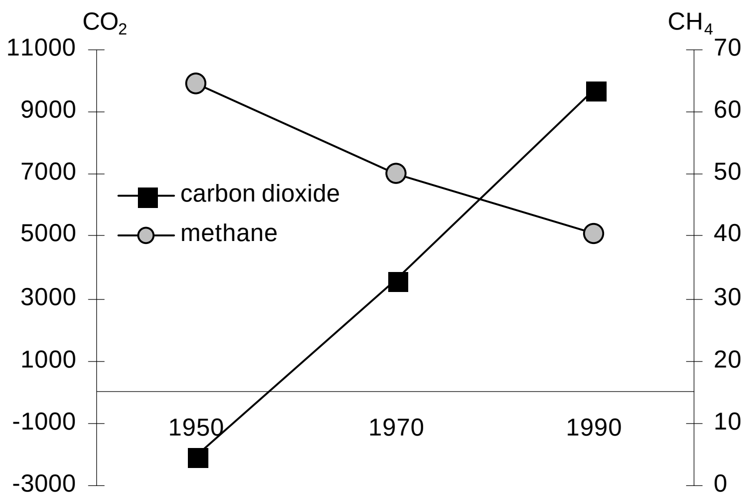

Figure 3.7.2. Carbon fluxes from wetlands, Gg

The values for methane emissions are an order of magnitude lower and their changes are not so substantial. The methane emission from peatlands has decreased about 2.2 times (from 18 to 8.1 Gg y^{-1}). The trends of carbon fluxes from wetlands since 1950 are given in Figure 3.7.2.

3.8 Summary

The data given in Table 3.8.1. demonstrate that, the total amount of emitted GHG in Estonia decreased from 1990 to 1996 by about 49%. It must be mentioned that besides direct dropping of GHG the emission of other pollutants like SO_2, fly ash, aromatic chemicals etc. has also decreased.

Table 3.8.1. Changes in GHG emissions in Estonia, Gg.

Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996
Carbon dioxide	**36251**	**35189**	**25136**	**19597**	**21527**	**17363**	**18549**
Energy and transformation	34528	33957	26030	20179	20882	18938	19682
Transport	2656	2386	1423	1607	1786	1700	1534
Industrial processes	613	614	313	193	215	222	206
Land-use change and forestry	-1545	-1767	-2630	-2382	-1355	-3496	-2874
Methane	**105.2**	**102.1**	**91.3**	**79.7**	**79.5**	**67.7**	**63.2**
Fuel combustion	2.6	2.5	1.9	1.6	1.8	1.7	1.8
Agriculture	60.2	60	54.7	47	46.4	34.3	30.2
Waste management	42.4	38.6	34.7	31.1	31.3	31.7	31.2
Nitrous oxide	**2.3**	**2.3**	**1.7**	**1.4**	**1.3**	**1.2**	**1.2**
Fuel combustion	1.4	1.4	1	0.9	0.8	0.8	0.8
Agriculture	0.9	0.9	0.7	0.5	0.5	0.4	0.4

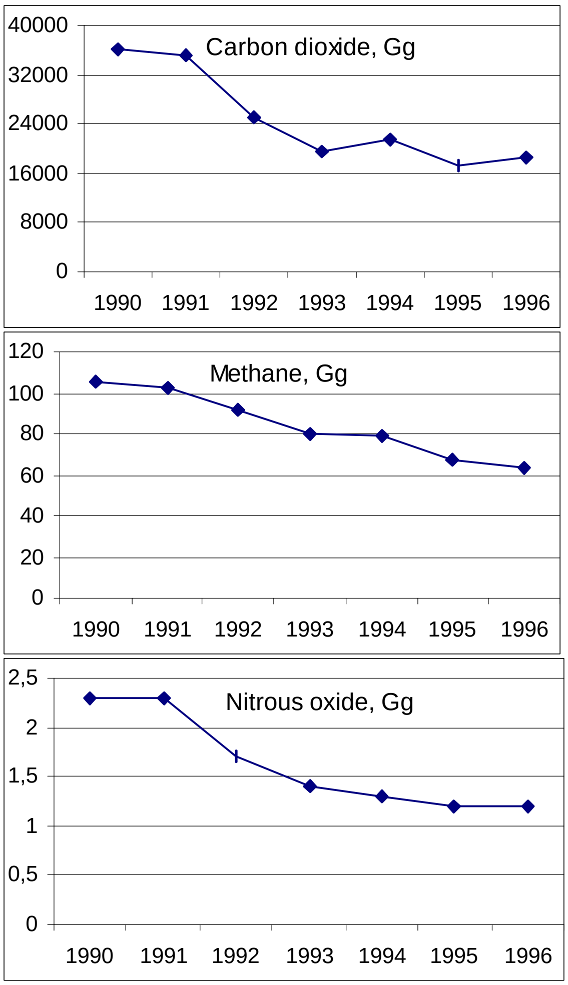

Figure 3.8.1. Trends of GHG emissions in 1990–1996

4 Actions and programs to reduce emissions

4.1 Introduction

The National Environment Strategy, approved by the Estonian Parliament on 12 March 1997, envisages as one of the priorities reduction of negative effects of the energy sector and improvement of air quality. The following goals are fixed:

"To reduce the environmental impact of the energy sector, to direct energy policies towards energy efficiency technology development programmes, more extensive use of renewable energy resources and reduction of greenhouse gas emissions, to include all environment-related costs of energy consumption in the energy price."

"To reduce emissions of air pollutants, focusing primarily on substances causing climate change and ozone depletion, and on pollution originating from transport"

The milestones for achieving the main goals are:

Tasks by the year 2000

- To elaborate development trends in electricity production, taking into account environmental requirements;
- To reduce dust and ash emissions by 25% from the 1995 levels;
- To terminate the use of high-sulphur fuel oil;
- To terminate the sale of ozone depleting substances and impose considerable restrictions on the consumptions of such substances;
- To stabilize emissions of nitrogen compounds at the 1987 level and to aim for their futher reduction;
- To establish stricter requirements for imported and existing motor vehicles with regard to their emissions;
- To reduce the emission of volatile organic compounds by 50% compared to the 1990 level.

Tasks by the year 2005

- To reduce the emission of sulphur compaunds by 80% compared to the 1980 emission level;

Tasks by the year 2010

- To ensure that emissions of polluting substances do not exceed the European Union standards;
- To dispose 40% of municipal waste in accordance with environmental and health protection requirements;

Future GHG emissions will be strongly influenced by steps to improve energy efficiency.

The main problems and goals of Estonian energy development are described in:

- Energy Law;
- Energy Strategy for Estonia;
- Long-Term National Development Plan of Fuel and Power Supply.

The energy development plan is presently under treatment in the Parliament. The development plan forecasts the development of fuel and energy supply, mainly to the year 2005 while some principal development trends to 2018 are also given.

The main objective of the development plan is to provide a stable energy supply consistent with the quality requirements and at optimal prices, which will provide such a development of fuel and energy economy that potentials for the increase of the GDP in Estonia will reach the level compatible with the standards required for integration with the European Union.

Taking the estimated annual GDP increase of 5% a basis (investigations made by the Estonian Institute of Economics, the Estonian Institute of Future Studies and the PHARE Estonian Energy Strategy), conclusions have been drawn in the energy economic studies that such GDP accrual will increase the annual energy demand about 2%.

Some measures have already been taken according to a new energy policy, including increased utilization of domestic wood, peat and other biofuels. In order to assess the potential environmental impacts and to draw up overall mitigation and monitoring plans, a sectoral Environmental Assessment on the Utilization of Domestic Peat and Wood Raw Material as a Fuel Source for Heating Systems (1994) has been carried out. Analyses of the available data show that it is possible to increase the share of domestic biofuels up to 12%.

There are considerable possibilities for public energy savings. These include creating direct economic incentives for energy saving, providing consumers with concrete recommendations, tax credits to be used for energy-saving purposes, and information about energy saving to households.

At the beginning of the nineties several forecasts of energy consumption were made, but none of them foresaw the actual rapid decline in energy consumption that occured. At present, the energy production and consumption are stabilizing. In the near future, the energy supply will increase, but it will depend on the energy policy, environmental regulations and the general economic situation in Estonia. This means that energy related CO_2 emissions will increase in the future.

4.2 Planning climate policy

Oil shale power engineering will remain the prevailing energy resource for the next 20–25 years. Oil shale combustion in power plants will be the greatest source of GHG emissions in the near future. The main problem is to decrease the share of CO_2 emissions from the decomposition of the carbonate part of oil shale. The Estonian State Enterprise (SE) Eesti Energia has planned several activities. Among the main targets the following should be underlined: to increase the efficiency of power plants, to reduce the level of SO_2 emissions to internationally acceptable levels, to solve the ash removal problem. To solve these problems SE Eesti Energia is planning to study the feasibility of CFB technology for oil shale combustion to replace the PC technology. Some very large energy companies (Lurgi, ABB, Foster-Wheeler) are engaged in this project. The

CFB combustion technology facilitates a substantial reduction of the decomposition rate of carbonates in the mineral part of oil shale, and that of CO_2 content in flue gases of oil shale power plants.

In Estonia heat is produced mainly from imported fuels (fuel oils and natural gas). But imported fuels are now being partly replaced by domestic wood fuels and peat. In district heating boiler houses, the boilers are over thirty years old and their efficiency is low. In a short term, the efficiency of old boilers could be improved by furnishing them with elementary control equipment for optimizing combustion regimes and for facilitating necessary repairs.

The prognoses for the future development of power engineering depend essentially on the environmental requirements. Under the highly restricted development scenario, which includes strict limitations to emissions (CO_2, SO_2, thermal waste) and a severe penalty system, the competitiveness of nuclear power will increase. The conceptual steps taken by the Estonian energy management should be in compliance with those of neighbouring countries, including the development programs of other Baltic states.

The energy intensity of Estonian economy is high. The main reason for this must be attributed to the low GDP value and high energy consumption per production unit.:

Table 4.2.1. Energy intensity (energy consumption MJ per USD GDP) of different European countries for 1994 (Phare Multi-Country Project, *Convergence of Energy Policies of CEE and EU Countries,The Netherlands, 1996.*)

Denmark 6.4	Germany 8.6	France 9.6	UK 10.7
Sweden 15.0	Finland 20.0	Belgium 20.6	Hungary 46.0
Estonia 64.0	Czech Republic 114.4	Bulgaria 137.3	Slovakia 175.6

It follows from the figures given above that energy saving is one of the most important options for decreasing the energy intensity in Estonia.

The objectives of the future mitigation analysis in the energy sector are: oil shale mining and combustion processes, use of economical analysis for energy saving programs, CO_2 sinks in alkaline environment, education and training.

Estonian forests are of the boreal type and essentially variable ranging from the forests on sandy dunes to the humid and highly productive mixed forests in the central part of the country, from the declined forests growing under the air pollution impact in the industrial areas in the north-east to the miserable forests in bogs. A general goal of the Estonian forest policy is the preservation of forests and development of new management options.

The main objectives for future mitigation analysis in the forest sector are: management of conservation problems of valuable ecosystems, finding out the optimum proportion between the volumes of timber from final and improvement felling, recultivation of mined and agricultural abandoned areas, promotion of the rational use of forest resources in all forest holdings, education and training.

In agriculture the main tasks concern the increase of production efficiency. The activities in cattle raising are directed to the improvment of the milk and meat production ratio per head, including energy conservation from the improved genetic parameters. The reduction of fertilizer amounts and development of ecologically-economically sustainable agriculture are the main goals.

Policy and measures aimed at reducing GHG emissions by sectors are summarized in Table 4.2.2, Table 4.2.3 and Table 4.2.4.

Table 4.2.2. Policy and measures for the reduction of CO_2 emission levels

Economic sector	Economic measures	Laws	Education information	Governmental measures	Voluntary actions	Scientific studies
1. Energy sector 1.A. Combustion of fuels 1.A.1. Energy production and transformation	Differentiated excise tax for different fuels	1. Power engineering regulation laws 2. Natural resource tax	1. Energy Program "Energy 2000" 2. Promotion of heat saving measures in mass media	1. Reconstruction of oil shale power plants 2. Reconstruction of heat distribution networks and installation of heat meters 3. Reconstruction of buildings (insulation of outer walls and roofs, substation windows) to reduce heat losses 4. Utilization of domestic fuels (wood, peat) 5. Organization of energy saving campaigns	1. Replacement of old equipment with new more energy-efficient equipment (refrigerators, fans, pumps, compressors) 2. Reduction of heat losses by improving the insulation of buildings during the cold season	1. Investigation of new combustion technologies 2. Investigation of alternative energy sources (wind, solar) 3. Studies on heat insulation of buildings
1.A.3. Transport	1. Differentiated excise tax on different types of gasoline 2.Governmental tax policy for renovation of car fleet	Rigorous regulations of annual vehicles check-up	Profound education of vehicle drivers	1. Improvement of public roads quality 2. Improvements in public transport system 3. Changes in transport vehicles in favour of electric transport vehicles in towns		Development of control systems for vehicles and fuels
5. Forestry	Fines for unauthorized felling	Laws on forest and forest land management	Consulting and training of private forest owners	1. Preservation of forests, their stability, high productivity and biological diversity 2. Efficient production and utilization of forests-based products	Tidying-up of forests	Studies on energy forests

Table 4.2.3. Policy and measures for the reduction of CH_4 emission levels

Economic sector	Economic measures	Laws	Education information	Governmental measures	Voluntary actions	Scientific studies
1. Energy sector 1.A. Combustion of fuel	Natural resource tax	1. Power engineering regulation laws 2. Natural resource tax	1. Energy Program "Energy 2000" 2. Promotion of heat saving measures in mass media	1. Reconstruction of oil shale power plants 2. Reconstruction of heat distribution networks and installation of heat meters 3. Reconstruction of buildings to reduce heat losses 4. Utilization of domestic fuels (wood, peat) 5. Organization of energy saving campaigns		Investigation of new combustion technologies
1.B. Emission of fugitive fuel 1.B.1. Natural gas	1. Natural resource tax 2. Fines on actions leading to gas leakage			1. Reduction of gas leakages during shale oil production 2. Technical inspection services for gas management		Study of the combustion of oil shale, oil production by products (gas, semicoke)
4. Agriculture			Training of farmers	Breeding of dairy cattle to increase their productivity	Environmentally sustainable production and manure management in small farms	
6. Waste	Fines for unauthorized dumping	Drafting of new laws		1. Improvement in waste storage conditions 2. Utilization of biogas from dumps	Reduction of the waste amount	

Table 4.2.4. Policy and measures for the reduction of N_2O emission levels

Economic sector	Economic measures	Laws	Education information	Governmental measures	Voluntary actions	Scientific studies
1. Energy 1.A. Combustion of fuel 1.A.1. Energy production and transformation	Natural resource tax	1. Power engineering regulation laws 2. Natural resource tax	1. Energy Program "Energy 2000" 2. Promotion of heat saving measures in mass media	1. Reconstruction of oil shale power plants 2. Reconstruction of heat distribution networks and installation of heat meters 3. Reconstruction of buildings to reduce heat losses 4. Utilization of domestic fuels (wood, peat) 5. Organization of energy campaigns		
4. Agriculture		Acts on land management	Providing consultations to farmers	1. Development of ecologicallyeconomically sustainable agriculture 2. Usage of fertilizers according to soil requirements, cultivated plant species and the corresponding yield level	Proper storing of organic fertilizers	

4.3 Possible fuels

The possible fuels for energy production in Estonia are: oil shale, shale oil, coal, heavy fuel oil, natural gas, peat, wood and wood chips, waste.

4.3.1 Oil shale

The active consumption reserves of oil shale in Estonia as of 1 January 1997 were 3972 million tons, including the consumption reserve 2289 million tons and the resource reserve 1683 million tons (Estonian Environment 1996, 1997). The caloric value of commercial oil shale layers is 5–20 MJ/kg and that of limestone interlayers, 0.5–3 MJ/kg. Selectively produced oil shale (approximately 80%) with caloric value of 8.5–9 MJ/kg is used as boiler fuel in big power plants. Part of the rock mined with the lump size over 25 mm is subject to enrichment. The enriched lumpy shale (25–125 mm) with the caloric value of 11–13 MJ/kg is used in the oil shale industry. The organic matter content of selectively produced raw shale is 22–24%, the crude oil yield being 11.5–13%. The organic matter content of enriched oil shale is 28–32%, the crude oil yield by the Fisher Assay retorting procedure is 15–17%.

Current benefits

- Oil shale is an indigenous fuel in Estonia.
- The technology is available from mining to power production.
- Cheapness and high competitiveness in the energy market.
- Through the energy technological cycle the high quality shale oil is provided.
- Provides employment to several thousands people.

Current drawbacks

- Gives 80% of the total emissions in Estonia.
- High factor of carbon emission, resulting from the decomposition of the mineral carbon part of oil shale rock during the high temperature combustion.
- Outdated technologies with low control and automatization level, low efficiency.

To improve the efficiency of oil shale combustion and reduce hazardous and CO_2 emissions, the circulating fluidized bed (CFB) burning technology and extensive flue gas cleaning will be used in large Estonian power plants

4.3.2 Shale oil

Having the same price as heavy fuel oil, this domestic oil will not be competitive with cheaper fuels for heat and power production. But in critical situations with the lack or shortage of heavy fuel oil, shale oil has been and will be the best substitute. Its advantages are lower viscosity and sulphur content. It also does not need so intensive preheating before burners and for transportation. This quality allows the use of shale oil as a basic fuel for gas turbines.

4.3.3 Coal

With the large coal reserves available throughout the world, the price of coal is likely to be less affected than that of gas. This would give coal an advantage. So coal will be one of the most promising imported fuels for power plants as well as for heat and power plants. If the equivalent price of domestic oil shale exceeds the price level of coal, the largest power plants could be refurbished to burn coal instead of oil shale. To burn coal simultaneously with oil shale, using CFB technology, would solve both burning and environmental problems for large oil shale fired power plants.

4.3.4 Heavy fuel oil

The fuel oil is not considered a promising fuel in long-term, due to the high sensitivity of its market to geopolitical aspects of resources and sudden crises.

4.3.5 Natural gas

In spite of its high price, natural gas will be one of the best choices for small boilers, for district heating boiler houses and also for Combined Heat and Power Plants. The carbon emission factor of dry natural gas (15.3 t C/TJ) is the lowest among fuels. For wider availability and in order to decrease the dependence on the monopolistic Russian gas supplies, Estonia has to participate in building the Baltic Ring Line – a gas pipe-line connecting the Stockmanovskoe gas field in the Barents Sea with the European gas suppliers. The possible use of Latvian gas storage will also increase the reliability of gas supplies.

4.3.6 Peat

Peat is a promising domestic fuel in Estonia, both in local and industrial heat and electricity generation. The total peat reserves are estimated at about 1.6 billion tonnes, but only a part of them have energetic value. Annual production of peat is estimated to be 2.4 million tonnes. If burned, this would cover about 30% of Estonia's annual heat demand. During some decades, Estonian peatlands were affected by drainage activities and therefore the peat production is now higher than increment. It means that peatlands have lost their importance as carbon accumulation ecosystems and transformed into sources of CO_2 and only formerly drained peatlands should be taken into use.

As the investment costs in peat fired power plants and boiler houses are about the same order or higher than those in coal fired plants, the peat energy price must stay lower than that of oil shale to be competitive. The carbon emission factor of peat is very high – 28.9 t C/TJ and it is impossible to reduce it even with applying the modern combustion technology. For some towns where large peatfields are nearby the conversion of local boiler houses from expensive oil or gas to peat will be acceptable.

4.3.7 Wood and wood-chips

Wood is used in the countryside, but as a fuel it has only marginal importance, although the forest resources are very large. As wood has become one of the most important Estonian export articles today, it will be a good choice for forestry enterprises to use wood for their auxiliary energy production and for the production of wood-chips and pellets, which can be used by local boiler houses on equal bases with peat. As firewood burned one year regrows the next year, it only supports carbon recycling.

Preliminary estimates of the potential available quantities of forest biomass for fuels have shown that about 2–4 million m^3 of wood (stemwood, tops and branches) should be possible to harvest. The quantity of firewood depends to a large extent on the quantity of industrial wood (saw logs, pulp and boardwood) taken out. The upper part of the interval refers to a harvesting level of industrial wood, guided by the mechanical wood industry, approximately twice as high as the earlier level. These quantities of wood fuels represent about 30 PJ/year.

4.3.8 Waste

Waste cannot be considered seriously as a fuel until a careful waste handling and collection system is arranged. When peat or wood-chips fired (fluidized bed or grate technology) boilers will be installed, the waste should be used to some extent as an additional fuel. Near Tallinn, two boiler houses are already working on methane collected from a city waste dump.

4.4 Programs and measures resulting in the reduction of GHG emissions.

The legislation concerning air protection in Estonia consists of several acts and regulations of the Government and the Minister of the Environment. Most of these legislative acts include also measures reduction of greenhouse gases emissions. Some standards for ambient air quality established during the Soviet period and set mainly to protect human health are still in force. The long-term goal in Estonia will be the full implementation of the European Union environmental legislation. As a result, the overall objective of an ecologically sustainable development will be promoted.

In 1994–97, the following acts and regulations, regulating air protection, were passed, approved or drafted in Estonia:

1. Act on Pollution Charges (RT I 1994, 1, 2). The aim of environmental charges is to stimulate enterprises on environmental protection economically. An environmental charge means monetary compensation enforced by the Estonian Government for the damages caused to the environment (including air pollution) and paid by the polluter.
2. Act of Sustainable Development (RT 1995, 31, 384). The Act contains articles concerning the establishment of standards for air pollutants and the preparation of

national and regional programmes and relevant action plans to reduce emissions of pollutants into the air.

3. Ambient Air Protection Act (draft). The Act contains main principles of the control of ambient air quality, caused by emissions from polluters; the orders of establishment of emission standards and air pollution permits; measures to reduce air pollution, etc.
4. Regulation of the Minister of the Environment on the establishment of the order of application, calculation and payment of the pollution charge (amended by regulation RTL 1995, 4). Compensation for pollution damages caused by pollutants emitted into the ambient air (EEK per tonne) is calculated on the basis of the amount permitted by the pollution permit.
5. Regulation of the Minister of the Environment on the establishment of ambient air pollution permits (RTL 1994, 55; amended by regulation RTL 1995, 4). Permits are issued for a five-year period and are mandatory for all polluters with annual emissions exceeding certain limit values for the various pollutants. Emission permits are issued by the environmental authority that is responsible for the territory where the pollution source is located (county level), or by the department of Environmental Protection of the Ministry of the Environment (national level).
6. Regulation of the Minister of the Environment on the establishment of maximum permissible concentrations of pollutants in the air layer near land surface (RTL 1995, 4, 116–124; amended by regulation RTL 1995, 69, 2417 and regulation RTL 1997, 83, 479). Regulations are prepared under the Act on Nature Conservation and Act on Sustainable Development. The list of standards includes 140 pollutants divided into four classes of toxicity. Air quality limit values of the major pollutants, such as SO_2, NO_2 and particulates correspond to the WHO and EU standards. The Maximum Permissible Concentrations for specific pollutants are partly too strict as compared with the WHO standards.
7. Regulation of the Government on the establishment of pollution charge rates (RT 1995, 36, 1211–1212). Air pollution taxes depend not only on the particular pollutant but also on the character of the polluted area. Direct taxes have been established for six polluting substances: SO_2, CO, non-toxic dust, oil shale fly ash, ash, and NO_x as calculated per NO_2. Taxes for other pollutants are calculated based on the Maximum Permissible Concentrations of the respective substances.
8. Regulation of the Minister of the Environment on the establishment of environmental protection standards for the buildings connected with oil products (RTL 1996, 42, 282).
9. Regulation of the Minister of the Environment on the establishment of standards for the content of pollutants in exhaust gases of motor vehicles (RTL 1996, 144, 698). Standards have been worked out on the basis of EU standards and give limit values for carbon monoxide, hydrocarbons, etc. which are based on the corresponding Council Directive 70/220/EEC (with amendments), 72/306/EEC (with amendments), 88/77/EEC (with amendments).

10. Regulation of the Government on the establishment of emission standards of pollutants into the ambient air from large combustion plants (draft). Emission standards of particulates, sulphur dioxide and nitrogen oxides from large combustion plants are based on the corresponding Council Directive 88/609/EEC (with amendments).
11. Regulation of the Government on the control of volatile organic compound emissions from the storage of petrol and its distribution from terminals to service stations (draft). Technical measures on the control of VOC emissions are based on the corresponding Council Directive 94/63/EC.

4.4.1 Additional information on programmes worked out

Estonia has signed to a number of international conventions. One of these is the 1992 Convention on the Protection of the Marine Environment of the Baltic Sea Area (the Helsinki Convention). The Convention reinforces the priority objectives previously defined to limit eutrophication and polluting substances (including heavy metals and organic compounds) emissions. Estonia participates in different programmes and studies of the Baltic Sea.

Estonian National Environmental Monitoring Programme (incl. Monitoring Programme of Air Quality) was launched in 1994 and is supervised and co-ordinated by the Ministry of the Environment. The main purpose of this Programme is to monitor the long-term and large-scale changes in the environment (incl.air quality) thus identifying problems and helping to find solutions.

Estonia ratified the1992 Framework Convention on Climate Change. Estonia participated in the OECD Common Actions Study, which aims at the identification of relevant policies and measures on the Annex 1 level to the Convention, which could bring along substantial reduction in greenhouse gases emissions. Estonian National Programme on Climate Change is being prepared. Necessary data for the complitation of a realistic action plan for climate change are available.

In 1994 an Estonian Country Study Project was initiated within the U.S. Country Studies Program. It is a comprehensive project, covering all sectors and directions of activity in Estonia that might impact climate change or be influenced by Global Climate Change. Furthermore, the measures for mitigating negative shifts have to be foreseen. To fulfil the Project, a well-qualified team was set up including leading scholars from the Institute of Ecology, Tallinn University of Educational Sciences, University of Tartu, Tallinn Technical University, Estonian Agricultural University and other institutions engaged in different aspects of the Project.

The Project has been very effective – tens of scientific papers, reports and a monograph have been published and widely distributed, tens of interviews have been given in the radio and TV, series of workshops and public presentations have been organized.

The research in the field of climate change is co-ordinated by the Commission on the Implementation of the UN FCCC, formed at the Ministry of the Environment. The Commission is actively involved in work plan development and evaluation, mediation of the members of the team with governmental strategic plans, in data collection and interpretation, and implementing the results of practical work.

In 1997, the Parliament provided the Estonian National Environmental Strategy (RT I, 1997, 26, 390, 834–880), which identified the principal environmental problems facing Estonia, establishes short-term (up to 2000) and long-term (up to 2010) objectives and activities aimed at addressing these problems and achieving set objectives, proposes reforms for instruments and institutions of environmental management. A separate chapter deals with international co-operation in the field of environmental protection and research. Measures for reducing emissions of air pollutants included in the Strategy, are mainly the same as included in the bilateral agreement with Finland (on 2 July, 1993, the Governments of Estonia and Finland signed an agreement in which they agreed to restrict emissions of NO_x to the level of 1987 by the end of 1994, reduce their SO_2 emissions by 50% of the 1980 level by the end of 1997 and draw up plans to reduce SO_2 emissions by 80% of the 1980 level by 2005 at the latest).

National Environmental Action Plan (draft). The plan is focused on defining the concrete conceptual, legislation, organizational, educational, training and especially investment measures in sponsoring the activities of various legal bodies that lead to reaching objectives of the adopted strategy, including concrete measures for reduction of emissions of pollutants into the air to be implemented.

Estonia participated in the work within the 1979 ECE Convention on Long-Range Transboundary Air Pollution. The Act on acceded to the 1979 ECE Convention on Long-Range Transboundary Air Pollution and its protocols concerning reductions of sulphur, nitrogen and volatile organic compounds has been drafted.

4.4.2 International cooperation on climate change

- Economics of Greenhouse Gases Limitations - Phase 1: Establishment of a Methodological Framework for Climate Change Mitigation Assessment. Estonian Case Study. UNEP/GEF project GF/2200-96-15. Sept 1996 - April 1998
- Joint Implementation - Accounting and Accreditation of Joint Implementation Projects Under the Framework Convention on Climate Change and the Oslo Protocol.
- Country Case Study on Climate Change Impacts and Adaptations Assessment in the Republic of Estonia (GF/2200-96-45). 1996-1997
- Sectoral Environmental Assessment on the Utilization of Domestic Peat and Wood as a Fuel Source for Heating Systems. Swedish Board for Investment and Technical Support (BITS). 1993-1994
- Estonia: Climate Change Country Study. U.S. Department of Energy. 1994-1996

4.4.3 Main activities to promote public awareness

- National Workshop on Climate Change Impacts and Adaptation Assessments
  Venue and dates: Roosta, 31 Oct.-1 Nov. 1996

- Workshop on Climate Change and Water Resources
  Venue and date: Tartu, 18 Dec.1996
- Workshop on Climate Change and Forestry
  Venue and date: Tartu, 14 Jan. 1997
- Workshop I on Climate Change Impacts and Adaptation Assessments
  Venue and date: Pühajärve, 12-14 February 1997
- National Workshop on Climate Change Impacts and Adaptation Assessments
  Venue and dates: Pärnu, 25-28 November 1997
- National Workshops on Climate Change Country Study:
  1. The GHG Emissions in Estonia. 15. February 1995
  2. The Impact of Climate Change on the Environment and Society. 2. October 1995
  3. The Possibilities to Mitigate the GHG Emissions in Estonia. 16. April 1996
- Three national reports.
- 72 publications (in the end of 1997), among them monography "Estonia in the climate system" that was distributed to schools in Estonia.
- Many publications in newspapers, presentations in TV and radio broadcasts.

5 Projections of CO_2 emissions

5.1 Energy demand projections

During 1996-97 the EU PHARE Programme financed project "Energy Strategy for Estonia" was carried out. It was accomplished by Tebodin BV (The Netherlands) with the help of several Estonian and Dutch consultants and experts. The main purpose of this study was to assist the Government of Estonia in the preparation of an Integrated Energy Strategy within the framework of the change of the country toward a new and market based policy. The key policy objective for the energy sector was *reliable supply at least cost* where the "least cost" means economic efficiency in all stages of the supply chain, from production to consumption, with regard to the impact on population and the environment.

As one of the results of the above-mentioned study, the final and useful energy demand forecasts were elaborated. At that the following sectoral breakdown of economy was used:

Table 5.1.1. Sectoral breakdown of energy consumers

Industry	Residential and commercial	Transportation
Chemical industry	Specific el. use in households (HH)	Railways
Mechanical industry	Space heating in HH	Road transport
Textiles and leather	Hot water in HH.	Private cars
Food industry	Cooking in HH	Shipping
Wood processing	Lighting in HH	Other transport
Paper and printing	Specific el. use in services	
New large paper mill	Space heating in serv.	
Other non-metallic products		
Fuels and power engineering		
Other industry		
Agriculture		
Construction		

In addition to the sectors given in the Table 5.1.1. also the non-energy use of fuels was projected.

Energy consumption forecasts were derived from two different economic growth scenarios elaborated by Estonian economists in 1996. Both scenarios assume that global political and economic development has a strong influence on the economic development in Estonia. The moderate growth scenario called West-West (WW) assumes Estonia's close integration with western political and economic structures, especially with EU, but relations with Russia and other CIS countries are relatively weak. The high growth scenario called West-East (WE) assumes that Estonia's market is oriented towards both the west and the east and Estonia could become a transit country. As the basic information for the study, the 1995 data were used.

In the WW scenario, an average annual GDP growth 2.5% during 1995 - 2035 was foreseen. In the WE scenario the corresponding figure was 5.3%. In developing useful energy demand projections, an average annual energy intensity improvements 1.4% and 2.9%, respectively, were assumed. In other words, useful energy demand per capita is expected to grow from 76 MJ/capita in 1995 to 121 MJ/capita and 168 MJ/capita in the year 2030 in the WW and WE scenario, respectively. It was assumed that the population of Estonia will not grow during the whole planning horizon, but will even decrease in the first decade.

Except residential energy demand for which useful demand projections were projected, the sectoral final energy demand scenarios were developed (for those sectors final demand equals the useful demand).

In the industry and agriculture sector, the total final consumption projections for sub-sectors were determined as products of 1995 consumption level, macroeconomic volume growth projections and energy intensity improvement assumptions. However, the new large pulp & paper plant was modelled separately.

In the residential sector, the useful demand projections for specific electricity use, lighting, space heating, water heating and cooking were made using forecasts on the number of households and service level per household. The following assumptions were made:

Useful demand for space heating will remain constant (no population growth, more and bigger apartments but better insulation).

70% of households will be connected to district heating grids and 30% will burn their own fuels (firewood, peat briquettes, natural gas, light fuel oil). These shares are not expected to change.

The useful demand for cooking will remain constant.

Useful demand projections for specific electricity consumption and space heating in the services result from macroeconomic growth figures of the sector and energy demand elasticity assumptions

In the transport sector, the final energy demand projections are based on volume growth figures and indicator analysis of transport activities.

Energy demand projections for WW and WE scenarios are presented in Figure 5.1.1.

Aside domestic consumption, electricity export of up to 10 PJ was also envisaged.

Estonian energy system was modelled with MARKAL model. MARKAL (an acronym for “market allocation”) is a demand-driven, multi-period linear programming model of the technical energy system. It is a cost-minimizing energy-environment system planning model used to investigate mid- and long-term responses to different future technological options, emissions limitations and policy scenarios. The MARKAL model optimizes a network representation of an energy system depicting entire system from resource extraction through energy transformation and end-use devices to useful energy demand. This network is called Reference Energy System (RES). Each link in the RES is characterized by one or more technologies available to the model. The model creates the best RES for each time period by selecting the set of options that minimizes cost.

MARKAL calculations for Estonian energy strategy study were carried out by Tallinn Technical University and the Netherlands Energy Research Foundation ECN. Aside making the demand projections, the modelling encompassed also developing of the fuel price projections, assessment of resources and technologies existing today and available in the future, etc. It was assumed that there will be no limits on fuel import and investments, but the electricity import will be restricted.

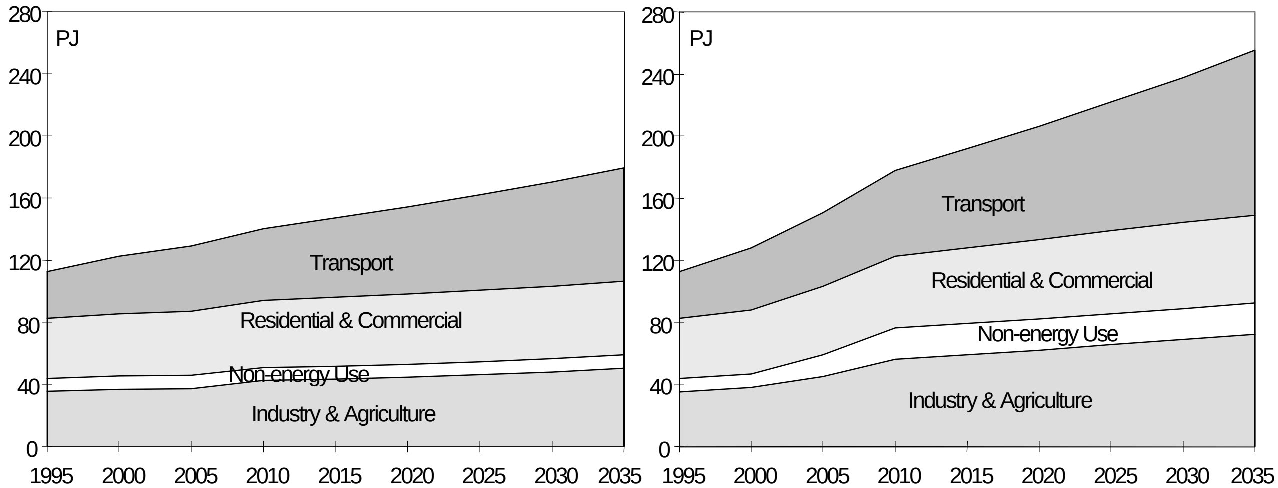

Figure 5.1.1. Useful energy demand projection for WW (left) and WE (right) scenario

Optimal primary fuel supply for WW and WE Base-Case scenarios which correspond to the assumption that Estonia will follow only the existing agreements on emissions limitations are depicted in Figure 5.1.2. In addition to the Base-Cases, several model runs were made to investigate the influence of different fuel prices, technology data, emission charges, etc.

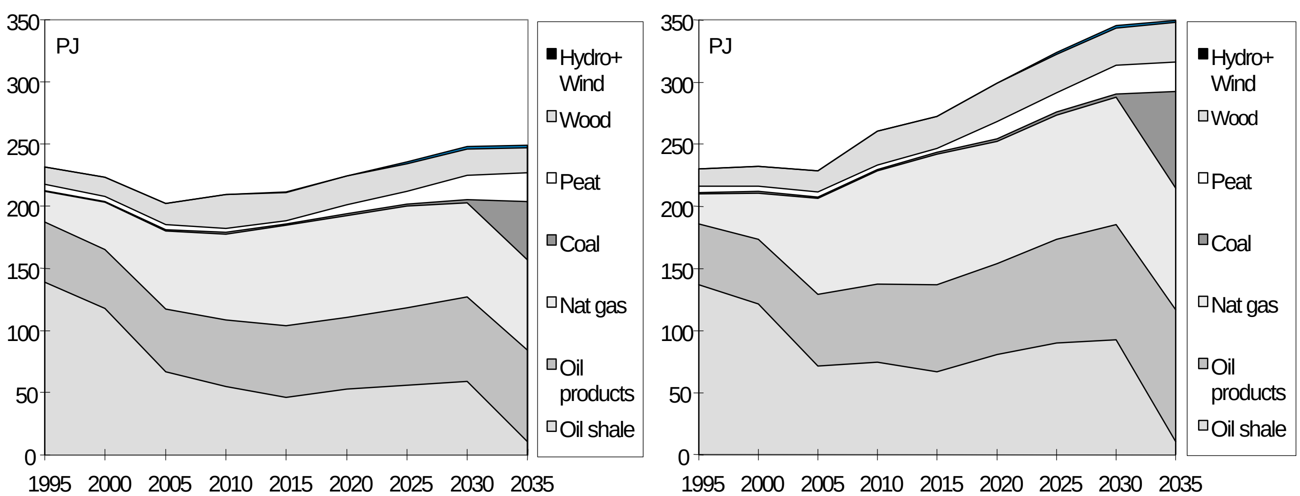

Figure 5.1.2. Primary fuel supply for WW (left) and WE (right) Base-Case scenario

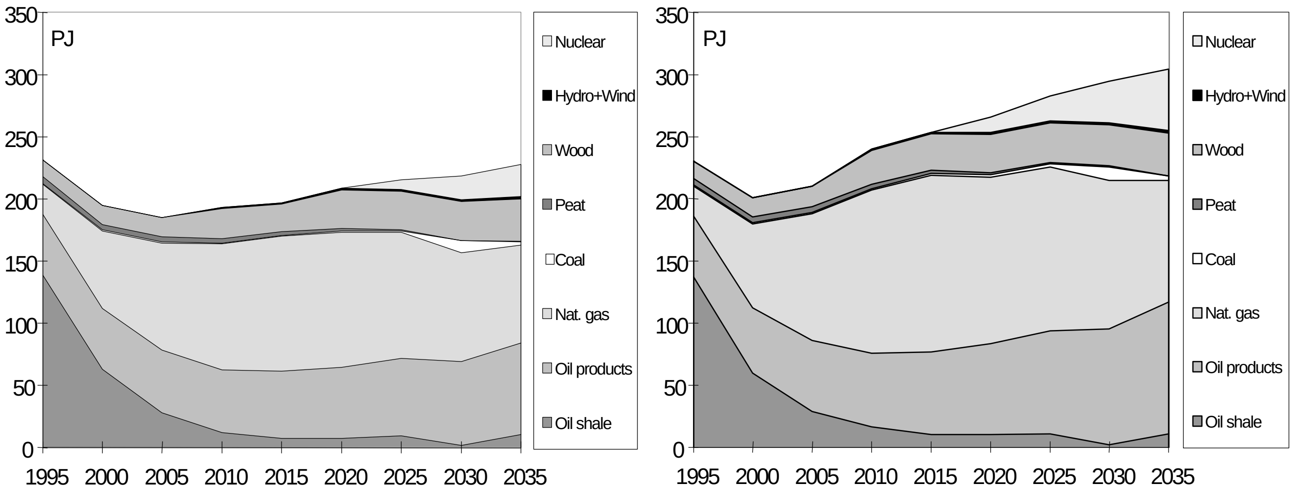

Figure 5.1.3. Primary fuel supply for WW (left) and WE (right) High Taxes-Case scenario

Optimal primary fuel supply for WW and WE scenarios corresponding to the highest emission taxes case considered are presented in the Figure 5.1.3. These taxes correspond to the ExternE study high tax case proposal for EU to introduce 5500 \$/t of SO_2 and 11460 \$/t of NO_X externalities and 20 \$/t of CO_2 tax.

5.2 Energy and industry related CO_2 emissions

Under Estonian energy strategy project only the total CO_2 emissions from the energy system were estimated. Depending on different assumptions on fuel prices, technology data and emission taxes, several CO_2 emission projections were calculated. These projections correspond to the optimal fuel and technology mix under each scenario and can be, therefore, lower than the actual emissions. Still, in all cases the CO_2 emissions stay well below the 1990 level - 37.8 Mt.

CO_2 emission projections for both WW and WE corresponding to the Base-Case assumptions and high emission taxes are depicted in Figure 5.2.1. High emission taxes case means the introduction of mentioned above externalities proposed by EU (5500 \$/t of SO_2, 11460 \$/t of NO_X and 20 \$/t of CO_2) after year 2000.

In all cases the useful energy demand projections did not change. Energy intensity improvements and basic conservation measures were already considered in these forecasts. CO_2 reduction will be achieved by changing the fuel and technology mix. The higher the environmental taxes will be, the more attractive becomes nuclear energy. It became also clear that introduction of wind generators in a large scale and small biomass cogeneration plants needs special political decisions and economic measures.

Considering that Estonia's actual economic growth during 1996-97 exceeded even the optimistic WE scenario assumptions and significant changes in the energy conversion sector have not taken place yet, the CO_2 emissions will hardly be lower than the WE Base-Case projection in the near future.

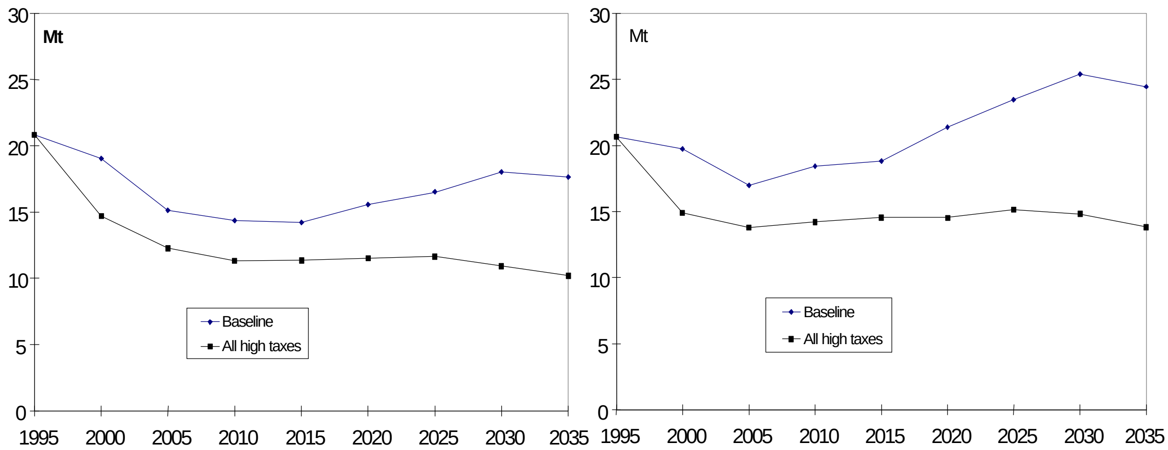

Figure 5.2.1. CO_2 emissions from energy system for WW (left) and WE (right) scenario

More detailed analysis of CO_2 emission projections from Estonian energy system and mitigation options will be carried out under the UNEP/GEF project "Economics of GHG Limitations - Phase 1: Establishment of a Methodological Framework for Climate Change Mitigation Assessment. Estonian Case Study" that ends in 1998.

5.3 Land-use and forestry related CO_2 emissions

The area of managed forests is planned to grow about 300,000 hectares This additional area will be mainly former agricultural It is projected to reach at maximum for the year 2010 when land restitution to private owners is finished and the fate of lands is finally clear. By 2020 about a half of Estonian lands will be under forests and after that the area of managed forests will stabilize.

The increase in the area of forest stocks will be the main reason for an increased CO_2 uptake by forest biomass and soil. But the increased uptake of CO_2 is also caused by increased annual increment. This tendency is expected to continue everywere in Europe.

The emission of CO_2 from forest management activity (harvest) is expected to grow more than twice comparing with CO_2 emission in 1990. As the current total increment in forests is estimated at over 9 Mm^3 per year and it is probably increasing, the current harvest accounting only for a half of it. It is projected that fellings in forests will reach 7.5 Mm^3 per year.

The emission from forest conversion will decrease. The main reason is that there is no need to convert new areas under ditches and forest roads and it is projected only to keep existing drainage network in order.

During the next decade the removal of CO_2 will decrease and after that increase again (Figure 5.3.1.). After the increase of forest land area will end (in 2020) the uptake of CO_2 will decrease, but the budget of CO_2 will be positive. The fellings are not planned to be higher than annual growth increment.

Figure 5.3.1. Projected CO_2 emission and removal

Table 5.3.1. Projected removals (–) and emissions (+) of CO_2 due to forestry and land use change, Gg

Activity	2000		2005		2010		2015		2020	
	–	+	–	+	–	+	–	+	–	+
Forest management										
Biomass growth increment	15,488		16,219		15,995		17,821		18,813	
Harvest		4,910		5,680		6,643		6,932		7,221
Forest conversion										
On- and off-site burning		4		4		4		4		4
Decay		7		1		1		1		1
Soil		246		169		103		33		15
Abandoned managed lands										
Aboveground biomass	1,282		1,038		1,481		1,105		1,077	
Soil	711		576		821		565		550	
Total	**17,481**	**5,167**	**17,833**	**5,854**	**18,297**	**6,751**	**19,491**	**6,970**	**20,440**	**7,241**

Wetlands

As by regulations legislative acts only formerly drained peatlands should be taken into account for projection of CO_2 emissions in wetlands, we can extend the calculated data for years 1990–1996.

6 Effects of climate change in Estonia

6.1 Baseline climate scenario

Within the U.S. Country Study Program the trends and longterm periodical fluctuations in meteorological timeseries in Estonia were established using different general circulation models (GCM) (Kont, et al., 1996). The first regular meteorological observations in Estonia date back to the late 18^{th} century (Figure Mean annual air temerature in Tallinn during 1828–1980), but 1961–1990 was chosen for developing baseline climate scenarios for Estonia because of concerns about the quality of data for Estonia from the 1950s. The later baseline period also allows to use of high quality solar radiation data measured at the Tõravere actinometrical station.

The baseline scenario was developed from spatial mean values of monthly temperature, precipitation, and solar radiation measured at meteorological stations in Estonia and averaged for 1961–1990. Mean temperature was calculated for 25 stations. Spatial mean totals of precipitation were found by interpolating average values into grid points using data recorded at more than 100 precipitation stations. Solar radiation was measured only in Tõravere.

Despite the comparatively small territory, climatic conditions across Estonia are very different. For instance, the monthly mean temperature in January varies from -2.5^{o}C at Vilsandi, the westernmost island of Estonia in the Baltic Sea, to -7.6^{o}C in eastern Estonia. Therefore, temperature was analyzed using not only spatial mean values but also the values measured at the three stations in different locations (Figure 2). Võru (58^{o}N, 27^{o}E) is situated in southeastern Estonia between two uplands; it has the most continental climate. Kuusiku (59^{o}N, 25^{o}E) lies in the plain in western Estonia, and Sõrve (58^{o}N, 22^{o}E) is located in the southwestern point of Saaremaa Island, with the most maritime climate.

The grid points where the GCM results were calculated usually did not lie within the territory of Estonia, so it was necessary to apply spatial interpolation. In this study, the GCM results (air temperature, precipitation) are interpolated for the center of Estonia, and also for the above- mentioned three stations as well as Tõravere (solar radiation). The GCMs were chosen through comparisons between observed and calculated values.

6.1.1 GCM Climate Change Scenarios

Five GCM outputs were evaluated to determine which model provided the best results for Estonia: the Canadian Climate Centre Model (CCCM), the Goddard Institute for Space Studies (GISS) model, the United Kingdom Meteorological Office (UK89) model, and the Geophysical Fluid Dynamic Laboratory (GFDL30) equilibrium run and GFDL transient model. These outputs were combined with the baseline climate data to produce climate change scenarios that could serve as inputs for vulnerability assessments.

No one GCM describes current climatic conditions in Estonia sufficiently. The results of the model runs for precipitation are highly variable. Four models were chosen for V&A assessment in Estonia (GISS, CCCM, GFDL30, GFDL transient). One model (UK89) was not used because of excessively low values of mean air temperature, particularly in winter.

General circulation models are the best sources for developing climate change scenarios. The GCM climate change scenarios are developed by adding the difference between $2xCO_2$ and $1xCO_2$ scenarios to observed values (for temperature) and by multiplying the ratios of $2xCO_2$ and $1xCO_2$ scenarios by the observed values (for precipitation and solar radiation).

The adjustment statistics of the difference between the equilibrium GCM outputs for monthly mean air temperature and precipitation are presented in Table 6.1.1 and Table 6.1.2. All the values are interpolated for the Türi meteorological station (58°49'N, 25°25'E) which is located in the center of Estonia. The data can be used as a spatial mean estimates.

Table 6.1.1. Adjustment Statistics for the Difference Between $2XCO_2$ and Current ($1XCO_2$) Generated by the GISS General Circulation Model

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Year*
Temper.	6.5	5.6	4.8	4.2	3.8	1.5	1.2	1.0	3.4	3.6	5.2	5.5	3.9
Prec ratio	1.18	1.37	1.35	1.48	1.45	1.07	1.88	1.43	1.27	1.32	1.28	1.13	1.35

Table 6.1.2. Adjustment Statistics for the Difference Between $2XCO_2$ and Current ($1XCO_2$) Generated by the CCCM General Circulation Model

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Year*
Temper.	6.5	6.4	5.8	4.9	3.1	3.0	3.1	3.3	2.9	3.3	2.9	3.9	4.1
Prec ratio	1.12	1.33	1.39	1.42	1.09	1.00	0.79	1.20	0.97	1.14	1.29	1.39	1.18

Table 6.1.3. Adjustment Statistics for the Difference Between $2XCO_2$ and Current ($1XCO_2$) Generated by the GFDL30 General Circulation Model

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Year*
Temper.	4.9	4.0	5.8	6.5	5.4	4.2	5.0	4.0	2.9	3.8	7.0	6.9	5.0
Prec ratio	0.96	1.17	1.08	1.50	1.41	1.04	1.00	0.95	1.38	1.25	1.36	1.30	1.20

All the scenarios show an increase of temperature of 1^o to 7°C. As a rule, warming should be stronger during the cold half of the year. The climate change scenarios for precipitation are highly variable. In most cases, increased precipitation is expected.

The results of the GFDL transient model are presented in Table 6.1.4. Adjustment statistics are calculated for the fourth (2000), seventh (2030), and tenth decades (2070) of the transient period. It can be noticed that, as the increase in air temperature is gradual, the most substantial increase in precipitation should take place at the end of the period.

In conclusion, it can be said that the GCM climate change scenarios estimate a general increase in temperature in Estonia, and that winter warming is more substantial than summer warming. They also predict an increase in precipitation, but single model results are quite different. The transient scenario shows that the main increase in precipitation will take place at the end of the transient period, in 2070.

Table 6.1.4. Transient Scenario Using Adjustment Statistics from the GFDL Transient General Circulation Model and Daily Weather Data from 1961-1990

	Fourth decade (2000)		Seventh decade (2030)		Tenth decade (2070)	
	Temp.	Precip. ratio	Temp.	Precip. ratio	Temp.	Precip. ratio
January	1.6	0.98	3.6	1.16	6.4	1.23
February	2.3	0.98	2.9	1.05	3.0	1.16
March	2.9	1.19	3.9	1.25	4.4	1.15
April	1.9	0.82	3.1	0.82	3.7	0.91
May	0.8	1.14	3.0	1.05	3.5	1.03
June	-0.7	1.27	1.5	0.91	2.6	1.52
July	-0.6	0.74	2.1	0.76	3.6	1.15
August	0.5	1.01	2.5	0.93	4.1	1.10
September	1.2	1.12	2.9	1.19	4.2	1.35
October	2.8	1.07	3.3	1.11	4.8	1.28
November	1.1	0.88	3.3	0.97	4.7	1.11
December	1.2	1.17	5.7	1.25	6.9	1.44
Annual	1.2	1.03	3.2	1.04	4.3	1.20

6.1.2 Incremental Scenarios

Developing incremental scenarios is the simplest way to obtain climate change scenarios. They provide a wide range of potential regional climate changes and help identify sensitivities to changes in temperature and precipitation. For Estonia, increases in temperature (+2°C, + 4°C, +6°C) were combined with no change, and with ±10 % and ±20 % changes in precipitation. As a result, 15 incremental climate change scenarios were developed.

The main disadvantage of using incremental scenarios is that they may not be physically plausible. Also, uniform climate changes throughout a year are not realistic. For instance, in higher latitudes (between 57°N and 60°N), including Estonia, estimated warming in winter should be much greater than in summer. Despite these concerns, incremental scenarios are feasible for Estonia, which has great variability in precipitation; warm and rainy years as well as hot and dry years have occurred.

6.2 Agriculture

Agriculture is one of the most vulnerable sectors to climate change in Estonia. It is obvious that changing climatic conditions will affect the productivity of different crops. If it really happens, the policy makers have to apply respective adaptation strategies.

Despite the small size of Estonia, the soil and climate conditions are extremely variable and affect suitability for plant growth. Thus, the effects of changes depend foremost on local meteorological conditions and soil properties. As the results of modeling show, in the case of temperature rise the crop yields will decrease everywhere in Estonia. The most vulnerable are the cultivated areas on dry sandy soils. The fields on gleyic and gleyed soils would be less affected. However, on these soils the yield is so low (1.42–3.20 t/ha) and unstable that cultivation of barley is not profitable there.

Resulted from higher temperatures, the duration of growth period shortens and the biomass formation of barley decreases. A temperature rise of 6^{o}C shortens the growth period by three weeks, which in its turn decreases the amount of precipitation. On dry sandy soils barley yields mainly depend on the rate of nitrogen fertilization and the plant water supply. On the other soils the relative effect of fertilization is less important. In general, fertilization may increase barley yield as much as threefold.

Earlier experiments using biophysical models for the productivity of various crops indicate that the effect of climate change on herbage cultivation is more favourable than on cereals. The productivity of pastures in Estonia depend on light interception, temperature and water supply. The best conditions for herbage cultivation are in western Estonia.

Potato - the main food crop in Estonia - is very sensitive to climate conditions. Usually, high temperatures during planting and sprouting periods of potato exercise a beneficial effect. Various potato cultivars have different disease - resistance, which, in our conditions, has a great importance to the formation of potato yield. By climate change scenarios, it can be concluded that the potato yield becomes unstable, and it may fall, particularly on unfertile and overmoist soils. Unlike herbage, the soil and climate preconditions for cultivation of potato in western Estonia are relatively unfavourable.

Introducing adaptation strategies for the agriculture sector, changes in planting date, application of nitrogen fertilizers, irrigation, and breeding of various cultivars would be of great importance.

6.3 Forestry

The Forest Gap Model generalizes the possible successional directions of forest ecosystems in changing climatic conditions. This prediction is based solely on a knowledge of the ecology of the tree species of contemporary Estonian forests. The results of FGM calculations indicate that the competitive ability of several deciduous tree species (*Populus tremula, Betula* spp., *Quercus robur and* others) could increase significantly in conditions of rising temperature with a subsequent increase of their biomass in the ecosystem, particularly in Central Estonia. The biomass of conifers, currently the dominants in at least 70% of Estonian forests, might decrease in the case of a potential doubling of CO_2 in the atmosphere and a warming of the climate.

The results of the simulation show that the responses of forests to transient climate change depend on the age of trees and the stage of their development, but also on local conditions. A drastic inhibition of biomass and basal area formation in the present forest tree species occurred from the very beginning of their development in the case where climatic conditions were altered from the very beginning. A logical consequence of such a situation would be the replacement of the present species in forest ecosystems by those of more southern distribution.

The analysis of the diagram given by Holdridge (1967) Life Zone Classification Model showed that the forest vegetation of Estonia belongs to the class 'Moist forest' and the postulated climate change would not change the main ecosystem type. Possible changes in the species composition of forest ecosystems were predicted by the comparison of Estonian forest vegetation with that of areas characterized by a warmer climate. It was shown that the invasion of many new tree species, in particular of *Fagus sylvatica, Carpinus betulus* and *Quercus petraea*, is expected. It should be noted that the distribution area of these species is, even nowadays, not very far from Estonia. Consequently, it is probable that if the real changes do take place, a decrease in forest stand biomass and basal area will only occur during the relatively short transitional phase which is needed for the migration of the above mentioned tree species. If human activity accelerates the invasion of new tree species, e.g. by planting and/or sowing them in forest clearcuts, the transitional phase will be even shorter.

In Estonia, the heterogeneity of the landscape, particularly the distribution of various soils, will become an important factor determining forest responses to climate change. In more fertile soil conditions, one could expect the development of *Fagion* forest communities, while in more oligotrophic conditions, the development of *Quercion* communities is expected. However, many landscape characteristics are not incorporated in the framework of the Forest Gap Model which means that precise predictions are difficult to make.

Also, many forest ecosystems are currently under considerable pressure from human activities. Firstly, excluding the protected areas, all forest stands in Estonia are clearcut after certain time intervals. The regeneration of the forest communities depends not only on the technology of clearcutting, but also on the subsequent management of the clearcut areas (fertilization, use of herbicides to suppress herbaceous species, sowing and planting of trees, cutting deciduous trees to favour conifers, burning). The herbivory of large mammals may also influence the direction of changes. Secondly, environmental stresses of anthropogenic origin can not be ignored. Since conifers are typically more vulnerable to air pollution, successional changes due to climatic changes may significantly be accelerated by air-pollution induced processes.

6.4 Water resources

The modelling results indicate that the climate change will be followed by a rise of annual mean groundwater level about 0.5 m in northern Estonia and 0.1–0.2 m. in the south. Significant changes will occur in seasonal variation of the groundwater regime. The water level in spring and autumn will rise, and floods begin earlier. The smallest water level rise is calculated by the climate change scenario of temperature increase of

4^oC and precipitation decrease of 20 %. In this case the weather conditions will be less unfavourable for restoration of groundwater resources than by the other scenarios.

There is no particular need to use additional groundwater resources. In 1994 the total consumption of groundwater in Estonia was 336 mill. m^3 (920.000 m^3 per day). 66 % of the above mentioned amount was pumped out from the oil shale mines. The rest was used for drinking-, agricultural and industrial water supply.

The water resources and groundwater regime analysis, using the climate change scenarios, show that the problems concerning the water resources management do not serve as a limiting factor for socio-economic development in Estonia. Natural variability of precipitation and their infiltration into the ground exceed all calculated changes caused by the climate warming.

In conclusion we can report that future dangers in the utilization of groundwater may be caused rather by negative changes in the groundwater quality than by the decrease in quantity. At the present water consumption level, the reserves of the Estonian groundwater aquifers will be sufficient enough for hundreds of years. Despite this, it is very important to address both the quantity and quality aspects to the future designs of the water supply management.

6.5 Coastal resources

The present analysis makes possible to conclude that the average sea level rise of 1.0 m would result in considerable changes in coastal ecosystems, and lead to remarkable economic hazards. In particular, different regions of Estonia would suffer from different reasons. Increasing erosion and changes in sedimentation regime would cause serious disturbance in the areas of sandy beaches and dunes, particularly in southwestern and northeastern Estonia. In addition, vanishing of sandy beaches will have negative impact on recreation. In the western part of Estonia (including large islands) the direct destruction of the coast will not be so strong, but the interaction of changing water level and land use would cause a decrease in biodiversity. Seashore plant and animal communities would relocate landwards. Moreover, inundation of one of the most important objects of nature conservation in Estonia – the Kasari flooded meadow in Matsalu Nature Reserve as a well known breeding ground for many rare bird species – would have negative influence not only on many local bird populations, but also on populations of migrating birds species of all Europe. The economic hazards will be the highest in the surroundings of Tallinn where the roads, houses and other constructions are often very close to the present shoreline. Saltwater intrusions, in general, would not provide a problem for Estonia. Freshwater consumption by the people do not depend on the upper layers of the groundwater. Drinking water is usually pumped up from very deep aquifers of the Vendian, Ordovician and Silurian sedimentary rocks, which would not be affected by sea level rise and saltwater intrusions. The only problem would come from salinization of coastal soils and plant communities.

6.6 Conclusion

The provided study is concentrate on the influence of global climate change on four main socio-economic sectors: agriculture, forestry, water resources, and coastal resources.

The impact of a 1.0 m sea level rise on the economy of Estonia is also taken into account. The future forecasts do not include the shifts in economy caused by socio-political changes(membership of EC) and the possible shifts in migration due to the climate change. All the studies are based on the present socio-economic structure influenced by the future climate change.

Global climate change will have the most significant effect on agriculture, forestry, and coastal resources. The changes in agriculture will accordingly influence the whole structure of Estonian economy. In the assessment of Estonian agriculture the emphasis was laid on the cultivation of crops. The results showed that due to the climate change the barley yield decreased 17–18% and the potato yield became unstable. The weather conditions were more favourable only for herbage cultivation.

The total effect of the climate change is probably not damaging to agriculture. Moderate rise of temperature and stability of moisture will favour agricultural production, although some restructing activities will be needed: breeding new cultivars as well as changes in planting dates, fertilization, irrigation, and land usage. An increse in the biomass of grasslands and more mild winters will result in the development of dairy-farming, which in its turn would support the production of one of the traditional export articles - foodstuffs.

The effects of the climate change on Estonian forest resources can't be defined so accurately. A summary of the different sample plots shows that the total biomass of forests may decrease 21–35%. The migration of species was not taken into account in the models used in this study. A logical consequence of the climate warming would be the replacement of the present species in forest ecosystems by those of more southern distribution. In this case the results of productivity and economic assessment could be completely different.

The total economic loss because of the sea level rise would be considerable, especially in the storm surge zone. A 1.0 m sea level rise would risk several natural values, but would not cause particular mobility of the population because of relatively sparce settlements and low density of population in the coastal zone. As a result of the sea level rise scenario, about 3% of the territory of Estonia would be inundated or temporarily damaged. As the economic losses are distributed between different owners and take place during a comparatively long period, the activities to protect the seashore are unrealistic in general. The exceptions could be the seaside cities and some beaches of high recreational value.

The climate warming would not cause any problems with water supply. The results of water supply and demand analysis indicate that possible climate change has no particular effect on water management in Estonia. The positive effect may be in lower energy consumption because of milder winters, but also in better navigation conditions because of longer ice free periods in our harbors.

Climate warming will probably cause some changes in the life style and cultural habits (no snow any more), but the shifts because of temperature rise will be less important than those because of cultural contacts.

Finally, we can conclude that the climate change will not have catastrophic effect on Estonian economy. Vice versa, the summary of changes will be even favourable from the economic point of view. It will increase the producers (food manufacturing) surplus and decrease the consumers (heating) surplus in Estonia.

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