EE9800005

13. ENERGY EFFICIENCY AND GREENHOUSE GASES

A. Hamburg[1], *A. Martins*[2], *A. Pesur*[2] *and I. Roos*[2]

[1] *Ministry of Economy – 11 Harju Str., EE0001, Tallinn, Estonia*

[2] *Institute of Energy Research – 1 Paldiski Rd., EE0001, Tallinn, Estonia*

Introduction

The Government of Estonia has identified the development of infrastructure, which includes the energy sector as a strategy component in the movement towards a market economy.

Estonia's domestic production of natural gas, oil and coal is unsubstantial. Those fuels are therefore imported. However, Estonia has substantial domestic primary fuel resources of oil shale, peat and forests as well as secondary fuel resources of shale oil and peat briquette. Estonia produces almost all of its electricity at two large oil shale power plants. The environmental effects are significant because of gaseous and solid pollutant emissions(mainly CO_2, SO_2, and fly ash). Furthermore, the social affect is marked due to the employment and demographic situation in particular regions. It is evident that Estonia will continue to use oil shale in future. This will contribute to the security of supply and will maintain independence of imported energy resources.

Taking into consideration the present political and economic situation and Estonia's energy resources, the main targets of reducing greenhouse gases (GHG) emission in the energy sector are:

* to improve the efficiency of oil shale power plants, by use of new combustion technology, better control and automation equipment;
* to improve the efficiency of heat production in district heating boiler houses;
* to substitute imported fuels, in particular, fuel oils, with domestic wood fuels and peat ;
* to reduce the heat losses in heat transmission, distribution and consumption.

Energy Balance

Half a century, Estonia was part of the former Soviet Union. Power-intensive and large material-consuming industries were developed in Estonia. At the same time, very low prices of fuels did not stimulate their economical use. Such a situation did not encourage anyone to economize energy. After restoration of Estonia's independence in 1991, the exports of electrical energy and industrial products decreased substantially, in particular, to the eastern market. In free market conditions, fuels prices rose sharply. This process caused a decrease in production and consumption of energy nearly twice.

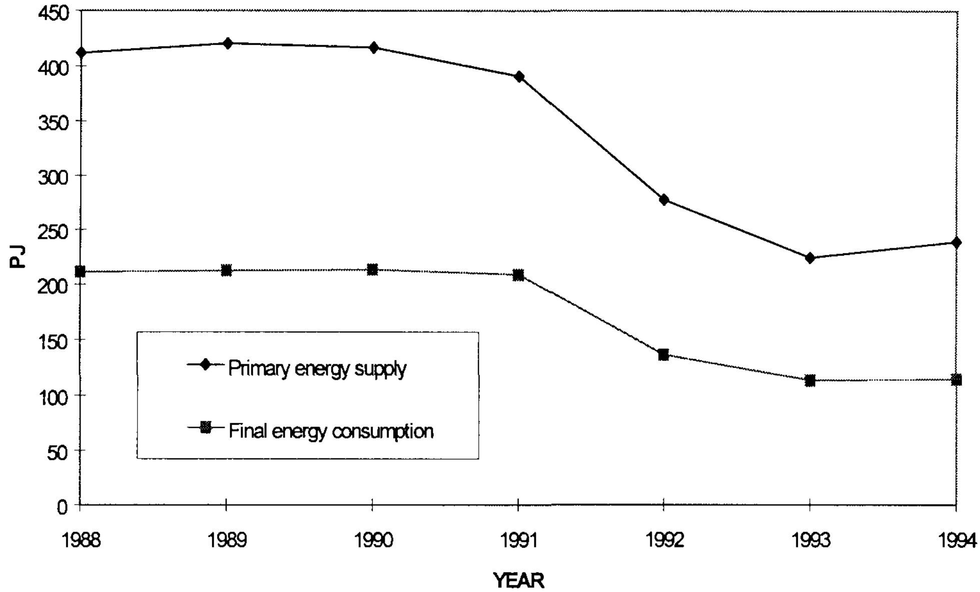

Fig. 1. Primary energy supply and final energy consumption in 1988 – 1994.

In 1990-1993, primary energy supply decreased from 416.613 PJ to 224.169 PJ and final energy consumption, respectively, from 213.436 PJ to 114.048 PJ (Table 1, Fig.1) (Energy Balance, 1995).

Table 1. Energy production and consumption, PJ

Year	Primary Energy Resources	Primary Energy Supply	Final Energy Consumption
1988	535.273	411.698	211.263
1989	530.791	420.315	212.585
1990	520.663	416.613	213.436
1991	462.511	390.614	208.878
1992	337.241	277.302	136.873
1993	277.043	224.169	114.048
1994	306.213	238.720	114.931

In 1993, the decrease in energy supply and consumption stopped, and in 1994, a slight increase followed (Table 1, Fig.1). In 1994, the production of primary energy was approximately 11% higher than in 1933. The 1994 fuel imports increased by 13% as compared to 1993. It was mainly due to the imports of natural gas (30%).

Fuels

Domestic Fuels

Oil shale is obtained from the Estonian and partly from the Leningrad field of the Baltic oil shale basin. In 1986, oil shale reserves in the Estonian field formed 4,200 million t, while commercial supplies were estimated at 1,200 million t. The total thickness of the payable bed in Estonia's field is 2.5 – 3.2 m, of which oil shale layers account for 1.8 – 2.6 m, the other ones are limestone interlayers (State Energy Department, 1992).

The dry matter of Estonian oil shale consists of three main parts: organic, sandy-clay and carbonate. Estonian oil shale as fuel is characterized by a high ash content (45 – 50%), a moderate constant of moisture (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%).

Oil shale is mined from three open pits (50%) and from six underground mines. In 1990, 22.5 million tons of oil shale were produced and in 1994 – 14.53 million tons (Energy Balance, 1995). Oil shale is produced in two qualities: with the grain size of 0 – 25 mm and 25 – 125 mm. The enriched lumpy oil shale (25 – 125 mm) with calorific value 11 – 13 MJ/kg is used in the oil shale industry to produce oil shale oil and as fuel in cement kilns. 80% of the minable oil shale (grain size 0 – 25 mm) with calorific value of 8.5 – 9 MJ/kg is suitable as boiler fuel in large power plants. Net calorific value of oil shale is changeable, showing a decreasing tendency, because best quality oil shale layers are mostly exhausted already.

Oil shale mining and burning place severe strains on the environment, giving 80% of total harmful emissions in Estonia. The impact of oil shale mining on ground surface depends on the type of mining, either opencast or underground, and on the mining methods. Oil shale mining and handling is a source of methane emissions.

As GHG emissions regard, it is important that during combustion of pulverized oil shale, CO_2 forms not only as a burning product of organic carbon, but also as a decomposition product of fuel mineral part. But obviously Estonia has to produce oil shale-based power and heat as long as it is economically, technically and environmentally viable. It is because oil shale is an Estonian indigenous fuel and technologies from mining to power production and processing are available. Oil shale mining, power production and processing provides occupation to thousands of people.

The crude *oil shale oil* is produced by the State Enterprise Kiviter (former Oil Shale Chemistry Enterprise at Kohtla-Järve and the Kiviõli Oil Shale Chemical Integrated Plant) in internal combustion vertical retorts and by the Estonian Power Plant in solid heat carrier retorting units. In 1994, 301,000 t of oil shale oil was produced (Energy Balance, 1995).

The crude oil shale oil has a low solidification point (-10°C) and a moderate sulphur content, $S <$ 0.8%. The density of crude oil shale oil at 20°C is 1.00 t/m^3, and ash residue content is below 0.3%. The calorific value of shale oil is 40 MJ/kg. Crude oil shale oil is used as a fuel in medium and small boilers. In critical situations, with lack or shortage of heavy oil, oil shale oil has been and will be the best fuel to replace imported fuel oils or natural gas.

Approximately 22% of Estonia's territory is covered by peatlands. The resources of *peat* for heating are estimated at 2,646 PJ (at moisture 40%) and production capacity is 58.49 PJ (IVL , 1994; Biomass Tech., 1995). In 1994, the primary energy supply from peat was 4.29 PJ (Energy Balance, 1995). Peat is used as peat briquette, pressed peat, and sod peat. Peat briquette is mostly used in households. Pressed peat and the recent sod peat are burned in boilers of central heating systems. The calorific value of peat briquette is approximately 17.3 MJ/kg, that of pressed peat 12.6 MJ/kg (at 30% moisture), and that of sod peat 8.9 MJ/kg (at 45% moisture).

It is estimated that some 48% of Estonia's territory is covered by forests. As *wood* has become one of the most important Estonia's export article today, it will be beneficial for forestry enterprises to use wood for energy production and for wood-chip sales. Wood chips are used in local boiler houses. The calorific value of wood is 11.5 MJ/kg (at 30% moisture). It is estimated that 22 – 35 PJ of wood fuel could be used annually in Estonia (Biomass Tech., 1995). In 1994, wood fuel use formed 12 PJ (Energy Balance, 1995).

Imported Fuels

Among imported fuels, the share of *heavy fuel oil* (HFO) is the largest. HFO and *light fuel oil* (LFO) have been imported mostly by rail from Russia. From overloading places (Tallinn, Tartu, Pärnu, Võru, Narva and Kohtla-Järve), HFO and LFO are transported by trucks to boiler houses in towns and settlements. In 1994, 26.049 PJ of HFO and 2.069 PJ of LFO were used (Energy Balance, 1995).

At present, *natural gas* is imported to Estonia only from Russia. The length of pipelines for gas transport is 2,139 km, that of transmission pipelines 930 km and that of distribution systems 1,209 km. The 1994 consumption of natural gas 1994 was 21.387 PJ (Energy Balance, 1995). Natural gas is best for boilers of district heating boiler houses and central heating power plants as well as for condensing power plants. Natural gas-based gas turbine or gas-combined cycle technologies can provide for small-town heating through high efficiency heat and power co-generation. To achieve wider availability and to loosen the dependence on Russian gas supplies, Estonia and other Baltic states (Latvia and Lithuania) have to collaborate in the studies of a possible interconnection to the Polish gas system. Further-more, the possible use of Latvian gas storage will increase the reliability of gas supplies. Norway-based pipeline projects appear in feasible within the considered period (PHARE , 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). Over the recent years, coal was imported to Estonia from Poland (Silesian coal) and from Russia. In 1994, 2.2 PJ of coal was used (Energy Balance, 1995). If oil shale price exceeds that of coal, large power plants could be refurbished to burn coal instead of oil shale. To burn coal with oil shale, using circulating fluidized bed (CFB) technology, would solve both burning and environmental problems for large oil shale-fired power plants.

The *motor fuels* (gasoline, diesel oil, and jet kerosene) are imported chiefly from Russia. However, small quantities come from Lithuania, Finland, Byelorussia, Kazakhstan, Azerbaijan, Norway, and Sweden. Estonian road, railway, air and water transport is completely dependent on imported motor fuels. In 1994, motor fuels consumption was at 29.197 TJ, thus exceeding that of 1992 by 2.38 TJ.

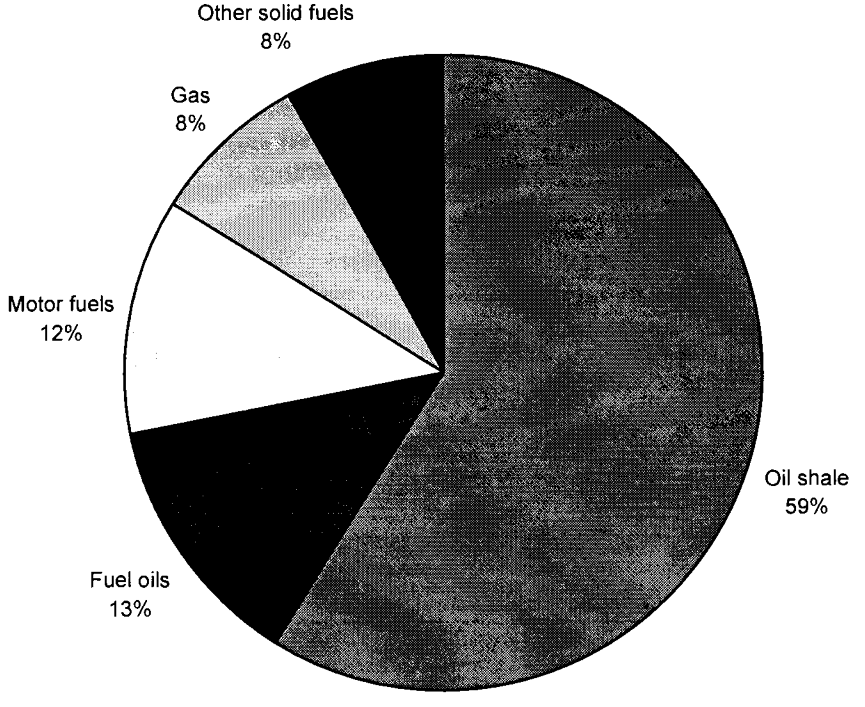

Fig. 2. Consumption by kinds of fuel in 1994, % of PJ.

Among the fuels described above, oil shale is the most important fuel for Estonia. In 1994, 151.7 PJ of oil shale was used, which forms 59% of the total fuel consumption (Fig. 2). The share of other fuels was: fuel oil – 13%, natural gas – 8% and other solid fuels – 8%.

Oil shale is the main source of GHG emissions in Estonia. For oil shale burned in power plants, physical cleaning (enrichment) is not used. It means that limestone is not separated from oil shale. An important means of reducing CO_2 emissions from limestone decomposition during oil shale combustion is separation of limestone particles from oil shale before burning. Another method of oil shale beneficiation is to use advanced mining technology, where oil shale layers and limestone interlayers are mined separately.

Imported fuels are being substituted with domestic wood fuels and peat. This process can continue when efficient production and preparation technologies for domestic fuels have been established and implemented, and proper boiler types and combustion technologies have been selected.

To reduce GHG emissions in combustion processes, it is crucial for the Ministry of Economy of the Republic of Estonia to elaborate the quality requirements for all fuels available and to implement the quality control and quality assurance systems in Estonia (Energy 2000, 1995).

Power Plants

Two large power plants fired by oil shale: the Baltic Power Plant and the Estonian Power Plant are located near Narva (Table 2) (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 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 is about 38% (Sathaye & Mayers, 1995). The aim is to achieve an approximate efficiency of 40%. The higher efficiency of a power plant corresponds to lower CO_2 emissions per MWh electricity generated. 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 peculiarities of burned 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. The Kohtla-Järve and the Ahtme CHP Plants were built in the 1940s and the 1950s.

Table 2. Largest power plants in Estonia

Name of Power Plant	Real Capacity, MW_e	Heat Capacity, MW_{th}	Efficiency, %	Fuel
Estonian Power Plant	1,610	84	29	Oil shale
Baltic Power Plant	1,390	686	27	Oil shale
Iru CHP Plant	190	749	49	HFO, natural gas
Kohtla-Järve CHP Plant	39	534	28	Oil shale, HFO
Ahtme CHP Plant	20	338	25	Oil shale
Ülemiste CHP Plant	11	278	68	Natural gas, HFO
TOTAL:	3,260	2,669		

Each year, millions of tons of alkaline ash containing several microelements are disposed of from the power plants to ash fields. Ash fields now cover surrounding areas of about 2,000 hectare, over 200 million t of ash having been disposed of there.

To restructure the power plants in Narva, the State Enterprise (SE) Eesti Energia has planned several activities. Among the main aims established are: to increase the efficiency of power plants, to reduce the level of SO_2 emissions to internationally acceptable values, to solve the ash removal problem. Theoretically, the molar Ca/S ratio of 8 – 10 in oil shale should be high enough for effective sulphur removal, but to the high temperature in pulverized combustion (PC) processes, the SO_2 capture efficiency is low. In world practice, molar Ca/S ratio value 2 – 3 is enough in fuel for effective removal, in particular, using circulating fluidized bed (CFB) combustion technology. Therefore, SE Eesti Energia is planning to study the feasibility of using CFB combustion technology for oil shale instead of the PC technology. The largest energy companies (Lurgi, ABB, Ahlstrom) are engaged in this project (Refurbishment of Narva PP, 1995).

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.

Several other cheaper SO_2 removal methods (wet gypsum process, semi-dry process, Ahlström scrubber) are being tested and studied for flue gas cleaning preserving pulverized combustion technology (Refurbishment .... , 1995). In this case, CO_2 reduction in flue gases is insignificant.

Heat Production

Heat is produced by power and co-generation plants in district heating boiler houses and industrial enterprises. Table 3 shows the number of boilers, capacity and generated heat for 1992 – 1994 (Energy Balance, 1995).

Table 3. Number of boilers, capacity and generated heat

	Years		
	1992	1993	1994
Number of boilers at the end of the year	7,315	5,353	5,586
Total capacity, MW	11,777	11,449	11,810
Generated heat, PJ	46.79	33.53	33.14
The share of, % coal	6.3	4.9	4.2
oil shale	1.9	1.9	1.5
peat	1.2	1.5	2.4
wood	2.0	4.1	7.7
fuel oils	51.7	59.8	53.8
gaseous fuel	33.6	26.4	23.3
electric energy	1.2	1.0	1.3
other fuels	2.1	0.4	5.8

About 75% of district heating boilers are small with capacity up 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 capacities 2 – 116 MW.

As the technical equipment is thirty years old, the boilers' efficiency is lower than stated on the manufacturer certificate, automation and control of burning process are non-existent or fail. As a result, boilers' efficiency and availability are low, heat losses are high, and repairs are frequent. Heat production efficiency of oil shale-based boilers is 62 – 70%, 70 – 85% for plants and boiler houses operating on heavy fuel oil and natural gas, and 50 – 70% for boiler houses operating on coal (Energy Master Plan ..., 1992/93). The efficiency of wood- and peat-fired boilers is 65 – 80%. In the highly developed countries, the efficiency of boilers with the same capacity is 85 – 90% and more (Lampinen, 1991). The higher efficiency of boilers corresponds to the lower CO_2 emissions per PJ heat produced. Replacement of all old-fashioned boilers needs time and investment. However, the efficiency of old boilers could be increased by furnishing them with elementary control equipment to optimize combustion regimes and carry out necessary repairs. Based on our experience, in many cases, the efficiency of old boilers could be increased by 5 – 10%.

Heat Transmission, Distribution and Consumption

District heating, well developed in Estonia, supplies most towns and small towns with heat and steam. The system is also well developed in the rural areas.

The total length of heat pipelines is about 2,200 km (Energy Master Plan ..., 1992/93). More than 90% of all pipelines are underground encased in concrete channels and isolated with mineral wool and covered with laminated or non-laminated bitumen board. The average age of heat pipelines exceeds ten years, and their condition is bad because of insufficient repairing facilities. Heat losses in the networks are estimated at 6 – 12%, but total heat losses through leakages from the heat source to the consumer are considerably higher, forming up to 30%. For instance, in highly developed countries, power transmission and distribution systems generally have losses in the range of 5 – 10% (Sathaye & Mayers, 1995). To achieve a good technical level, modern preinsulated pipes with control and adjustment equipment must be installed in district heating systems.

Over 60% of state-owned buildings are post-war apartment buildings, mainly five- or nine-storeyed prefabricated concrete block constructions with very thin insulation layers. Heat losses in these buildings are very high, for instance, because of poor-quality window design, low heat resistant outer walls, natural ventilation. Major repair work to improve the insulation has started. But as these projects are very expensive, they can cover only a fraction of the real need.

GHG Emissions from Energy Use

Energy-related activities are the most significant contributor to Estonia's GHG emissions. Emissions from fossil fuel combustion contribute massively to these energy-related emissions with releases of CO_2 from fossil fuel combustion. Activities related to the production, transmission, storage and distribution of fossil fuels also emit GHG. The main gas emitted through these activities is methane, while smaller quantities of non-methanous volatile organic compounds (NMVOCs), CO_2 and CO can also be emitted. The emissions of these gases are much lower than those of CO_2.

The amount of carbon in fuel varies significantly by fuel type. To estimate the GHG from energy activities, the IPCC methodology (Greenhouse ... Workbook, 1994, 1995) was used. Carbon emission factors (CEF) used for calculating CO_2 emissions from energy sources are given in Table 4.

Greenhouse Gas Inventory Workbooks (1994, 1995) do not contain information about Estonian oil shale and its carbon emission factor. Therefore a formula compiled by A.Martins for calculating the carbon emission factor of Estonian oil shale, taking into account the decomposition of its mineral carbonate part, is as follows:

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

where Q^r_i - net caloric value oil shale as it burned, MJ/kg;

C^r_t - carbon content of oil shale as it burned, %;

$(CO_2)^r_M$ – mineral carbon dioxide content of oil shale as it burned, %;

k - decomposition rate of ash carbon part (k = 0.95 – 1.0 for pulverized combustion of oil shale) (Kull & et. al., 1974).

Table 4. Carbon emission factors (CEF)

Fuel	CEF, tC/TJ	Fuel	CEF, tC/TJ
Primary Fuels		Primary Fuels	
Liquid Fossil		**Solid Fossil**	
Crude Oil	20.0	Anthracite	26.8
Natural Gas Liquids	17.2	Coking Coal	25.8
		Sub-Bituminous Coal	26.2
Secondary Fuels		Lignite	27.6
Gasoline	19.9	Peat	28.9
Jet Kerosene	19.5	Oil Shale	29.1
Other Kerosene	19.6		
Gas/Diesel Oil	20.2	Secondary Fuels/Products	
Residual Fuel Oil	21.1	BKB & Patent Fuel	25.8
LPG	17.2	Coke	29.5
Ethane	16.8		
Bitumen	22.0		
Lubricant	20.0		
Petroleum Coke	27.5		
Refinery Feedstocks	20.0		
Other Oil	20.0		
Gaseous Fossil		**Biomass**	
Natural Gas (Dry)	15.3	Solid Biomass	29.9

Table 5 shows reference approach of CO_2 emissions from energy sources for 1990 – 1994. Fuel wood burned one year but regrown the next year only recycles carbon (short carbon cycle). As a result, carbon dioxide emissions from biomass have been estimated separately from fossil fuel-based emissions and are not included in national totals.

Since 1990, energy production and consumption have continuously declined up to 1993 because of the economic depression in Estonia (Statistical Yearbook, 1994). The result was a decrease in CO_2 emissions (Table 5, Fig. 3). For instance, in 1990 total CO_2 emissions from fossil fuel combustion were 37,183.8 Gg, but in 1993 – 20,214.8 Gg. Thus, during these years CO_2 emissions from energy sources have decreased by 45.6% in Estonia.

Table 5. CO_2 from energy sources, Gg

Fuel Types	1990	1991	1992	1993	1994
Fossil Fuels Total	***37,183.8***	***36,342.2***	***27,453.3***	***20,656.1***	***21,412.6***
Liquid Fossil Fuels	**9,734.4**	**8,566.6**	**5,023.4**	**4,393.6**	**3,868.0**
Natural Gas Liquids	95.6	91.9	40.4	21.7	30.4
Gasoline	1,688.4	1,417.3	681.4	694.6	858.1
Kerosene	419.8	262.7	68.8	157.6	147.2
Jet Kerosene	112.1	109.9	37.3	57.4	47.4
Diesel Oil	1,886.9	1,826.2	1,198.9	1,280.1	1,174.7
Heavy Fuel Oil	5,500.2	4,700.0	2,921.2	2,182.2	1,608.9
Other Oil	31.4	158.6	75.4		1.3
Solid Fossil Fuels	**24,595.4**	**24,908.6**	**20,753.5**	15,429.4	**16,350.8**
Oil Shale	23,051.4	23,011.7	19,347.8	14,855.0	15,867.0
Coal and Coke	890.3	872.8	544.4	187.6	96.4
Peat	653.7	1,024.1	861.3	386.8	387.4
Gaseous Fossil	**2,854.0**	**2,867.0**	**1,676.4**	**833.1**	**1,193.8**
Natural Gas	2,854.0	2,867.0	1,676.4	833.1	1,193.8
Biomass Total	**1,073.9**	**796.5**	**843.7**	**793.5**	**1,289.3**
Solid Biomass (Wood)	1,073.9	796.5	843.7	793.5	1,289.3

In 1990 – 1993, the largest decrease occurred in the consumption of imported fuels. Therefore, CO_2 emissions decreased for natural gas – 71%, kerosene – 60%, gasoline – 57%, heavy fuel oil – 64%. From oil shale, a 35% decrease of CO_2 was observed. Over this period, the prices of fuels have increased very sharply. The price of natural gas has risen more than 700 times, heavy fuel oil about 450 times, gasoline and diesel oil 150 times within a year and a half. Peat and wood are not used on a large scale, though their prices have not increased so steeply as those of imported fuels. There was several reasons. It is impossible to burn wood and peat directly in oil- or gas-fired boilers. Reconstruction of old boilers and purchase of new ones needs investment, but loans are often unfavourable. Out-of-date equipment hinders the further expansion of peat fuel production. If modern equipment is introduced, the price of peat energy will rise.

In 1993, the decrease in energy production and consumption stopped and in 1994, a moderate increase followed. The increase in energy production led to an increase in CO_2 emissions (Table 5 and Fig.3). In 1994, the increase in CO_2 was 5.6% higher than in 1993 (excl. CO_2 from wood burning).

The relative parts of CO_2 emissions from fuels burned in 1990, 1993 and 1994 are presented in Fig.4. The share of CO_2 emission from oil shale burning is continuously increasing and that from liquid fossil fuels burning are decreasing. The share of CO_2 emission from natural gas burning reached a minimum in 1993, but in 1994 it increased.

Activities concerning the production, transmission, storage and distribution of fossil fuels also serve as sources of GHG. These are primary fugitive emissions from natural gas systems, oil shale mining and processing. The largest amount of non-CO_2 emissions comes from the transport sector (Table 6).

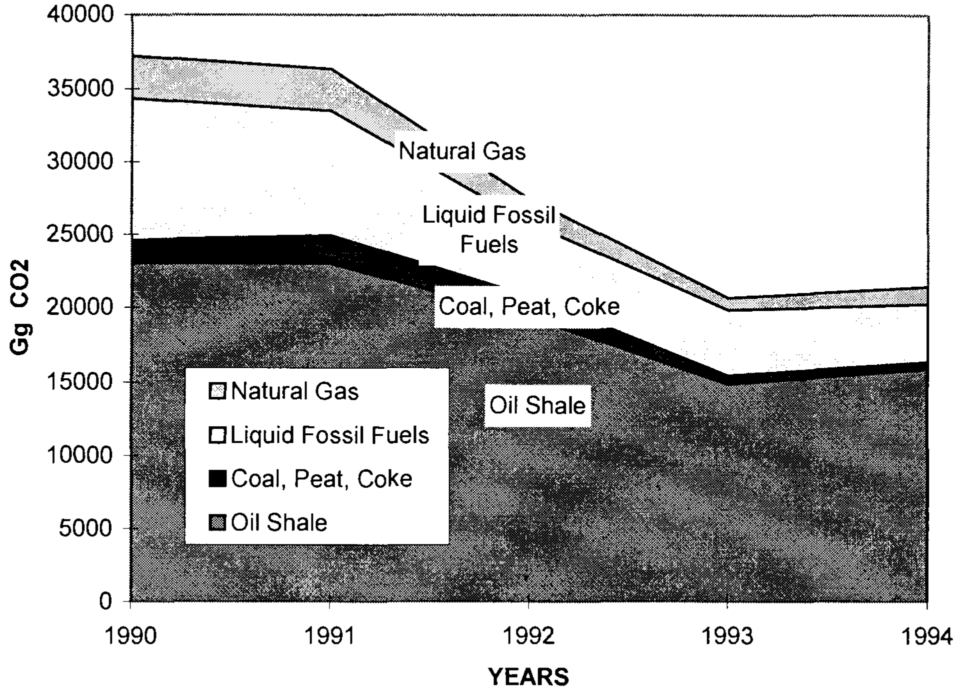

Fig. 3. CO_2 emissions from different energy sources

Table 6. CO_2 and non-CO_2 emissions from energy use and transport, Gg

Sector	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
Energy Conversion	28,461.0	0.047	0.002	35.780	7.329	NA
Residential	1,588.7	0.461	0.425	3.043	0.969	NA
Commercial	1,581.1	0.116	0.954	3.131	1.625	NA
Industrial	2,897.5	0.051	NA	4.812	1.676	NA
Transport	2,655.5	1.934	0.036	32.646	171.95	22.925
TOTAL	**37,183.8**	**2.609**	**1.417**	**79.412**	**183.549**	**22.925**

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

NA – not available NMVOC – non-methanous volatile organic compounds

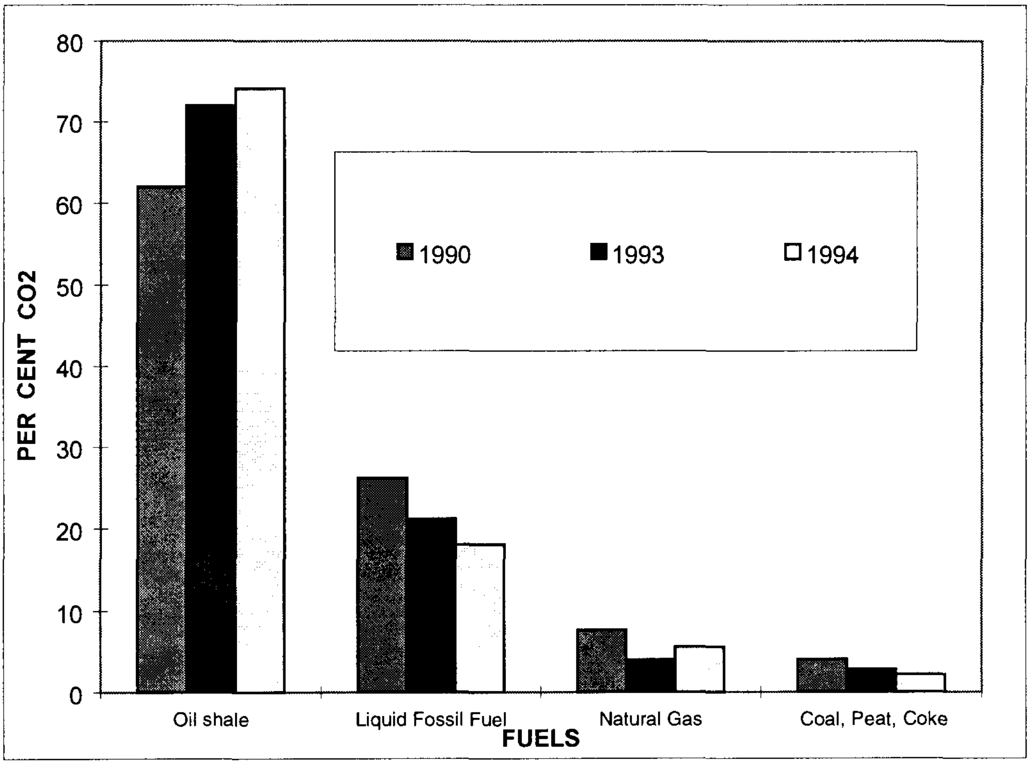

Fig. 4. The relative shares of CO_2 emissions from fuels burned in 1990, 1993 and 1994

The prices of available fuels in Estonia do not reflect the environmental risks of these fuels. Figure 5 demonstrates the prices of fuels (Nov. 1995) and their carbon emission factors. The price of natural gas with CEF = 15.3 tC/TJ was 185 EEK/MWh, and the price of oil shale with CEF = 29.1 tC/TJ was 34 EEK/MWh. CEF of oil shale is 1.9 times higher than that of natural gas, but the price of oil shale was 5.4 times lower than that of natural gas in 1995. This situation could be motivated by the origin of these fuels: natural gas is imported, but oil shale is a domestic fuel. Oil shale has high CEF resulting from decomposition of mineral carbon part of oil shale rock during the high temperature combustion. Without decomposition of mineral carbon part, oil shale could be qualified as a fuel with medium CEF (22 tC/TJ) (Fig. 5). As an extensive use of oil shale will continue, the reduction of oil shale CEF is very important.

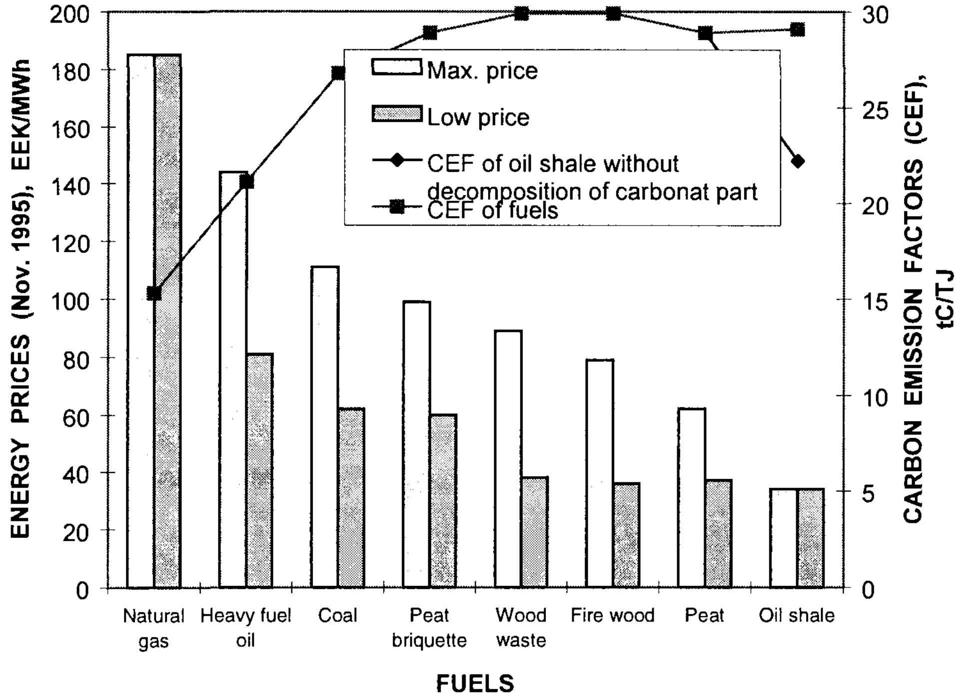

Figure 5. The prices of fuels (Nov. 1995) and their carbon emission factors.

Energy Development Plans in Estonia

The main objectives for creating a new infrastructure in the energy sector are:

* to establish laws regulating Estonian power engineering;
* to favor local fuels use through tax and price policy;
* to harness the program of oil shale mining and heat power production on the basis of oil shale;
* to increase the possibilities of liquid fuels imports (terminals in the ports);
* to identify and solve the strategic and technical issues of supply, distribution and use of gas in the Baltic states, particularly in Estonia;
* to achieve the energy conservation by use of sophisticated commercialized technologies without imposing such curbs as of capital, labour force;
* to apply administrative measure establishment of ownership forms and business of operating companies, and to guarantee the rights of the property owners;

* to develop the standards, implement international agreements, and guarantee the implementation of the directives of EU.

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

1. Energy Development Plan to 1995;
2. Energy Development Scenario to 2030;
3. Energy Master Plan for Estonia;
4. Energy Program "Energy 2000";
5. Refurbishment of the Narva Power Plants and the Optimization of Oil Shale Mining in Estonia.

Conclusions

Estonia's energy balance for 1990 – 1994 is characterized by the dramatic changes in the economy after regaining independence in 1991. In 1990 – 1993, primary energy supply decreased about 1.9 times. The reasons were a sharp decrease in exports of electric energy and industrial products, a steep increase in fuel prices and the transition from the planned to a market-oriented economy. 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, a moderate increase occurred (about 6%), which is a proof stabilizing economy.

Oil shale power engineering will remain the prevailing energy resource for the next 20 – 25 years. After stabilization, the use of oil shale will rise in Estonia's economy. Oil shale combustion in power plants will be the greatest source of GHG emissions in near future. The main problem is to decrease the share of CO_2 emissions from the decomposition of carbonate part of oil shale. This can be done by separating limestone particles from oil shale before its burning by use of CFB combustion technology. Higher efficiency of oil shale power plants facilitates the reduction of CO_2 emissions per generated MWh electricity considerably.

In Estonia, heat is produced mainly on the basis of 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. 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 reduction of heat losses in heat transmission, distribution and consumption spheres is crucial.

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 neighboring countries, including the development programs of the other Baltic states.

References

Biomass Technology Group University of Twente (1995). Estonia: Utilisation of Wood and Peat for Heat Supply, pp. 517.

Energy Balance 1994 (1995). Statistical Office of Estonia, Tallinn, pp. 48.

Energy Master Plan for Estonia: Pre-Feasibility Study (1992/93). Ministry of Industry and Energetics, Vattenfall AB, Imatran Voima OY, State Enterprise Eesti Energia. Tallinn, pp. 119.

Energy 2000 (1995) National Energy Research and Development Programme to Year 2000, Tallinn, pp. 25.

Greenhouse Gas Inventory Workbook. Final Draft (1994). Vol. 2. IPCC, Washington D.C.

Greenhouse Gas Inventory Workbook. Final Draft (1995). Vol. 2. IPCC, Washington D.C.

IVL, Jaakko Pöyry Consulting AB Sweden, Swedish Development Consulting Partners AB, Institute of Ecology, Institute of Energy Research (1994) Estonia: Sector Environmental Assessment on the Utilisation of Domestic Peat and Wood Chips as a Fuel for Heating Systems, Stockholm and Tallinn, pp. 318.

IVO International LTD (1995), Operation, Repair, Maintenance and Conservation Plan for the Narva Power Plants, pp. 131.

Kull, A., Mikk, I. & Ots, A. (1974). Heat Engineering, Tallinn, pp. 494 *(in Estonian).*

Lampinen, K. (1991). Annual Report of LAKA 1992, Tampere, pp. 227 *(in Finnish).*

PHARE Regional Programme (1995). Gas Interconnection Study, Executive Summary. Final Version, pp. 52.

Refurbishment of the Narva Power Plants and Optimisation of Mining of Oil Shale in Estonia. Subproject: Investment Programme for Flue Gas Desulphurization (1995), SE Eesti Energia, Ministries of Estonia and Finland, Nordic Investment Bank, Tallinn, pp. 49.

Sathaye, J. & Mayers, S. (1995). Greenhouse Gas Mitigation Assessment: A Guidebook, Dordrecht / Boston / London, pp. 203.

State Energy Department (1994). Estonian Energy 1992, Tallinn, Estonia, pp. 46.

Statistical Yearbook (1994). Statistical Office of Estonia, pp. 246.