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MITIGATION ANALYSIS FOR ESTONIA

Synthesis of Results from the U.S. Country Studies Program

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Summary:

The present report provides data on the mitigation analysis of Estonia. The results for energy, forest and agricultural sectors and macro-economic analysis are given. The Government of Estonia has identified the development of energy production as the main strategical means in the movement towards market economy.

Now 99% of electricity generation and about 25% of heat production in Estonia is based on oil shale combustion. During 1990 - 1993, energy demand lowered due to the economic decline and a sharp rise in fuel and energy prices. Also the electricity exports decreased, resulting in the 50% reduction of total emissions. In spite of the considerable decline in electricity generation, oil shale mining and burning put severe strains on the environment, giving about 80% of the total hazardous emissions in Estonia. To increase the efficiency of oil shale-fired power plants and decrease CO₂ emissions, the State Enterprise (SE) Eesti Energia (Estonian Energy) is planning to reconstruct these power plants and introduce the Circulating Fluidized Bed (CFB) combustion technology for oil shale burning to replace the Pulverized Combustion (PC). The CFB combustion technology for oil shale burning facilitates substantial reduction of the decomposition rate of carbonates in the mineral part of oil shale, and that of CO₂ content in flue gases. In the MARKAL runs the level of 1990 for CO₂ emissions will be exceeded only along with the rapid growth of energy demand growth and absence of emissions control.

According to the Estonian Forest Policy (1996), two general objectives are of importance: sustainability in forestry and efficiency in forest management. These objectives foresee the management and utilisation of forests and forest land in a manner and at a pace, which will maintain their biological diversity, productivity and capacity for regeneration.

For the reduction of greenhouse gases (GHG) emissions from agriculture, it is necessary to increase the efficiency of production resource usage. Under the Estonian conditions, the animal productivity must increase first of all in such a way that methane emissions per production unit will decrease. Nitrous oxide emissions depend on soil-climatic conditions and nitrogen fertilizers applied. In the future fertilizer amounts will not grow. The efficiency of crop production should be increased through the whole soil management.

Regaining independence in 1991 resulted in several changes in the institutional framework of the Estonian economy. The cumulative decline of GDP during the period of 1990 - 1994 was 36 per cent. Estonian economy started to stabilise during the second half of 1994. The growth of the GDP in 1995 was 2.9% as a result of large-scale privatisation activities in Estonia and re-introduction of the available, but unused production capacities with the help of foreign and domestic investments. It is assumed that the medium growth rate of GDP reaches 6% in 1998.

1. INTRODUCTION

The Republic of Estonia is located in the north-western part of the flat East European plain, entirely within the drainage area of the Baltic Sea between 57.30 and 59.49 degrees of latitude and 21.46 and 28.13 degrees of longitude. Estonia is bordered by the Russian Federation in the east, by the Republic of Latvia in the south and has the coastline of about 3,790 km. The total area of the country is 45,221.5 square kilometres (km²), including 4,132 km² of more than 1,500 islands and islets.

Estonia is characterised by a flat topography. The average elevation is 50 m with the highest point being 318 m above sea level. The country belongs to the Atlantic continental region of the temperature zone, which is characterized by moderately warm summers (+17°C in July)

and comparatively mild winters (-4.5°C in February). The amount of solar radiation varies widely during the year. The prevailing winds in Estonia are from the south, south-west, and west, and mainly carry atmospheric emissions from Estonia towards the north and north-east. Since 1990, the resident population of Estonia was 1,571,648; on January 1, 1994, it was 1,506,927. In 1990 and 1994, 71.48% and 70.20% of the population, respectively, lived in urban areas (Statistical Office of Estonia, 1994).

Before World War II Estonia was an independent state for the period of 1918 to 1940. In this period mainly agriculture, light industry, and food industry were developed in Estonia. In 1940 Estonia was annexed by the former Soviet Union. At the beginning of 1950s, special attention was paid to the development of heavy industry based mainly on imported raw materials and immigrant workers. A priority was given to the development of the energy industry based on local oil shale. Electricity generation was concentrated in two oil-shale-fired power plants (1,610 MW_e and 1,390 MW_e) in north-eastern Estonia. These plants were designed to supply power to the north-western region of the former Soviet Union, and therefore approximately 50% of electricity was exported.

Estonian is a parliamentary state with a single-chamber Parliament: the State Assembly of 101 members. The members of Parliament are elected with direct voting, but individual parties must obtain at least 5% of the popular vote in order to be represented. The legislative period of the Parliament is four years.

The Estonian currency an Estonian kroon (EEK) was introduced in June, 1992: Estonian kroon is fixed with DEM (1 DEM = 8 EEK).

The map of Estonia that identifies the main study sites included in the Country Mitigation Assessment is given in Figure 1.1.

After reinstatement of independence the electricity production in Estonia has decreased considerably due to the decrease in exports and restructuring of industry. This process resulted in the decrease of energy production and consumption almost twice in the years 1990 - 1993. In spite of the decrease in energy production, the energy sector is the biggest source of greenhouse gases (GHG) emissions in Estonia. At the same time the number of vehicles is continuously increasing, mostly that of private cars.

Forests cover almost half of Estonia's territory and are an important terrestrial sink for carbon dioxide (CO₂). During the last half-century, the area of forests stands in Estonia has increased more than twice (from 20.2% in 1935 to 47.7% in 1993). Estonian forests belong to the boreal type and are essentially variable, ranging from the forests on sandy dunes to the humid and highly productive mixed forests. The responses of forests to global climate change varies in a large extent.

Estonian agriculture is specialized in animal husbandry. During soviet regime the Estonian agriculture depended on the collective and state farms, and the majority of dairy and meat products were exported to the former Soviet Union. After re-establishing independence in Estonia, smaller units - private farms, and family farms - were established instead of collective and state farms. Since 1990, the field crop areas sown in Estonia and gross agricultural output have decreased by approximately 5% and 28%, respectively (Statistical Office of Estonia, 1994). This is expressed in part by the increase of the area covered with forests, and in part by the expansion of pastures and wastelands. The ongoing restructuring of the agricultural sector may mean a further decrease in sown areas.

Estonian integration into the world economy has been promoted by liberal economic policy and several agreements signed on the state level. Participation in several organizations promoting trade co-operation (free trade and association agreement with the EU, with other Baltic states, the EFTA countries) has accumulated benefits for Estonia, which could be pursued in partnership with other countries.

Based on the data of emissions inventory and assessment of the vulnerability of ecosystems and areas of human activity, mitigation of the climate change in the energy and non-energy sectors was considered. Taking into consideration the present political and economic situation in Estonia, the main objectives in the energy sector are the following:

- * efficiency improvement of oil shale power plants, by the introduction of a new combustion technology (advanced atmospheric fluidized bed combustion of oil shale in power plants);
- * efficiency improvement of heat production in district heating boiler houses;
- * substitution of imported fuels, in particular, fuel oils, with domestic wood fuels and peat;
- * reduction of heat losses in heat transmission, distribution and consumption;
- * replacement of old equipment with new more energy-efficient equipment (electric motors, pumps, fans, compressors, boilers);
- * restructuring of the Estonian economical system to the energy saving regime.

In the non-energy sector the objectives are:

- * fostering of sound forestry and natural resource management practices that limit deforestation and other carbon-emitting, land-use changes:

- * evaluation of the current and future wood product demand and economical evaluation of efficiency in forest management;
- * improvement of animal productivity to decrease methane emission per production unit;
- * better seed selection and fertilizer use in agriculture;
- * taking into account the results of vulnerability assessment to estimate the economical need for further meliorative measures in forestry, agriculture and wetland management.

Figure 1.1. The main sites of study on the mitigation assessment in Estonia

2. ENERGY SECTOR

2.1 Method and Data

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 60%. The actual hydro power 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 economical conditions for its utilisation are non-existent today.

The main fuel used in Estonia is oil shale: 99% of electricity generation and ca 25% of heat production is based on its combustion. The Estonian oil shale as a fuel is characterized by a high ash content (45 - 50%), a moderate moisture content (11 - 13%) and that of sulphur (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, 22.5 million tons and in 1994 - 14.53 million tons of oil shale was produced (Energy Balance, 1995). Oil shale is produced in two quality categories: with the grain size of 0 - 25 mm and that of 25 - 125 mm. The 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 oil shale oil and as a fuel in cement kilns. 80% of the minable oil shale (grain size 0 - 25 mm) with the calorific value of 8.5 - 9 MJ/kg 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, CO₂ 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 (Punning, et al., 1995). If without the decomposition of mineral carbon part, oil shale could be qualified as a fuel with medium CEF = 22 tC/TJ (Hamburg et al., 1996).

Among imported fuels, the share of *heavy fuel oil* (HFO) is the largest. In 1994, 26.049 PJ of HFO and 2.069 PJ of *light fuel oil* (LFO) were used. The consumption of *natural gas* in 1994 was 21.387 PJ (Energy Balance, 1995). In Estonia *coal* is used in small boilers up to 1 MW where fuel handling and ash removal is performed manually (Statistical Yearbook, 1992). In 1994, 2.2 PJ of coal was used in Estonia (Energy Balance, 1995). The Estonian road, railway, air and water transport is completely dependent on imported *motor fuels* (gasoline, diesel oil, and jet kerosene). In 1994, the consumption of motor fuels was at 29.197 TJ (Energy Balance, 1995).

The data on the primary energy supply, final energy consumption and generating capacities are presented in Table 2.1, Table 2.2, Table 2.3 and Table 2.4. (Energy Balance 1993, 1994; Energy Balance 1994, 1995; Energy Balance 1995, 1996, Energy Master Plan, 1992/93).

Table 2.1. Estonian primary energy supply and final energy consumption

Year	1990	1991	1992	1993	1994	1995
Total supply	416.6 PJ	390.6 PJ	277.3 PJ	224.2 PJ	238.7 PJ	225.3 PJ
Oil shale	58 %	56 %	66 %	63 %	63 %	63 %
Fuel oil	18 %	17 %	10 %	14 %	12 %	6 %
Motor fuels	12 %	12 %	10 %	13 %	12 %	13 %
Gas	13 %	13 %	11 %	7 %	9 %	11 %
Coal	2 %	2 %	2 %	1 %	1 %	0
Wood and peat	3 %	4 %	5 %	5 %	7 %	8 %
Electricity	-6 %	-4 %	-4 %	-3 %	-2 %	-1 %
Final consumption	213.4 PJ	208.9 PJ	136.9 PJ	114.0 PJ	114.9 PJ	110.0 PJ

Table 2.2. Primary energy use in 1993

Category	Share in total resources, %
Electricity generation	36.2
District heat production	19.9
Oil shale processing	9.0
Peat processing	0.8
Direct use of fuels	15.1
Non-energy use	1.1
Fuel losses	0.3
Export	3.4
Stockpiles	14.2

Table 2.3. Structure of final energy consumption in 1993 [PJ]

Sector	Electricity	Heat	Fuels	TOTAL
Industry	7.0	25.5	7.1	39.6
Construction	0.2	0.3	1.3	1.8
Agriculture	2.7	0.9	4.8	8.4
Transport	0.5	0.9	20.2	21.6
Households	3.9	16.5	17.2	37.6
Other economy	3.1	1.9	0.2	5.2
TOTAL	17.4	45.9	50.8	114.0
Losses	5.3	3.4	0.7	

Table 2.4. Electricity and heat production capacity

Plant	Erected	El. cap. MW	Th. cap. MW	Effi- ciency	Fuel
Eesti PP	1969-73	1610	84	29%	oil shale
Balti PP	1959-66	1390	690	27%	oil shale
Iru PP	1981-	190	460	49%	oil, gas
Kohtla-Järve PP	1949-59	39	301	28%	oil shale
Ahtme PP	1951-56	20	102	25%	oil shale
Other power plants		64	138		oil, peat, diesel
Boilerhouses			11450		oil, gas, solids
TOTAL		3313	13225		

Two large power plants fired by oil shale: the Baltic Power Plant and the Estonian Power Plant are located near Narva (Figure 1.1, Table 2.4) (Energy Master Plan ..., 1992/93). These plants produce over 95% of total electricity consumption 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% (Sathaye & Mayers, 1995). A comparison of the efficiencies of oil shale-fired power plants with those of conventional and advanced coal-fired power plants shows that CO₂ 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 technically backward. The Estonian Power Plant is over twenty and the Baltic Power Plant thirty years old. These power plants were designed to supply north-west region of the former Soviet Union, nearly neglecting the environmental impact. During the Soviet

regime approximately 50% of electricity was exported (see Figure 2.1).

Figure 2.1. 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 75% of district heating boilers are small with the capacity to 1 MW. Their total share in heat production was 20% in 1994. 80% of total heat 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 their availability are low, heat losses are high, and repairs are frequent. Heat production efficiency of oil shale-based boilers is 62-70%. 70-85% of plants and boiler houses are operating on heavy fuel oil and natural gas, and 50-70% of boiler houses on coal (Energy Master Plan ..., 1992/93). 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 (Energy Master Plan ..., 1992/93). Total heat losses through leakage at the transport from the heat source to the end consumer are up to 30%.

The data on atmospheric emissions is presented in Table 2.5 (Energy Master Plan, 1992/93;

Punning, etc., 1995; Estonian Energy 1992, 1994). Here CO₂ is not presently considered a pollutant in Estonia.

Table 2.5. Gaseous emissions 1990-1992 [Gg]

Year	Solids	SO ₂	CO	NO _x	CO ₂
1990	300	240	440	74	37,184
1991	278	232	390	60	36,342
1992	130	177	125	30	27,453

According to international agreements Estonia must reduce its SO₂ 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.

The comprehensive energy system planning by mathematical modelling was accomplished in 1994. Then the Tallinn Technical University acquired the MARKAL model (Fishbone & Abilock, 1981) from the Swedish National Board for Industrial and Technical Development (NUTEK). The model training was provided by Chalmers University of Technology, Göteborg, Sweden. First this model facilitated data base building and conversion technology options (mainly for electricity production) (Liik, 1995). The impact of air pollution constraints on the development of energy system was first investigated in 1995. To the end of 1995, within the U.S. Country Studies Program a detailed analysis of future CO₂ emissions was made and the reduction options were considered.

MARKAL (an acronym for "market allocation") is a demand-driven, multi-period linear programming model of the technical energy system. It is a cost-minimising energy-environment system planning model used to investigate mid- and long-term responses to

different future technological options, emissions limitations and policy scenarios (Fishbone & Abilock, 1981; Fishbone etc., 1983; Kram, 1993).

In Estonian applications the objective function has been the total discounted net present cost of the energy system over the whole planning horizon.

Key assumptions, new generating technology options, sectoral breakdown of Estonian database and scenario description are presented below.

Key assumptions for MARKAL runs:

- the base year for the MARKAL calculations is taken 1993; the planning horizon is taken 45 years and it is divided into nine 5-years periods;
- long-term annual discount rate is 0.06;
- no limits on fuel import and investments;
- upper capacity bounds established for coal- and gas-fuelled power plants only in the scenarios with forced oil shale use;
- electricity import restricted;
- social and political constraints non-existent or scarcely considered in the scenarios with forced use of oil shale in power production;
- Estonia will not be a large electricity exporter in the future;
- limit for annual wind power production is 10 PJ;
- gradual elimination of so-called "commercial losses" in the electric network during fifteen years (presently ca 10% of production);

- environmental constraints accounted as upper bounds on total emissions, taxes not considered.

Table 2.6. New generating capacity options

Plant type	First year of availability
Reconstruction of existing oil shale plant	1998
New oil shale power plant	2008
Coal fluidized bed (FB)	2008
Natural gas combined cycle	2008
Peak-load gas turbine	2003
Light water nuclear reactor	2023
Wind generator (land)	1998
Peat fired cogeneration heat and power (CHP)	2003
Coal CHP	2003

Table 2.7. Sectoral breakdown of final energy consumers.

Industry	Non-energy use of fuels	Residential and Commercial	Transportation
Chemical Industry	Non-energy use of fuels	Households	Railways
Mechanical Industry		Other Sectors	Road Transport
Textiles and Leather		Economy	Private Cars
Food Industry			Shipping
Wood Processing			Other Transport
Paper and Printing			
Other Non-metallic Products			
Fuels and Power Engineering			
Other Industry			
Agriculture			
Construction			

Scenario description:

Two final energy demand growth scenarios were considered: increasing twofold in forty years and in twenty years. It was assumed that economic growth leads to significant energy conservation. An electricity consumption growth rate higher than that of heat and fuels was taken.

Dynamics of CO₂ emissions was calculated for 9 scenarios:

1. Scenarios with low final energy demand growth:

1.a. BASE - no emissions control,

1.b. REF - reference case considering SO₂ and NO_x restrictions,

1.c. REF - 40% CO₂ - reference case + CO₂ emissions are not allowed to exceed 60% of 1990 level.

2. Scenarios with high energy demand growth:

2.a. BASEH - no emissions control,

2.b. REFH - reference case considering SO₂ and NO_x restrictions,

2.c. REFH-20%CO₂ - reference case + CO₂ emissions are not allowed to exceed 80% of 1990 level.

3. Scenarios with high demand growth and forced use of oil shale:

3.a. OSH_B - no emissions control,

3.b. OSH_R - reference case considering SO₂ and NO_x restrictions,

3.c. OSH_RC - reference case + CO₂ emissions are not allowed to exceed 82% of 1990 level.

Forced use of oil shale means that reconstruction of existing power generating capacity has lower bound and corresponding upper bound is almost three times higher than in other scenarios. At the same time upper bounds were put on the capacity of possible new coal and natural gas power plants.

The source for the energy consumption and supply data in the base year has been the Statistical Office of Estonia. Sectoral breakdown corresponds to the Classifications of Activities of Estonian National Economy. Technical data about existing conversion technologies are taken mainly from (Energy Master Plan, 1992/93). The future price estimates have been made on the basis of Energy Master Plan, 1992/93 and Swedish MARKAL data base used in Chalmers University of Technology. Such figures of new technologies as investment costs, fixed and variable operation and maintenance costs, efficiencies, etc. were taken as European average values from (Kram, 1994) or from the Swedish data base.

Because new prognosis has been published, the future energy demands, phase-out speed of existing capacity and availability of new technologies are the estimates made by the authors.

The early 1990s forecasts (General..., 1990; Energy Master Plan, 1992/93), appear improper because Estonian economy has changed drastically since then. Only in 1996/97, within an EU PHARE Programme project, work on the Estonian energy strategy can begin.

2.1.1 CO₂ Reduction Options

The CO₂ reduction options for Estonia are:

- energy conservation, more efficient appliances on the consumer side. The economically feasible energy conservation potential is estimated to be up to 50% of heat and 30% of electricity (Energy Master Plan, 1992/93). In the MARKAL runs, conservation was taken into consideration by assuming low demand growth;

- change of fuels, especially increasing use of natural gas;
- new clean and efficient conversion technologies, introduction of fluidized bed combustion of oil shale.

2.1.2 Results

2.1.3 CO₂ Emissions Dynamics by Different Scenarios

Results of model runs are presented in the Figure 2.2, Figure 2.3 and Figure 2.4.

Figure 2.2. Dynamics of CO₂ emissions under low energy demand growth

Figure 2.3. Dynamics of CO₂ emissions under high energy demand growth

Figure 2.4. Dynamics of CO₂ emissions under high energy demand growth and forced use of oil shale

Figure 2.5 illustrates increments in the total discounted system cost of all scenarios as compared to the BASE scenario (measured in 1993 GDP). The extra costs to reduce CO₂ are not high because the old and inefficient oil shale power plants must be closed. Moreover, measures to reduce SO₂ and NO_x will also reduce CO₂. Presently, approximately 50% of the 1990 level, CO₂ reduction is caused by a reduced domestic energy demand and a sharp decrease of electricity exports.

Figure 2.5. Increment of the total discounted system cost compared with the BASE scenario and measured in 1993 GDP

Expenditures for the scenarios with forced oil shale use are less than they should be. Factors related to highly extensive mining will raise oil shale price (such as opening of new mines, deeper mines, worsened quality of oil shale, environmental problems). Because no evaluations of the dependence of oil shale price on its amount extracted were publicly available in public, the same price forecast was used for all scenarios.

Marginal cost curves of CO₂ reduction for different scenarios for 2018 are illustrated in Figure 2.6.

Figure 2.6. Marginal cost of CO₂ reduction in 2018

Primary energy demand and fuel composition for the 9 scenarios are presented in the Figure 2.7 and Figure 2.8. Major differences can be noticed in the use of oil shale, coal and natural gas. Nuclear energy will be used in a large extent in the case of high demand growth and emissions control. Windpower will be used only under the high demand growth and constrained CO₂ emissions (Liik, 1995).

Figure 2.9 shows electricity production by fuel for the scenarios with high demand growth. During 1993-2000 slow growth or even reduction in the total generation under constrained emissions is caused by a decrease in electricity exports as compared to the unconstrained

cases. In 1993 electricity exports were 5.74 PJ (Energy Balance 1994, 1995). The upper limit of export was assumed to grow from this figure to 10 PJ in 2033. No electricity imports were allowed.

The total reduction (-) and increase (+) of CO₂ for years 1990-2033 by nine different scenarios are given in Table 2.8.

Table 2.8 Total reduction (-) and increase (+) of CO₂ for years 1990-2033 by nine different scenarios, Gg.

	1. Low final energy demand growth	2. High energy demand growth	3. High energy demand growth and forced use of oil shale
a. No emissions control (BASE)	- 11,954	+ 6,278	+ 9,739
b. Reference case considering SO ₂ and NO _x restrictions	- 12,034	- 4,084	- 1,031
c. Reference case + CO ₂ restrictions	- 14,874	- 7,414	- 6,693

Scenarios without emissions control 2.a and 3.a (see Table 2.8) show the increase of CO₂ emissions over the level of 1990 and therefore are not acceptable. The construction of a totally new oil shale power plant is not attractive under any scenario

a) BASE

b) REF

c) REF-40%CO2

Figure 2.7. Primary energy consumption under low demand growth (export of electricity and secondary fuels like oil shale oil, coke and peat briquettes is not subtracted)

a) BASEH

d) OSH_B

Figure 2.8. Primary energy consumption under high demand growth export of electricity and secondary fuels is not subtracted)

Figure 2.9. Electricity production by fuel under high demand growth

2.2 Conclusions

During 1990-1993, energy demand lowered due to the economic decline and a sharp rise in the fuel and energy prices as well as the decrease in electricity exports. It has resulted in the 45% reduction of CO₂ emissions. At the same period, primary energy supply decreased about 1.9 times. For the same reasons, Estonia has been able to meet the requirements set in the agreements on SO₂ and NO_x emissions with no special measures or costs. 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 CO₂ emissions from the decomposition of carbonate part of oil shale. To meet the higher restrictions to CO₂ and SO₂ and growing energy consumption in the future, Estonia must invest in the abatement and in new clean and efficient oil shale CFB combustion technology. When the available oil shale resources are exhausted and electricity consumption is growing, other fuels (coal, natural gas) will be used. Then the increase in energy demand should not be fast due to constantly rising prices and efficient energy use. Measures applied for the reduction of SO₂ and NO_x emissions will also reduce CO₂ content. In the MARKAL runs the level of 1990 for CO₂ emissions will be exceeded only along with high demand growth and absence of emission control. 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 (CO₂, SO₂, thermal waste) and a severe penalty system, the competitiveness of nuclear power will increase.

In Estonia heat is produced mainly on the basis of imported fuels (fuel oils and natural gas). In district heating boiler houses the boilers are thirty years old and their efficiency is low. It is impossible to replace all old boilers for new ones because it needs time and investment. In a short term, the efficiency of old boilers could be increased by furnishing them with elementary control equipment for optimising combustion regimes and for facilitating necessary repairs. The efficiency of reconstructed boilers for burning domestic fuels (wood and peat) has considerably improved. The reduction of heat losses in heat transmission, distribution and consumption spheres is crucial.

The results discussed here can also change, because the data base is being improved (such as detailed description of energy networks, description of demand-side technologies, accounting

of energy conservation measures, addition of new technology options, change of the base year, revision of costs and prices, etc.).

3. FOREST SECTOR

In 1994 the area of productive forestland in Estonia was over 2 Mha and it covered about 47.7% of the Estonian territory. At the present time the percentage of dominant tree species in the forest land is the following: pine 37.7, spruce 23.6, birch 30.3, aspen 1.6, alder 1.5, white alder 4.3, oak 0.6, ash 0.4.

3.1 Method and Data

Calculations made on the bases of official data from the Estonian Forest Department, and using the IPCC Methodology (UNEP et al., 1995), show that from 1990 to 1994, both emissions and uptake of CO₂ have decreased. There were no CO₂ emissions from forests conversion in 1994, but CO₂ emissions from commercial harvesting and fuel wood consumption increased 6% from 1990. Accounting for changes within the last 4 years, the gross emissions from Estonian forests have decreased 13%. In 1994 the annual removal of CO₂ by Estonian forests was 11,088.9 Gg CO₂, which was only 2% lower than that in 1990. The net CO₂ uptake by Estonian forests in 1994 was estimated at 8,099.8 Gg CO₂ (accounting for CO₂ emissions and removals in the forest ecosystem), which was 2% higher than the 1990 net uptake of 7,919.5 Gg CO₂. This increase in the net CO₂ uptake indicates a possible positive future trend in CO₂ uptake if changes in land use continue.

3.2 Forest Policy Measures

The general goal of Estonian forest policy is the preservation of forests, their stability, high productivity and biological diversity. The general principles of Estonian forest policy have been stated in the Forest Act passed by the Parliament on October 20, 1993. In developing the forestry legislation in Estonia all the principles are observed, which concern the management of forests and their sustainable and multiple use, as for example, the Helsinki Convention 1993, resolutions of the Conference in Rio de Janeiro in 1992 and the resolutions of the Ministerial Conference on Protecting of Forests in Europe, Strasbourg 1990.

In the Estonian Forest Policy (Estonian Forest ..., 1996) two general objectives are set to the Estonian forestry sector:

- * **sustainability of forestry**, which means the management and utilization of forests and forest land in a manner and at a pace maintaining their biological diversity, productivity, capacity for regeneration, and vitality as well as their potential to fulfil ecological, economic and social functions at local, national and global levels without damaging other ecosystems at the present and in the future.
- * **efficiency in forest management**, which entails securing an efficient production and effective utilization of valuable forest-based products and services for the present and future generations.

3.3 Forest Management Activities and Silvicultural Measures

Taking into account of the global warming, the main objectives of the Estonian forest policy to be realized by forest management activities and silvicultural measures are as follows (Estonian Forests , 1995; Yearbook , 1996):

1. To manage at least 20% of the forests as protected or protection forests, on the basis of their particular importance from the environmental, esthetical, cultural, historical or scientific point of view. To conserve valuable ecosystems and maintain forest biodiversity. the size of strictly protected areas will gradually be increased to 5% of total forest area by the year 2010 (the present area being 3%) in order to expand the area of old growth forests under protection, to improve the representatives of conservation areas, and to establish large, contiguous conservation sites. The area of multifunctional forests with light restrictions on cuttings will be maintained at the current level (approximately 15%). The present monitoring system must be improved in order to enable permanent evaluation of the environmental states of forests under the changed climate conditions.
2. To reduce planting on clear-cut areas, leaving more space than it was common in the past for the natural regeneration of birch, ash and other deciduous trees. To increase cultivating deciduous and mixed stands on economic and environmental consideration. To give up establishing pure coniferous stands on former arable lands. As a result of natural competition between tree species, natural regeneration and cultivation, the weight of coniferous will diminish and importance of deciduous will increase. For most deciduous trees Estonia lies in the north part of the area, it means there is no need to plant new tree species into Estonian forest, except beech (*Fagus silvatica*) which may occur in the future as a domestic species in the warmer climate conditions. Into parks many tree and brush species can be introduced. The introduction of seeds, seedlings and plants is suggested from east to west and from south to north.
3. To guarantee the optimum proportion between the volumes of timber from the final and improvement fellings (ca 2:1) and to carry out improvement cuttings while taking into

account also the commercial aspect of these cuttings as well as the aspects concerning environmental protection in the changed climate situation.

4. To consider of special importance the stability and good sanitary conditions of forests, provided by the strict observance of requirements for forest protection and by silvicultural means (selecting the tree species for cultivation in accordance with the site conditions, using natural regeneration more extensively, enriching the composition of species of the stands, reducing the number of wild animals) also in these cases when it will be accompanied by a certain decrease in the increment of timber or possibility of forests utilization. If the climate warming will cause increased mortality of trees, the amount of sanitary cuttings and also thinnings-tendings must increase.
5. To promote rational use of forest resources all forest holdings will be provided with forest management plans free of charge. Forest management will be guided towards environmentally friendly practices. Management practices increasing resistance of forest stands against pests, diseases and environmental changes will be promoted. The area of natural regeneration will be increased from the present level. Regeneration will aim at increasing the share of mixed and deciduous stands.
6. A strategy will be developed for the afforestation of abandoned agricultural lands and former industrial areas. The afforestation will be carried out in the areas where it brings more benefits than alternative land uses when considering the economic values as well as environmental and social values such as biodiversity and landscape conservation and provision of recreational opportunities for urban population.
7. To distribute the knowledge and information about global warming to private land owners.

To assist in the development of private forestry by uniting the private forest owners, by

advising and training private forest owners, by co-ordinating their co-operation and helping them directly by means of the state forestry programs. The latter must include all the forest owners and develop into the main levers of implementing the national forest policy.

8. To work out a taxation policy (prices, taxes, duties etc.) which would enhance the interest to use more deciduous species in forestry.

The precondition for achieving the above mentioned goals is radical reorganization of education, development activities and research work. At the same time the main stress must be laid on the forest ecology and in addition on the issues of forestry economics, planning, legislation and forest-friendly equipment and technology while taking into account the needs of both the large-scale forestry based on state property and these of the small-scale forestry based on private property (first of all the farms simultaneously).

4. AGRICULTURAL SECTOR

4.1 Introduction

Estonian agriculture is specialized in animal husbandry, which formed 2/3 of the total agricultural output before the restitution of independence in 1991. That time agricultural production depended on 300 state and collective farm activities. By the present time almost all of these large farms have stopped existing and over 14,000 small farms have taken their place. Several of these large farms have been restructured into joint stock companies. As private sector has emerged, the intensity of agricultural production has changed. Within the last five years the sowing area has decreased for 191,0 thousand hectares, mainly that of cereal and fodder crops (Table 4.1). The consumption of pesticides and fertilizers has

decreased essentially. In 1990 in average 67.4 kg N from commercial fertilizers and 42.0 kg N from organic fertilizers was used per hectare of arable land. Due to the high price, fertilizer usage has decreased more than twice in the last 5 years. In connection with that the yield of field crops and total production have dropped. In 1990 the total yield of cereals and legumes made 958 thousand tons and the total potato yield. 618 thousand tons accordingly (Statistical Yearbooks, 1991-1995). In the last years the total yield of cereals and legumes has been twice smaller and it does not cover the demand of the domestic market, i.e. 830 thousand tons.

Table 4.1. Use of sown area in Estonia (thousand hectares).

Year	Cereals and legumes	Potatoes	Vegetables	Industrial crops	Forage crops	Total sown area
1990	397.1	45.5	5.2	3.2	665.4	1116.4
1995	302.0	37.6	4.6	6.0	575.2	925.4
Change	-95.1	-7.9	-0.6	+2.8	-90.2	-191.0

Great changes have taken place in animal husbandry. The number of domestic animals has decreased twice (Table 4.2). Therefore, compared with the level of 1990 the production of meat and milk is accordingly over three and two times lower (Statistical Yearbooks, 1991-1995). This drop in production has caused the decrease of GHG emissions from agriculture. From agricultural point of view the emission of methane and nitrous oxide are essential. The emission of methane from enteric fermentation depends on the type and weight of the animal, the quantity and quality of fodder and the energy expository of the animals. Methane emission from animal manure depends on the amount of manure produced and the manure handling system.

Table 4.2. Number of animals in Estonia during 1990-1995.

Animal type	1990	1991	1992	1993	1994	1995
	1000 heads					
Dairy cows	293.9	280.7	264.3	253.4	226.7	211.4
Non dairy cattle	512.2	477.0	444.0	361.2	236.5	208.1
Sheep	140.2	139.9	142.8	124.2	83.3	61.5
Horses	9.6	8.6	7.8	6.6	5.2	5.0
Swine	1080.4	960.0	798.6	541.1	424.3	459.8
Poultry	6922.5	6536.4	5538.1	3418.1	3226.1	3220.0

Nitrous oxide emission depends on the properties of soil, crop type, management regime, fertilizers application, etc.

According to the national agricultural development program, it is foreseen that the production level will not decrease in the future. The goal in agriculture is to satisfy the domestic demand for the main agricultural products. It presumes the production level to reach that of the years 1990-1991. It increased effectivity production which makes the base for sustainable development. According to these principles mitigation options for the agricultural sector are set up.

4.2 Methods

The methane and nitrous oxide emission calculations were based on the IPCC Methodology (IPCC ..., 1994), which was used for GHG emissions inventory as well. Depending on animal type, in case of methane emission, the following coefficients were used Table 4.3.

Table 4.3. Methane emission coefficients.

Animal type	Entire fermentation emission coefficient kg CH ₄ /(head yr)	Manure management emission coefficient kg CH ₄ /(head yr)
Dairy cows	81	6.0
Non dairy cattle	56	4.0
Sheep	8	0.19
Horses	18	1.4
Swine	1.5	4.0
Poultry	-	0.078

The non-ruminant livestock (swine, horses and poultry) produces a relatively small amount of methane compared with ruminant livestock. For that reason in the following analysis the entire fermentation will be discussed in connection with cattle only. The possibilities to reduce methane emissions are dealt in connection with methane conversion factors (MCFs) for different manure management system usage. The manure emission factor was calculated by the equation:

$$EF_i = VS_i \times 365 \text{ (days /yr)} \times B_{oi} \times 0.67 \text{ (kg/ m}^3\text{)} \times \sum MCF_{jk} \times MS\%_{ijk},$$

where: EF_i = annual emission factor (kg) for the animal type i;

VS_i = daily VS excreted (kg) for the animal type i;

B_{oi} = maximum methane production capacity (m³ /kg of VS) for the manure produced by the animal type i;

MCF_{jk} = methane conversion factors for each manure management system j by the climate region k;

$MS\%_{ijk}$ = fraction of animal type i's manure handled using manure system j

in the climate region k.

To estimate the enteric fermentation emission factor for cattle, the feed intake is multiplied by the methane conversion rate as follows:

$$\text{Emissions (kg /yr)} = \text{Intake (MJ/ day)} \times Y_m \times 365 \text{ days} / 55.65 \text{ (MJ/ kg) of methane,}$$

where: Y_m = the methane conversion rate expressed in decimal form

(such as 0.06 for 6%).

Relationship between the productivity of field crops (y , t/ha) and the amount of applied nitrogen fertilizers (x , kg N/ ha) was analysed by using the equation:

$$y = a_0 + a_1x - a_2x^2.$$

Derivation of the equation ($y' = a_1 - 2a_2x$) made it possible to estimate differential efficiency of applied fertilizers, i.e. the efficiency of a fertilizer depending on its amount. Biologically effective amount of a fertilizer ($a_1/2a_2$) allows to obtain the maximum yield, but it is not economically effective. To find out the economic effect of fertilizers application, the present price and market situation was considered. Economically effective amount of fertilizers which enables the maximum profit, is about 20-40% less than the biologically effective amount of fertilizers. The difference will be bigger for unfavourable growing conditions and with a lower efficiency of fertilizers. Nitrous oxide emissions from agricultural soil were estimated using the methodology from the draft IPCC Guidelines (IPCC ..., 1994):

$$\text{N}_2\text{O-N Emissions (g N}_2\text{O /ha)} = F \times C \times 44/28,$$

where: F = amount of fertilizer applied (kg N /ha);

C = $\text{N}_2\text{O-N}$ emissions coefficient (0.0036).

The possibilities in reducing nitrous oxide emissions are analysed in connection with fertilizer requirements of soils and with the efficiency of fertilizers.

For comparing various crop yields and fertilizer efficiency, the yields are calculated in feed units (f.u.) (Oll, 1995). In calculations the following coefficients are considered:

Potatoes - 1 f.u. = 3.70 kg = 9.44 MJ metabolized energy;

Barley - 1 f.u. = 0.88 kg = 9.76 MJ metabolized energy;

Rye - 1 f.u. = 0.83 kg = 9.38 MJ metabolized energy;

Hay - 1 f.u. = 1.90 kg = 14.16 MJ metabolized energy.

4.3 Results

4.3.1 Methane Emission

The calculations done by greenhouse gas emission inventory show that the decrease of agricultural production has caused the decrease of methane emission from 64.1 Gg to 35.4 Gg, i.e. 44.8 % during the last five years (Figure 4.1). From the total methane emission in 1990 86-88% is formed from enteric fermentation, whereas 88% of the total CH₄ emission comes from cattle and 8.7% from swine husbandry (Roostalu & et. al., 1996).

Figure 4.1. CH₄ emissions from enteric fermentation and livestock manure management

Analysing Estonian dairy herd productivity it is possible to point out that the productivity had increased up to 1990 when milk production formed 4287 kg per year (Table 4.4). In the following years milk production has decreased and relative energy requirement has increased (Results 1989-1990; Results ..., 1991-1992; Results ..., 1993-1994). Methabolizable energy per 1 kg milk was consumed the most in the years 1970-1980, because the share of concentrated fodder in feeding was relatively high at that period. The practical energy requirement for lactation depends on the level of production. At the level of 15 kg a day 5.25 MJ are needed per 1 kg ECM (energy corrected milk yield - 3.14 MJ/kg). The requirement is less in the case of low milk production, and relatively higher if the milk production is higher (Oll. 1994; Oll & et. al., 1986). Results of the experiment checking cow's methabolizable energy allowances show that the higher the milk production level, the relatively less feed and energy per unit of the production will be consumed; (Table 4.5, Figure 4.2).

Table 4.4. Milk recording results of dairy herds.

Year	Average milk (3.14 MJ/ kg) production kg ECM/(head yr)	Metabolizable energy (ME) intake MJ/ yr	MJ / kg ECM	kg ECM / MJ
1921	1539	19850	12.9	0.078
1939	2538	25260	10.0	0.100
1960	2770	28070	10.1	0.099
1970	3104	35140	11.3	0.88
1982	3391	38230	11.3	0.089
1990	4287	43660	10.2	0.098
1991	4026	41940	10.4	0.096
1992	3510	38100	10.9	0.092
1993	3428			
1994	3530			

Table 4.5. Milk production of cows and actual metabolizable energy consumption.

Item	Average milk production (kg ECM /head yr)			
	3668	4534	5374	6299
Intake ME (MJ/ yr)	37572	43967	48447	54181
MJ / kg ECM	10.2	9.7	9.0	8.6
kg ECM / MJ	0.098	0.103	0.111	0.116
CH ₄ emission (kg/ head yr)	67.5	79.0	87.1	97.4
CH ₄ (g) / kg ECM (%)	100	95	88	84

By higher milk production the total energy requirement and methane emission from enteric fermentation is the highest. By the given data it is possible to conclude that while milk production increases 25%, the total metabolizable energy consumption will increase by

17%, but for 1 kg ECM milk production 5% less energy will be used. In these calculations ethabolizability of gross energy is taken equal to 60% (Oll, 1993; van Es, A.J.H., 1987).

Figure 4.2. Relationship between milk yield per cow and energy consumption.

(3668 kg ECM/head yr has been taken as 100%).

ECM - energy corrected milk yield = 3.14 MJ/kg,

ME - Methabolizable energy, MJ/yr.

Comparing the results of experimental farms and average state farms it is evident that in state farms the cattle management and nutrition are worse, as the consumption of methabolizable energy per 1 kg ECM is relatively higher. To reach the milk yield of up to 1990, it is necessary to increase methabolizable energy intake approximately by 20 %. In that case the total methane emission would increase, but per 1 kg ECM it would decrease by 6.4%.

Milk yield of Estonian Red breed top production cows varies from 8,500 to 9,500 kg milk in a year and the yearly fat yield is 350-400 kg. Estonian Black-and-White breed top production cows production is even higher, the milk yield reaches up to 10,000-12,000 kg and fat yield 450-500 kg accordingly. Consequently, breeding and improvement of animal husbandry management are one of the major factors, which enables to decrease relative emission of methane. At the same time it must be mentioned that milk recording results in a farm are essentially lower than breeding herd productivity (Table 4.6).

Table 4.6. Milk recording results on Estonian dairy herds and productivity of breeding herds in 1994.

Item	Average results on Estonian dairy herds	Average results on Estonian Red breed herds	Average results on Estonian Black & White breed herds
Milk production (kg ECM/ head yr)	3530	3796	4670
Fat yield (kg/ head yr)	141	156	185
Protein yield (kg/ head yr)	111	123	147

4.3.2 Nitrous Oxide Emission

Compared with 1980s the fertilizer consumption and nitrous oxide emissions have decreased many times by now (Figure 4.3.). It can be explained by the price advance of commercial fertilizers and the decrease in the number of domestic animals. The average amount of nitrogen from commercial fertilizers applied forms 25-30 kg N per ha at the present time. Taking into consideration the nitrogen from manure, the total nitrogen amount per 1 ha arable land forms 45-55 kg. If nitrous emission coefficient is 0.0036, the present nitrous oxide emission per ha is below 300 g. Compared with 1987, when 180 kg /ha nitrogen fertilizers was used, nitrous oxide emission has decreased approximately for 4 times (Roostalu & et. al., 1996).

Figure 4.3. Use of nitrogen fertilizers in agricultural enterprises and private farms.

The level of the present nitrogen fertilizer application is considerably lower than soil requirements (Table 4.7). Fertilizer requirement depends on soil properties and fertility. In the soils with low humus content (below 2%) biologically effective amount of nitrogen fertilizer for potato forms 190 kg N/ha (Piho, 1974; Piho, 1975). If humus content of soils is 2-2.5% or 2.5-4%, the maximum amount of nitrogen fertilizers will be 110 and 66 kg N/ha, accordingly. Applying animal manure for potato fertilization with the rate of 60 t/ha, the norms of mineral fertilizers will decrease for 30%.

Table 4.7 Differential efficiency of nitrogen fertilizers
($y' = a_1 - 2a_2x$; feed unit / kg N)

Crop	Yield on unfertilized soils(a_0 -feed unit/ha)	a_1	$2a_2$	Biologically effective amount of fertilizer	
				kg N/ ha	yield f.u./ ha
Potato	5480	13.8	0.125	110	6240
Barley	2050	17.0	0.170	100	2900
Rye	1960	11.5	0.085	135	2740
Clover/timothy mixture	2250	9.2	0.006	155	3600

As to cereals, the efficiency of nitrogen fertilizers also depends on humus content of soils. If to take for the base 2.5% humus content of the soil, in case of increasing to 3.5%, the efficiency of nitrogen fertilizers for cereal fertilizing decreases by 12-16%. Whereas the soils humus content lessens, the efficiency of nitrogen fertilizers increases at the same rate (Piho, 1974; Piho, 1975).

Considering the given data on biologically effective amount of fertilizers and corresponding yields, the maximum nitrous oxide emission under potato per 1 feed unit is 2-3 times lower than with other field crops. Depending on fertilizer amount applied, the total nitrous oxide emissions form 566-877 g/ ha (Table 4.8).

Table 4.8 Nitrous oxide emissions from agricultural soils in case of biologically effective amounts of fertilizers applied.

Field crop	Nitrous oxide emissions (g /ha)	Relative N ₂ O emissions (g N ₂ O / f.u.)
Potato	622	0.1
Barley	566	0.2
Rye	763	0.28
Clover/timothy mixture	877	0.24

While planning the crop rotations and fertilizer consumption it is very essential to consider soil suitability and fertilizer requirement. At the same time, in the Estonian soil-climatic conditions crop productivity and efficiency of fertilizers vary to a great extent and thus agricultural production has to deal with great risks. In case of more unfavourable soil-climatic conditions, the amount of nitrogen content in the form of N₂O (Figure 4.4) is relatively higher.

Figure 4.4. Relative nitrous oxide emissions from soil depending on soil-climatic conditions and fertilization of barley

I - in very favorable soil-climatic conditions, $P < 10\%$,

II - at early sowing time of barley,

III - at later sowing time of barley,

IV - in very unfavourable soil-climatic conditions, $P > 90\%$.

In 1990 the total milk production was 1208 thousand tonnes. If take this number as a basis, then with the increase of productivity the number of animals can be reduced resulting in the decrease of total methane emission (Figure 4.5).

Figure 4.5. Mitigation of CH₄ emissions from enteric fermentation depending on productivity of dairy cattle.

4.4 Summary

To decrease GHG emissions from agriculture, it is necessary to increase the efficiency of production resource usage. For decreasing methane emission, it is essential to improve

domestic animal management and nutrition. Under conditions prevailing in Estonia, first the animal productivity should improve, which enables considerable decrease of methane emission per production unit. Especially important will be breeding of dairy cattle and swine. Feeding must be balanced and should correspond to the production level.

As presently in a small farm environmentally sustainable production and manure management system are available, it will enable to reduce the total methane emission by 25-30%.

Nitrous oxide emissions depend on soil-climatic conditions and nitrogen fertilizers applied. As fertilizer amounts will not increase in the future, their efficiency should be improved through the whole soil management improvement. The development of ecologically-economically sustainable agriculture presumes the usage of fertilizers according to soil requirements, cultivated plant species and the corresponding yield level.

5. MACRO-ECONOMIC ANALYSIS

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, sharp changes in prices, rapid decrease in the availability of the Eastern market. But it is also due to the conviction in the efficiency of the strict monetary policy used by different governments and the determining effects of the market-oriented economic environment created by it. 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, GDP fell 3.6 per cent in 1990, 13.6 per cent in 1991, 14.2 per cent in 1992, 8.6 per cent in 1993 and 3.2 per cent in 1994. The cumulative decline of GDP during the period 1990-94 was 36 per cent. The decline of industrial production began in 1991 and was 10 per cent then. A further decline of 38.9 per cent followed in 1992, a 27 per cent decline occurred in 1993 and 6.7 per cent in 1994. During the second half of 1994 there seems to have started some stabilization in the economy. The GDP increased 2.9 per cent and industrial output 3.7 per cent in 1995. However, the figures published by the Statistical Office of Estonia have been rather strongly criticized. The Bank of Estonia estimated some economic growth also in 1994. Several reasons could be presented why statistical figures underestimate real economic changes. A very rapid increase of small enterprises not covered by regular statistics and attempts to diminish their turnover and incomes, a rather big share of the shadow economy are some of these reasons. Also the Statistical Office has changed the methodology of calculating several indicators, which complicates the comparing of figures for different years (see figures for 1989-95 in Table 5.1).

Estonia is overcoming the economic crisis with a notably changed economic structure. The shares of trade, transportation and service sector have increased rapidly. The share of manufacturing was 35.1 per cent and that of agriculture (together with hunting and forestry) 21.5 per cent in GDP in 1989. In 1994 the shares of these branches were respectively 16.7 and 8.3 per cent and in 1995 14.9 per cent and 6.7 per cent. At the same time the share of trade in GDP increased from 7.0 per cent in 1989 to 15.8 per cent in 1994 and to 16.4 per cent in 1995, the share of transportation from 6.9 per cent to 8.2 per cent and 8.9 per cent, the

share of financial institutions and insurance from 0.9 per cent to 2.8 per cent and 3.1 per cent, 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 a deep decline of economy and foreign economy shock (a rapid change in terms of trade, deep decline of trade with Russia), which was more complicated for industrial enterprises. Some restoration of the role of these industries should be expected during the next years.

Growth in 1995 occurred for two reasons. First, in 1995 large-scale privatization in the Estonian industry is very close to its end, and the private sector has the dominant role. This clarification of ownership relations is a very important starting point for future economic growth. And secondly, there has been a very deep 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.

Factors promoting Estonian economic development

The small size of the Estonian market and the need to export a great share 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.

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) should also guarantee realization of other advantages as educational level and geographical position.

Table 5.1. Estonian Economic Indicators¹ (Statistical Yearbook 1992, 1992; Statistical Yearbook 1994, 1994; Rajasalu, 1992; Bulletin of Estonian Bank, 1994; Foreign Trade 1993, 1994; Foreign Trade 4/94, 1995; Estonian Statistics, Monthly 5, 1996)

	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.

Future development trends

There are several objective factors, which favour Estonia's development: an advantageous location from the foreign trade point of view between the rich Scandinavian countries and Russia, close integration with the Finnish economy. The future development will depend to a large extent on different ways and possibilities of Estonia's integration.

The basic conditions are determined by Estonia's close integration with Western political and economic structures, above all the European Union. One standpoint of the economic growth is that Estonia will have to chance to become a transit country between the West and East. One prerequisite of this opportunity is that market economic development in Russia will continue. On the other hand, for Estonia such development must include political guarantees from the EU side. It is a scenario of rapid economic growth, especially favourable for the industries whose growth is closely related with providing services to commodity flows between West and East. Since in this case Estonian ports, railways, airports and communication facilities will partly serve also economic activities related with the Russian market, international corporations could be interested in making investments into these areas.

There is also possible a scenario while the economy develops under the condition of Estonia's integration into the EU, but at the same time the development of relations with Russia is notably retarded. This is a scenario of moderate economic growth where the implementation of the methods of solving social and regional problems characteristic of the EU members will play an important role. The economic activities will be restricted mostly to the Baltic and Scandinavian markets, the interest of big international companies in making investments will fall. At the same time, Estonian firms will integrate into the technological cycle of Western firms.

6. SUMMARY OF ASSESSMENT RESULTS

6.1 Energy Sector

Estonian energy balance for 1990-1994 shows dramatic changes in the economy that have taken place after regaining independence in 1991. In 1990-1993, the primary energy supply decreased about 1.9 times. Resulting from the rapid decrease in the export of electric energy and industrial products, a steep increase in fuel prices at the transition from the planned to a market oriented economy took place. Over the same period, the total amount of emitted GHG decreased about 45%. In 1993 the decrease in energy production and consumption stopped, and in 1994 moderate increase could be seen, which was a proof of stabilizing economy.

Oil shale power engineering will remain the prevailing energy resource for the next 20-25 years. After stabilization, the share of oil shale in the Estonian economy will increase. Oil shale combustion in power plants will be the greatest source of GHG emissions in the near future.

For the development of scenarios concerning CO₂ emissions in energy generation the MARKAL model was used. The base year for the MARKAL calculations was taken 1993 and the planning horizon 40 years, the latter being divided into nine 5-year periods. Two different final energy demand growth scenarios were considered: doubling in 40 years and in 20 years, since no new prognosis was available. Development of CO₂ emissions was calculated for 9 scenarios. Three scenarios were calculated for low final energy demand growth (doubling in 40 years): 1.a. - no emission control; 1.b. - reference case considering SO₂ and NO_x restrictions; 1.c. - reference case + CO₂ emissions not allowed to exceed 60% of the level of 1990. Other three scenarios were calculated for high energy demand growth (doubling in 20 years): 2.a. - no emissions control; 2.b. - reference case considering SO₂ and NO_x restrictions; 2.c. - reference case + CO₂ emissions not allowed to exceed 80% of the level of 1990. Last three scenarios were calculated for high energy demand growth and forced use of oil shale in power production: 3.a. - no emissions; 3.b. - reference case considering SO₂ and NO_x restrictions; 3.c. - reference case + CO₂ emissions not allowed to exceed 82% of the level of 1990.

Mitigation options are given in Table 6.1.

Table 6.1 Mitigation options by general criteria

Criteria	OPTIONS (scenarios, see Table 2.8)						
	1.a.	1.b.	1.c.	2.b.	2.c.	3.b.	3.c.
1. Potential for major impact on CO ₂ and other GHGs (total reduction for 1990-2033 in Gg)	11,954	12,034	14,874	4,084	7,414	1,031	6,693
2. Direct Benefit / Cost ratio of the option	Uncertain			Uncertain		Uncertain	
3. Indirect economic impacts:							
* Increase in domestic employment	Medium			Medium		High	
* Decrease in import payments	Uncertain			Uncertain		Medium	

4. Consistency with national environmental goals:				
* Reducing emissions of airpollutants	Medium		Medium	Uncertain
* Effectiveness in limiting other environmental impacts	Medium	High	Medium	Uncertain
5. Potential effectiveness of implementation policies	Medium		Uncertain	Uncertain
6. Sustainability of option	High		Medium	Uncertain
7. Consistency with national development goals	High		High	Medium
8. Data availability for evaluation:				
* Technology characterization	Medium		Uncertain	Medium
* Cost of implementation programs	Medium		Uncertain	Uncertain

The main problems and goals of Estonian energy development are described in: Energy Development Plan to 1995; General Principles of the Estonian Energy Development Until 2030; Energy Master Plan for Estonia; Energy Program "Energy 2000"; Refurbishment of the Narva Power Plants and the Optimization of Oil Shale Mining in Estonia.

6.2 Non-Energy Sector

Estonian agriculture is specialized on animal husbandry, which formed 2/3 of the total agricultural output before the restitution of independence in 1991. Great changes have taken place in animal husbandry. The number of domestic animals has decreased twice. Therefore, compared with the level of 1990 the production of meat and milk has decreased over three and two times, accordingly. The drop in production has caused the decrease of GHG emissions from agriculture. According to the national agricultural development program, agriculture must satisfy the demand for the main agricultural products in the domestic market.

It presumes the production level should increase to the level of the years 1990-1991. To decrease GHG emissions from agriculture, it is necessary to increase the efficiency of production resource usage. In the Estonian conditions first the animal productivity should increase, which enables to decrease methane emissions per production unit considerably. At present sustainable production and manure management system usage in small farms will enable to reduce the total methane emission by 25-30%. Nitrous oxide emissions depend on soil-climatic conditions and nitrogen fertilizers applied. As fertilizer amounts will not increase in the future, their efficiency should be increased through the whole soil management improvement.

Accounting for changes within the past 4 years (1990-1994), the gross CO₂ emissions from Estonian forests have decreased 13%. There were no CO₂ emissions from forests conversion in 1994, but CO₂ emissions from commercial harvesting and fuel wood consumption increased 6% against 1990. The annual removal of CO₂ by Estonian forests in 1994 was 11,088 Gg CO₂, which was only 2% lower than that in 1990. The net CO₂ uptake by Estonian forests in 1994 was estimated at 8,099.8 Gg CO₂, which was 2% higher than that of 1990. This increase in net CO₂ uptake indicates a possible positive future trend in CO₂ uptake if changes in land use continue.

The general principles of Estonian forest policy have been stated in the Forest Act adopted by the Parliament on October 20, 1993.

The main options of Estonian non-energy sector are: sustainability in forestry; efficiency in forest management; improvement of animal productivity; better seed selection and fertilizer use in agriculture.

6.3 Macro-Economic Analysis

Restoration of Estonia's independence in 1991 brought several changes in the institutional framework of the Estonian economy. The monetary reform in 1992 was a major turning point in economic reforms. The most direct consequence of the changed economic environment has been the sharp decline of production in all branches of economy. The cumulative decline of GDP during the period of 1990 - 1994 was 36 per cent. Stabilization of the Estonian economy took place during the second half of 1994. The real growth of GDP in 1995 was 2.9% due to the privatization in Estonian industry and revival of available production capacities with the support of foreign and domestic investments. Eventual growth of investment is the main factor fostering further economic growth. It is assumed that the government shall succeed in accelerating the process of investment. On this assumption the medium growth rate of the GDP reaches 6% in 1998.

Estonia is coping rather successfully with the task to create basic conditions for the future economic growth, but at the same time the Estonian Government must take advantage of other positive factors, such as Estonian educational level and favourable geographical position.

7. DEVELOPMENT OF MITIGATION MEASURES AND ACTION PLANS

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 CO₂ 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 tasks could 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. The largest 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 substituted 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 optimising 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. Energy intensity (energy consumption MJ per USD GDP) of different European countries for 1994 is

the following (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, CO₂ 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 improvement 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 is the main goal.

Policy and measures aimed at reducing GHG emissions by sectors are summarized in Table 7.1, Table 7.2 and Table 7.3.

Table 7.1 Policy and measures for the reduction of CO₂ 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 the private forest owners	1. Preservation of forests, their stability, high productivity and biological diversity 2. Efficient production and utilisation of forests-based products	Tidying-up of forests	Studies on energy forests

Table 7.2 Policy and measures for the reduction of CH₄ 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 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 oil 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 7.3 Policy and measures for the reduction of N₂O emissions level

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 ecologically-economically sustainable agriculture 2. Usage of fertilizers according to soil requirements, cultivated plant species and the corresponding yield level	Proper storing of organic fertilizers	

8. CONCLUSIONS

The main source of GHG emissions in Estonia is the energy sector. The Estonian energy supply will be determined by domestic oil shale for the next few decades. After restoration of Estonia's independence in 1991, the export of electrical energy and industrial products decreased substantially. Therefore the total GHG emissions in Estonia decreased about 40% from 1990 - 1993. In 1993 the decrease in energy production and consumption stopped and in 1994 moderate increase followed. In the future the increase in energy demand should not

grow fast due to constantly rising prices and more efficient energy use. According to the MARKAL runs, the 1990th level of CO₂ emissions will be exceeded only along with the rapid growth of demand and absence of emissions control.

Two big Estonian oil shale fired power plants will be reconstructed to increase their efficiency and to reduce emissions (CO₂, SO₂, NO_x). The PC combustion technology will be replaced by the CFB combustion technology. The CFB combustion technology facilitates substantial reduction of the decomposition rate of carbonates in the mineral part of oil shale, and that of CO₂ content in flue gases discharged from oil shale power plants. In district heating boiler houses the efficiency of old boilers could be improved by furnishing the boilers with elementary control equipment for optimising combustion regimes and facilitating necessary repairs. The reduction of heat losses in heat transmission, distribution and consumption sectors is crucial. The medium reduction potential for CO₂ emissions from the energy sector for years 1990-2033 is 8.3 Gg, if main planned actions will be carried out. The prognoses for the future development of power engineering depend essentially on the environmental requirements.

Restructuring of large-scale agriculture has reduced the total area of arable land by 10 to 20% and the number of domestic animals by 40 to 50%. The decrease in emissions from fermentation and fertilizer application has already stabilized. The decrease in the land area actively used for agriculture has increased CO₂ uptake by Estonian forests for 2% in the last 4 years (1990 - 1994). The net CO₂ uptake by Estonian forests in 1994 was 2% higher than that of 1990. This increase in net CO₂ uptake indicates a possible positive future trend in CO₂ uptake if changes in land use continue.

Cost assessments of mitigation options are highly uncertain, since the Estonian economy is at the transition to the market economy. Further studies should include cost assessments of mitigation options and define the situation in the Estonian energy sector when oil shale resources are exhausted or when strict limitations to emissions and severe penalty system are established.

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