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# ESTONIAN GREENHOUSE GAS EMISSIONS INVENTORY REPORT



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It is widely accepted that the increase of greenhouse gas concentrations in the atmosphere due to human activities would result in warming of the Earth's surface. To examine this effect and better understand how the GHG increase in the atmosphere might change the climate in the future, how ecosystems and societies in different regions of the World should adapt to these changes, what must policymakers do for the mitigation of that effect, the worldwide project within the Framework Convention on Climate Change was generated by the initiative of United Nations.

Estonia is one of more than 150 countries, which signed the Framework Convention on Climate Change at the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992. In 1994 a new project, Estonian Country Study was initiated within the U.S. Country Studies Program. The project will help to compile the GHG inventory for Estonia, find contemporary trends to investigate the impact of climate change on the Estonian ecosystems and economy and to formulate national strategies for Estonia addressing to global climate change.

# 1. National Circumstances

## *1.1 INTRODUCTION*

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

After the re-establishing their independency Estonia has experienced a difficult political and economic adjustment period, resulting in a substantial drop in domestic agricultural and industrial trade relations - especially with the republics of the former USSR - and a severe deteriotation of the national economy. However, several political, institutional, legal, and economic changes have recently been successfully implemented and thus improving conditions for future development.

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

- Law on the Protection of Nature in Estonia,
- Law on Protecting Nature Objects,
- Pollution Charge Law,
- Act of Suistanable Development etc.

Since 1990 12 Acts, 24 Regulations of the Government of the Republic and 61 Regulations of the Ministry of Environment have been worked out and adopted (Environment, 1994). During the same period a lot of Conventions having importance from point of view Global Climate Change have been ratified by the Parliament and thereafter declared by the Presidents. As a base there are the following coventions:

- Rio de Janeiro (1992) Convention on Biodiversity,
- New York (1992) UN Framework Convention on Climate Change,

- Ramsar (1971) Convention on Wetlands of International Importance Especially as Waterfowl Habitat.

Due to rapid changes in the economy there is lack some very important laws like energy law. Also are absent long-term plans of energy-use, agriculture development and macroeconomical predictions. Therefore the projection of greenhouse gas emissions and working out the mitigation options by different scenarios is rather difficult.

The transition from planned economy to market economy has brought about changes in all fields of society. In some fields changes are so quick that existing data can not follow the real situations. In compailing the review of natural circumstances the data from Statistical Yearbooks compiled by Statistical Office of Estonia have been mainly used (Statistical Yearbook, 1991,1992,1993,1994; Estonian Statistical Bulletin, 1994,1995).

### 1.2 NATURE

Estonia is situated in north-western part of the flat East-European plain, remaining entirely within the drainage area of the Baltic Sea (Figure 1). The coastline length is 3,794 km. The country is located between 57.30 and 59.49 degrees of latitudes and 21.46 and 28.13 degrees of longitudes. The total area of Estonia is 45,216 $km^2$, of which 4,132 $km^2$ (9.2%) is made up of more than 1,500 islands and islets.

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 can be divided into two regions: Lower Estonia and Upper Estonia. Upper Estonia comprises the more elevated areas in the central and southern parts of country, which were not covered by the sea during the Holocene. The soils of Upper Estonia are more fertile and the rural population is denser than in Lower Estonia.

Estonia belongs to Atlantic continental region of the temperate zone, which is characterized by rather warm summers (+17°C in July) and comparely mild winters (–4,5°C in February). The variety of climate regime within Estonia is remarkable - from typical maritime in West-Estonia to the continental in South-East Estonia. Since the annual amount of precipitations exeeds evaporation approximately twicely, the climate is excessively damp. The amount of solar radiation varies widely during the year. The length of summer day exceeds three times that of a winter day in northern Estonia. The height of the sun attains 55° at summers solstice and only 8° at winter solstice.

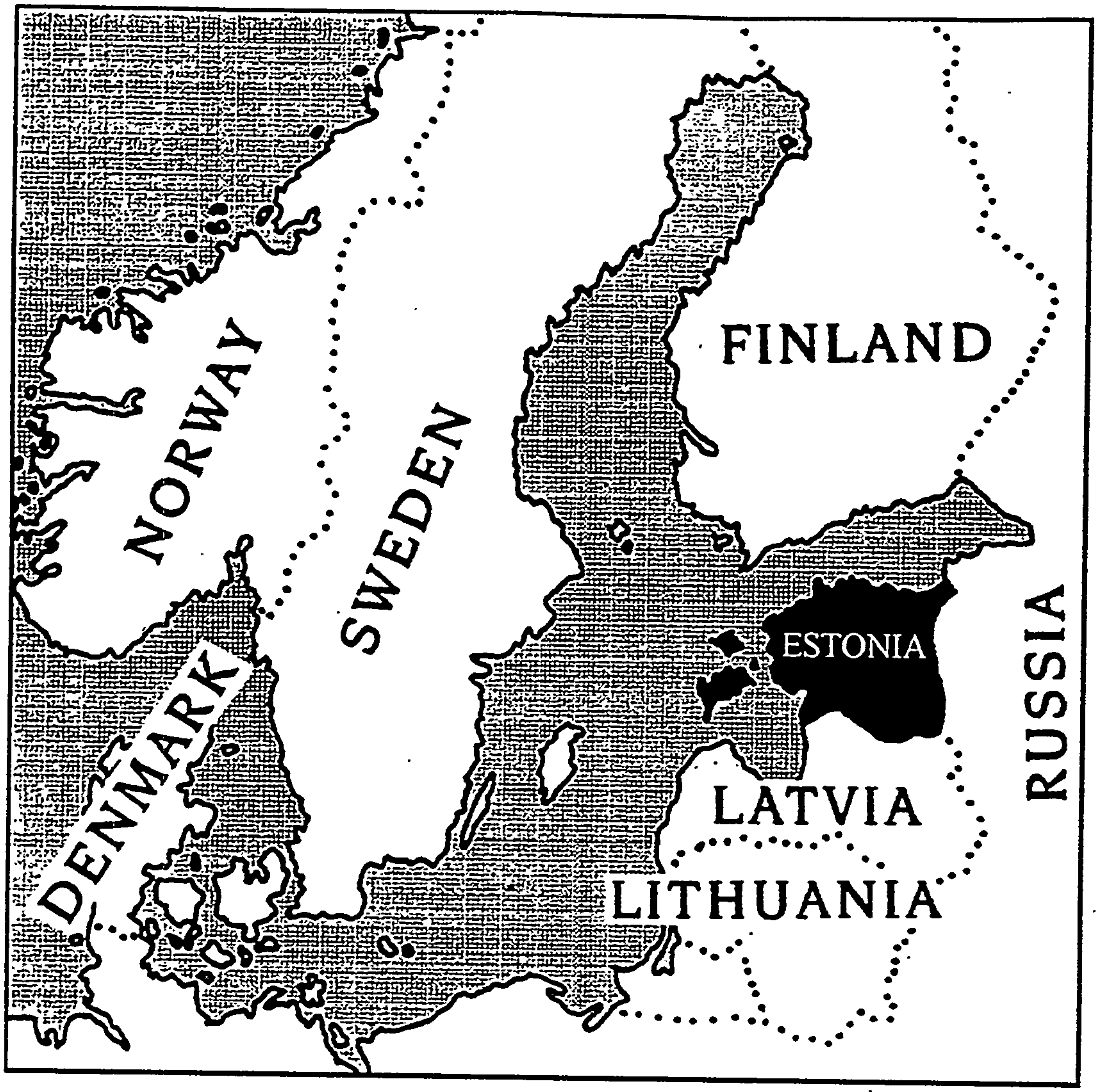


**Figure 1.** The situation of Estonia within the catchment area of the Baltic Sea.

Geologically the country is located on the southern slope of the Baltic Shield which is undergoing isostatic land uplift extending 2,8 mm/year on the north-western coast and 1,0 mm/year in the south-west. Only comparatively small south-eastern part of its territory is slightly subsiding. Isostatic land uplift is a potential reducer of sea-level rise impact on the Estonian coasts but it does not compensate latter.

The dominating bedrock is Ordovician-Silurian limestone in the northern and Devonian sandstone in the southern part of Estonia. Quaternary deposits are uneven distributed, almost lacking at the north and being up to 100-200 m thick in the south. The lithological composition of bedrock makes landscapes rather stabile against the acidification. Pleistocene deposits play a great role in respect to ground water protection.

Although not very large in area, Estonia is relatively rich in natural resources, both mineral and biological, which have been and will be the basis of Estonian economy. The production and processing of mineral resources give a considerable share of the cross national product (Table 1).

**Table 1.** Active deposits of Estonian mineral resources [Paalme, 1992].

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

Serious environmental problems are caused by the industrial use of these resources. One of the most important one is connected with the excavation of oil shale, which is accompanied by a decline of ground water table, degradation of the quality of the fields and forests, as well as direct reduction of useful land due to the subsidence of soil and the deposition of waste. The area made useless by excavation and industrial activity is at least 450 $km^2$, which comprises about 1% of Estonian territory. The restoration of land for recreation or for the development of industry helps to reduce the negative side effects of the excavated areas. Waste materials of oil shale mining and processing cover thousands of hectares, there are waste heaps with relative heights exceeding 100 m. Those terricones contain a number of compounds emitting or easily washed out with atmospheric precipitations.

## *1.3 ENERGY AND INDUSTRY*

The most important branch of industry in Estonia is energy production. The total power yield of the Estonian and Baltic Thermal Power Plants is about 3,000 MW. About half of the energy produced in 1990 was exported to Russia and Latvia. Approximately 75% of pollutants ($CO_2$, $SO_2$, $NO_x$, fly-ash) is emitted by the Baltic and Estonian TPP, which rank among the ten biggest sources of air pollution in Europe.

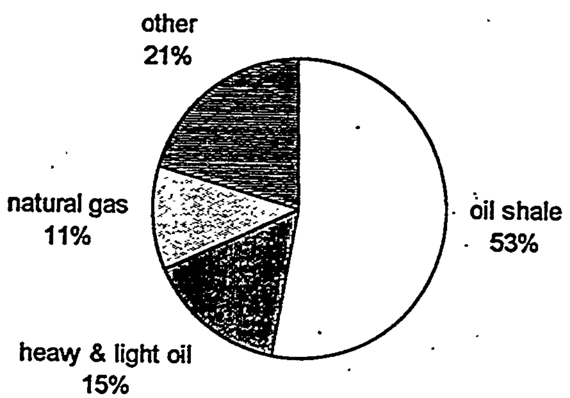


**Figure 2.** Fossil fuel for energy production

The center of chemical industry is in the north-eastern part of Estonia, the biggest enterprises being the Kiviõli Oil Shale Chemical Plants and the Kohtla-Järve Oil Shale Processing Association. The chemical industry has been mainly developed on the basis of oil shale and other imported raw materials (natural gas, apatite) for the production of fuel oil, aromatic hydrocarbons, phenols, solvents, cosmetics and pesticides.

In 1990 Estonian energy system consumed in total 452000 TJ of fuel. Estonia satisfies most of its energy demand by using fossil fuels. In 1990 oil shale constituted 52,8% of the energy balance.

In years 1990-1993 energy production has decreased considerably due to economical depression. At the same time emission from transport is increasing accordingly to the increasing number of transport vechicles. A lot of used old cars and lorries are imported from abroad. Therefore the total emissions from transport vechicles shows continual increase tendency.

From other types of industrial activities having direct influence on the GHG budget importancy have cement and lime manufacture (in 1990 consequently was produced 938 and 185 thousand tons); manufacture of foodstuffs and some chemicals.

## *1.4 LAND-USE*

Estonia is quite rich in renewable natural resources. During the last half-century the area of forest stands has more than doubled compiling in 1990 about 19,200 $km^2$ (42-43% of total land area) of the Estonian territory. This concerns true closed forests, in addition to which there are young forest plantation, open woodlands and bogs covered with trees. The total standing volume of forests constitute 264 million solid meters, the average standing volume being 144 solid meters per hectare. The Estonian forests belong to the zone of mixed and coniferous forests with relatively favourable growth conditions. Forests with conifers as dominant tree species make up 63% of the total area of the Estonian forests and 66% of the total forest yield; forests with deciduous trees as dominant species constitute 37% of the forested area and 34% of the forest yield. In 1988 the Estonian forests consisted of premature and mature stands (17%), middle-aged stands (53%), and young stands (30%). In exploitable profitable spruce, pine and birch forests young stands are respectively 1-40, 1-40 and 1-20 years old, middle age 41-60, 41-80 and 21-50, premature and mature stands 61, 81 and 51 years old (Karoles *et al.*, 1994).

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

Territory of arable land in Estonia is 1,300,000 hectares, the total sown area is 1,110,000 hectares. Estonian agriculture has specialized in livestock breeding of which cattle-breeding is most important. Loop production yields about one third of the gross agricultural product - as of 1 January 1990 the overwhelming majority of arable land belonged to collective and state farms. Since that the large farms began to break into private farms and now there are transitional period in full restructuring of agriculture.

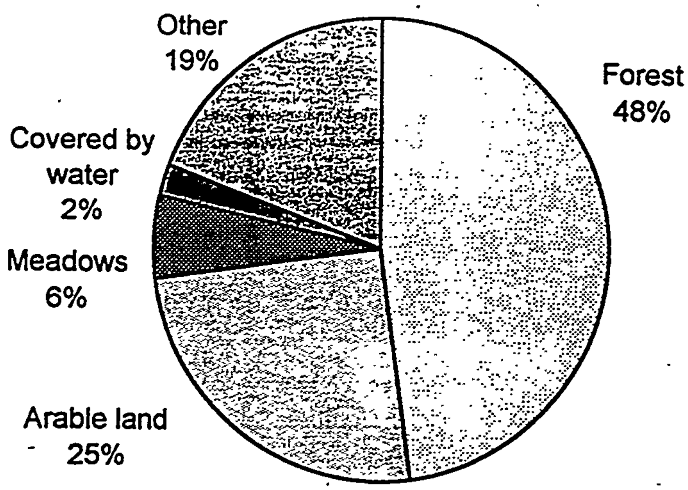


**Figure 3.** The structure of land-use on 1. Jan.1993 (Environment, 1994)

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

The peatland area is approximately 10,000 km$^2$, corresponding to 22% of the territory (partly coinciding with forest areas) and their contribution to the balance of GHG is significant. The calculations demonstrate that changes in the hydrological regime contribute to the increase in the emissions of $CO_2$ and $CH_4$. During the last decades Estonian peatlands have been strongly influenced by the amelioration for agricultural, forestry and peat industry concerning purposes. According to official data (Ilomets, 1994) about 34% of Estonian peatlands are affected by drainage activities, but the real value is higher due to the insufficient statistical data as well as to the influence of drainage on the surrounding areas. Most drastically affected are fens, swamps and floodplains of which only about 10% has not been subject to human impact (Figure 4).

Thanks to the variety of landscapes, differences in climate conditions at different distances from the sea, different types of bedrock, and the resulting high variety of soil types, the biological diversity is high. 8814 species of flora and 12,070 species of fauna are already known in the territory of 45,215 $km^2$; the probable number is estimated at about 35,000 (National Report, 1992). Unique landscapes and big list species included into Red Books demonstrate that Estonian ecosystems have importancy in European and worldwide size and therefore it is nessessary to pay especial attention to the vulnerability and adaptation assessment of ecosystems and landscapes on the Global Climate Change.

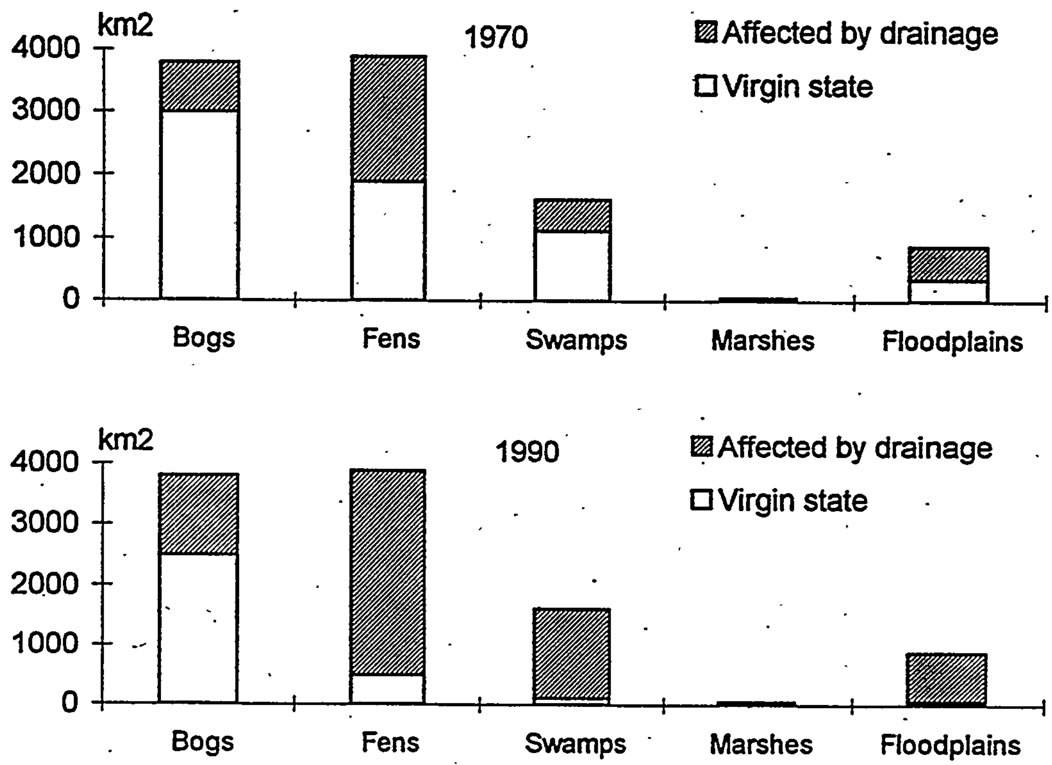


**Figure 4.** Area of main peatland types in Estonia in 1970 and 1990 in respect of amelioration affect to their state.

Today there are 4 state nature reserves, 4 national parks, 1 biosphere reserve and 479 various protected areas in Estonia (Nature Conservation, 1994) (Figure 5). Most of them will be under the direct influence of climate change processes.

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

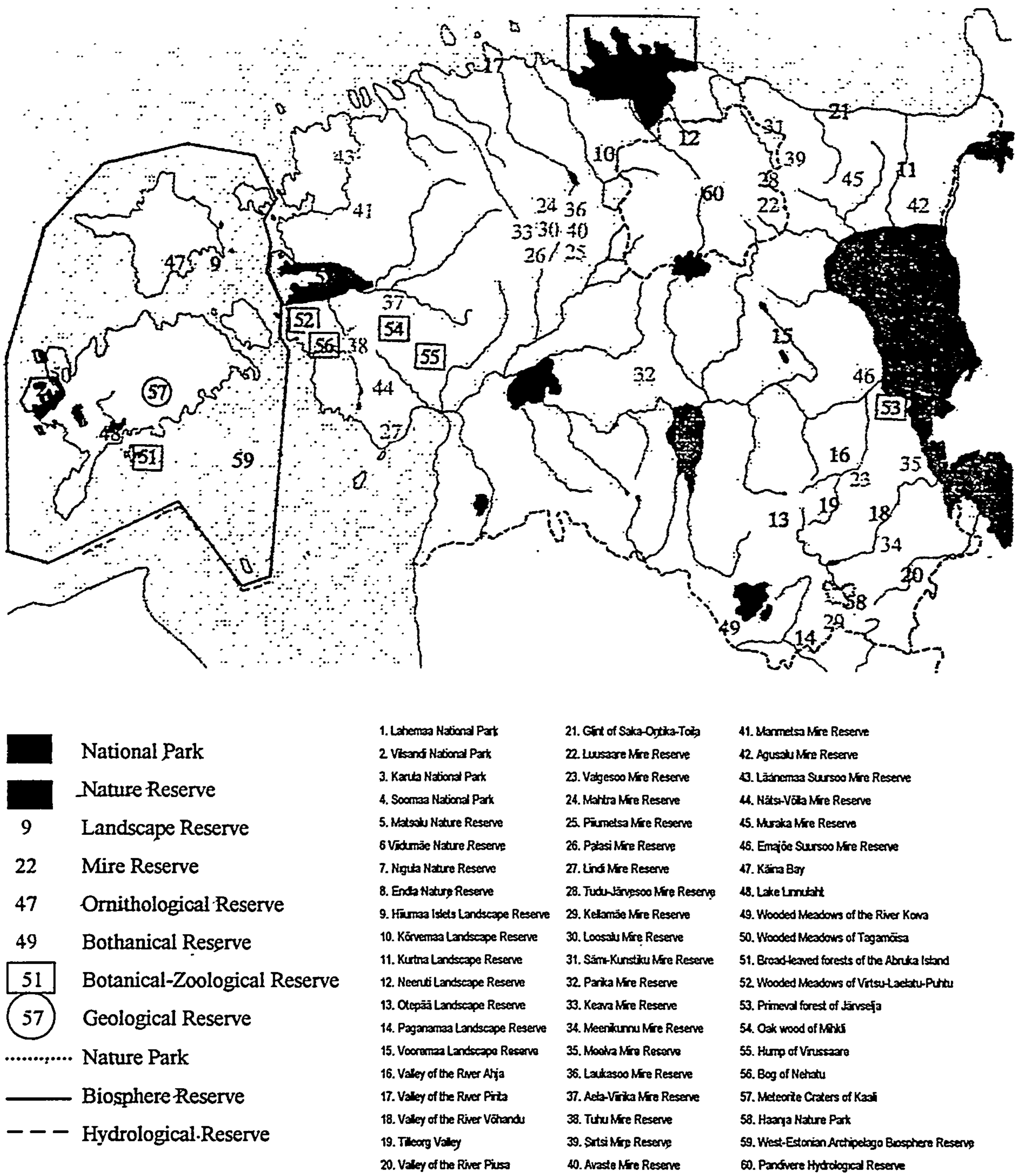


**Figure 5.** Nature conservation areas in Estonia.

### 1.5 POPULATION

Since 1990, the resident population of Estonia has been decreased. On January 1st, 1990, the population of Estonia was 1,571,648 but on January 1st, 1994 it was 1,506,927, among them 71.48% and 70.26%, correspondingly, live in urban areas (Statistical Yearbook, 1994). The population density is 35 persons/km$^2$.

On 1 January, 1994 there were 46 towns, 198 rural municipalities and 11 small town municipalities in Estonia.51% of the population live in five largest cities (Tallinn 484,400, Tartu 115,400, Narva 82,300, Kohtla-Järve 76,800 and Pärnu 54,200).

### 1.6 ECONOMY

Estonian economy is undergoing a transition period from the centralized planning to market relations, which has brought about rapid changes in all sectors of state activities, particularly in the energy sector and industries, thus complicating the analysis and modelling of emission projections very much. Therefore it is urgently necessary to compare emission data with the baseline year and follow the trends in the course of economical stabilization.

Before World War II mainly agriculture, light industry and food industry were developed in Estonia. At the beginning of 1950s special attention was paid to the development of heavy industry based mainly on using imported raw materials and employing immigrated workers. In connection with that priority was given to the development of energy industry based on local oil shale. Electricity generation is concentrated in two oil shale fired power plants in northeastern Estonia. These plants were designed to supply the northwestern region of former USSR and therefore approximately 50% of electricity was exported. In the years 1990-1994, electricity production decreased considerably due to the decrease in export and restructuring of the Estonian industry. This resulted in the decrease of oil shale consumption for electricity generation from 22.4 million tons in 1990 to 15 million tons in 1993.

According to the preliminary calculations (Statistical Yearbook, 1994), the GDP for 1993 was 22,8 milliard Estonian kroons (1 USD is ca 11,2 EEK). From 1991 to 1993, the GDP decreased, but the tempo of the decrease has fallen. The GDP at market prices was in 1991 1,832 million kroons and in the 1993 22,847 million kroons. In 1993, industrial production at current prices was 14,535 million kroons. In comparison with 1992, the industrial production decreased by 19%. Production as well as consumption of energy is showing a tendency to decrease. In the energy balance of Estonia, the consumption of fuels decreased by 45% in comparison with 1990, also the production of electric energy decreased essentially. By the opinion of experts and statistical data (Eesti majandusülevaade, 1995) the bottom in economy has been passed (Table 2).

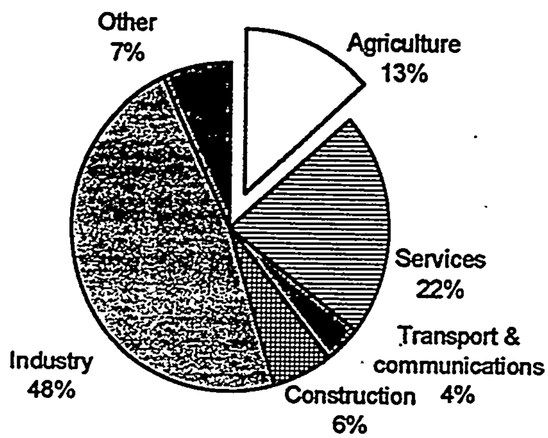


**Figure 6.** Gross domestic product of Estonia in 1991

**Table 2.** The dynamics of GDP

| Year | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|
| GDP against previous year, % | -8,0 | -14,0 | -14,2 | -6,7 | +3,5 |
| GDP against 1989, % | 92 | 79 | 68 | 63 | 65 |

# 2. Greenhouse Gases Budget

## *2.1 INTRODUCTION*

GHG Inventory for Estonia was compiled for energy, industry, transport, agriculture, forestry, land-use sectors: it means for all directions of man activities related with emission of greenhouse gases in Estonia. For estimation the emissions of GHG consequent IPCC methodologies were used.

Standard methods or original estimation are given in Appendix I. In this chapter only main results are given.

The main sources of data are the Statistical Yearbooks and other publications issued by Statistical Office of Estonia. Unfortunately the availability and reliability of data from different sectors differs. Also here must be pointed out that the GHG emission and sink data have only preliminary character, because now there is lack of scientific base for separation of natural and man-made part of GHG budget from wetlands.

## *2.2 ENERGY*

In Estonia main directions of fuel consumption are for electricity and heat production, fuel proceeding and chemical industry, production of building materials. Big consumers are also food mechanical engineering and textile industry.

Energy-related activities are the most significant contributor to Estonian greenhouse gas emissions. Activities associated with the production, transmission, storage and distribution of fossil fuels also emit greenhouse gases. These are primary fugitive emissions from natural gas systems, oil shale mining and oil shale oil production. The main gas emitted through these activities is methane, while smaller quantities of NMVOCs, $NO_x$ and CO can be also emitted.

Estonia satisfies most of its energy demand by using fossil fuels. The major part of primary energy in Estonia is converted to electricity and heat or refined to the peat briquettes and oil shale oil.

Reference Approach of $CO_2$ emissions from energy sources are given in Table 3.

In energy sector the main contributor of $CO_2$ emissions is the use of oil shale. In 1990 total $CO_2$ emissions from fossil fuel consumption were 37,183.8 Gg.

Biomass fuel was used in form of fuelwood and wood waste. For 1990 $CO_2$ emissions from biomass consumption were 1,073.9 Gg.

Approximately 68% of Estonian $CO_2$ emissions are caused by combustion of oil shale. The remaining 32% comes from heavy fuel oil, natural gas and other energy sources such as coal, light fuel oil etc.

Table 4 summaries Estonian emissions of carbon dioxide from fossil fuel consumption.

The energy conversion sector accounts 77% of Estonian emissions from fossil fuel consumption, making it the largest source of $CO_2$ emissions. Sectorial emissions of carbon dioxide in energy consumption were: industrial - 33%, transportation - 30%, residential - 19% and commercial - 18%.

In Table 5 non-$CO_2$ gases emissions from fuel combustion activities are given for 1990. In Estonia the biggest amount of non-$CO_2$ emissions was coming from transport sector.

**Table 3.** $CO_2$ from energy sources (Reference Approach).

| Fuel Types | $CO_2$ Emissions, Gg |
|---|---|
| **Liquid Fossil Fuels** | 9,734.4 |
| Natural Gas Liquids | 95.6 |
| Gasoline | 1,688.4 |
| Jet Kerosene | 112.1 |
| Other Kerosene | 335.7 |
| Diesel Oil | 1,887.0 |
| Heavy Fuel Oil | 5,500.2 |
| LPG | 84.0 |
| Other Oil | 31.4 |
| **Solid Fossil Fuels** | 24,595.4 |
| Oil-Shale | 23,051.4 |
| Coal | 890.3 |
| Peat | 653.7 |
| **Gaseous Fossil (Natural gas)** | 2,854.0 |
| **FOSSIL FUEL TOTAL** | 37,183.8 |
| Solid Biomass (Wood) | 1,073.9 |
| **BIOMASS TOTAL** | 1,073.9 |

**Table 4.** Sources of $CO_2$ emissions from energy use and transport.

| Source | $CO_2$ Emissions, Gg |
|---|---|
| Energy conversion | 28,461.0 |
| Residential | 1,588.7 |
| Commercial | 1,581.1 |
| Industrial | 2,897.5 |
| Transport | 2,655.5 |
| **Total Fossil Fuel Consumption** | 37,183.8 |

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

**Table 5.** Non-$CO_2$ gase emissions from fuel combustion activities.

| Sector | Emissions Estimates, Gg | | | | |
|---|---|---|---|---|---|
| | $CH_4$ | $N_2O$ | $NO_x$ | CO | NMVOC |
| Energy and Transformation Industries | 0.0471 | 0.0024 | 35.78 | 7.329 | NA |
| Industry | 0.051 | N/A | 4.812 | 1.676 | NA |
| Transport | 1.9345 | 0.036 | 32.646 | 171.95 | 22.925 |
| Commercial / Institutional | 0.116 | 0.954 | 3.131 | 1.625 | NA |
| Residential | 0.461 | 0.425 | 3.043 | 0.969 | NA |
| **Total Fuel Combustion Activities** | 2.6096 | 1.4174 | 79.412 | 183.549 | 22.925 |

NA - not available

NMVOC - Non-methanous volatile organic compounds

Among the greenhouse gases released as a result of energy production, transmission, storage and distribution activities the main compound is methane. The results of methane emissions from mining, oil and gas activities for 1990 are given in Table 6.

In 1990 approximately one half of oil shale was mined from underground mines and the second half from surface mines. Total amount of methane emissions from oil shale mining and postmining was 179.3 Gg.

In Estonia approximately 15 PJ of oil shale oil was produced and 132.5 PJ of that was used in 1990. Also approximately 51 PJ natural gas was imported in 1990. Methane emissions are caused by system leaks, distributions, routine maintenance releases and leakages at consumers. For 1990 methane emissions from these activities were 37.7 Gg.

**Table 6.** Methane emissions from mining, oil and gas activities.

| Source Category | $CH_4$ Emissions, Gg |
|---|---|
| **Oil shale mining and handling:** | 179.3 |
| Underground mines | 168.3 |
| Mining | 147.6 |
| Postmining | 20.7 |
| Surface Mines | 11.0 |
| Mining | 10.1 |
| Postmining | 0.9 |
| **Oil and gas activities:** | 37.7 |
| Oil | 0.4 |
| Production | 0.1 |
| Transport | 0.1 |
| Storage | 0.2 |
| Gas | 37.3 |
| Transmission and Distribution | 23.4 |
| Other Leakages : | |
| - non-residential gas consumed | 13.6 |
| - residential gas consumed | 0.3 |
| **Venting from Oil Production** | 0.1 |
| **TOTAL** | 217.1 |

## 2.3 INDUSTRIAL PROCESSES

By Estonian industry greenhouse gases are produced mainly from cement and lime production.

By thermal processing of calcium carbonate ($CaCO_3$) from limestone, chalk or other calcium-rich materials calcium oxide ($CaO$) and carbon dioxide ($CO_2$) are formed. Total $CO_2$ emissions from cement and lime production in Estonia were 612.948 Gg in 1990 (the Table 7).

**Table 7.** Sources of $CO_2$ emissions from industry: 1990

| Source | $CO_2$ Emissions, Gg |
|---|---|
| Cement Production | 467.6 |
| Lime Production | 145.3 |
| Total Industrial Processes | 612.9 |

## 2.4 SOLVENTS

In solvents sector data is very uncertain and mostly not available to calculate GHG emissions.

## *2.5 AGRICULTURE*

Estonian agriculture has been specialised on animal husbandry, the impact of which forms 65-70% of the total agricultural output. In the 1980's the agricultural production depended on 300 state and collective farms' activity. After the re-establishment of the Estonian Republic, more and more private farms are formed, the number of which at present exceeds 14 000. During the existence of state and collective farms the level of animal husbandry mostly depended on the amount of imported concentrated fodder. As pig husbandry was more preferred, 55% from the total meat production was pork, which was not rational for the Estonian conditions.

In 1990 the total landstock of Estonia was divided into 1 132 thousand hectares of arable land, 312 thousand hectares of natural grasslands and 1920 thousand hectares of forest. The total sown area formed 1.10 million hectares, whereas forage crops covered 665.4 thousand hectares, cereals and legumes 397.1 thousand hectares and potatoes, vegetables and industrial crops accordingly 4.1, 0.5 and 0.3% of the total sown area (Figure 7). Before World War II, compared to the year 1990, the sown area of cereals and legumes was 1.4 times larger, potatoes were cultivated 1.8 times and industrial crops 8.2 times more than at the present time. At the same time the acreage of forage crops has increased 2.8 times.

Restructuring of agricultural production, the development of private sector, decrease of traditional eastern market and finding new ones, the rise of prices for fuel and fertilizers have immensely influenced the total agricultural sector. At present the total sown area has decreased to 925.4 thousand hectares. In 1995 the sown area of cereals and legumes formed 302 thousand hectares and potatoes were cultivated on 37.6 thousand hectares. During the last five years the sown area of forage crops has decreased by 90.2 thousand hectares. Accompanying the above-given facts gross production of agricultural crops has decreased. In 1990 958 thousand tons of grain and 618 thousand tons of potatoes were produced. In 1994 total yield of cereals and legumes formed 512 thousand tons and yield of potatoes 563 thousand tons.

The use of fertilizers and pesticides has also decreased. In the 1980-s 100-120 kg of nitrogen from mineral in addition to 60 kg from organic fertilizers were used per hectare of arable land (Figure 8). In 1990 the amount of nitrogen from mineral fertilizers used was 75242 tons (Table 8), that is 67.4 kg N per hectare. The manure applied to the soil consisted 45387 tons of nitrogen. To compare the last years with 1985-1987 the use of mineral fertilizers and manure has decreased 2-5 times and more than 2 times respectively.

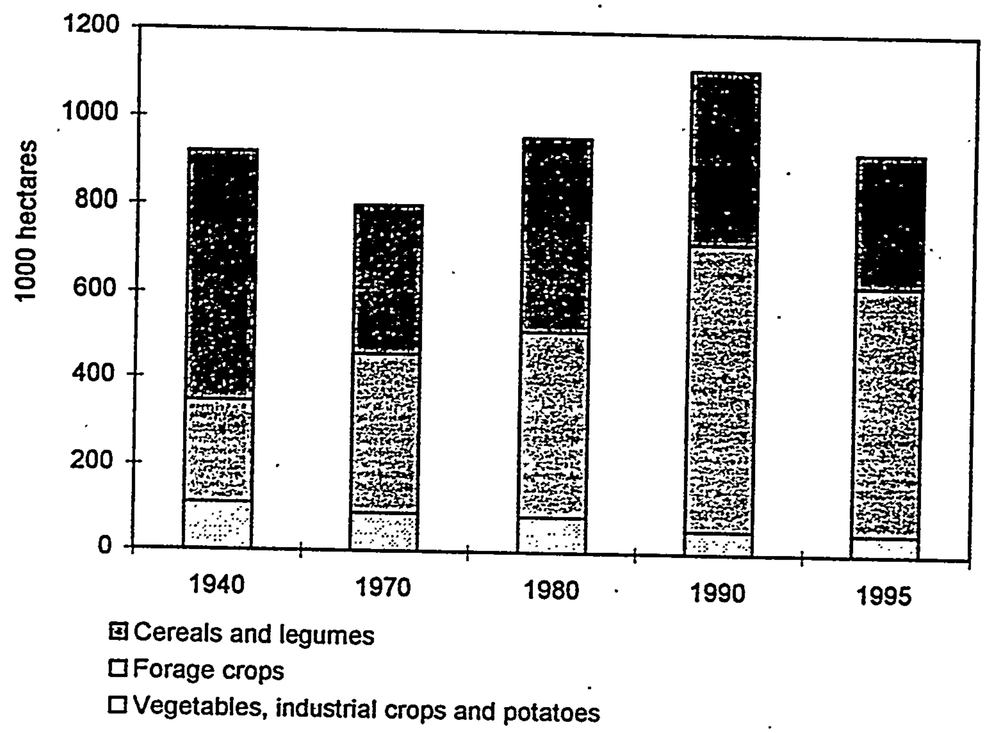


**Figure 7.** Use of sown area.

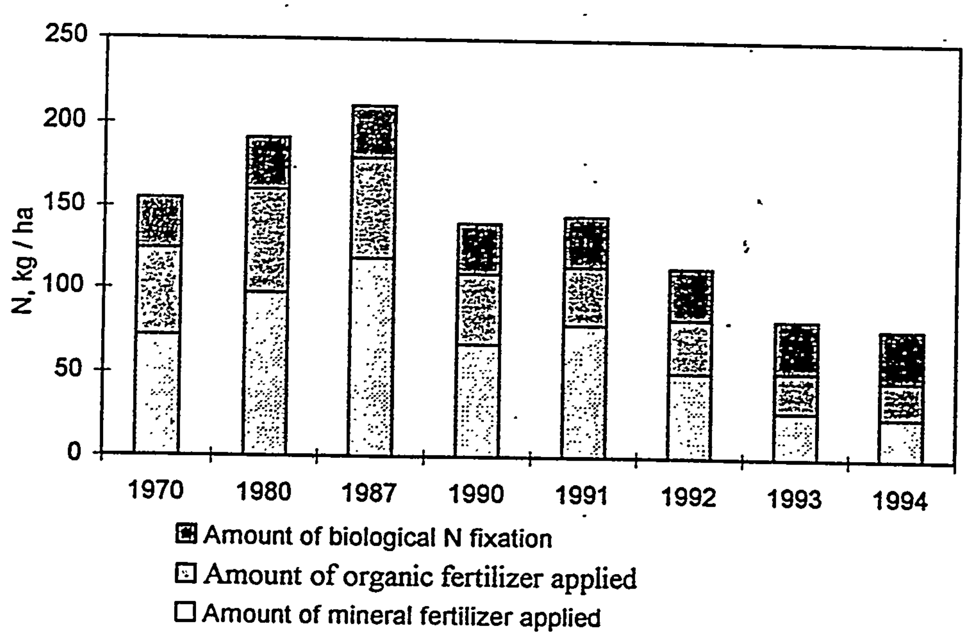

**Figure 8.** Use of nitrogen fertilizers in agricultural enterprises and private farms

**Table 8.** Total use of nitrogen in agriculture, t N.

| Sources of nitrogen | 1990 | 1991 | 1992 | Average |
|---|---|---|---|---|
| Mineral fertilizers | 75,242 | 88,368 | 56,991 | 73,538 |
| Organic fertilizers | 45,387 | 36,818 | 35,875 | 39,360 |
| Biological fixation | 35,089 | 35,089 | 35,089 | 35,089 |
| **Total** | 155,718 | 160,275 | 127,955 | 147,983 |

Great changes have taken place in animal husbandry. Just before World War II, in 1940, there were 528.4 thousand heads of cattle, including 401.8 thousand dairy-cows. In 1990 these figures were 806.1 thousand and 293.9 thousand respectively. The number of pigs increased from 319.2 thousand in 1940 up to 1080.4 thousand in 1990. During the five last years the herd of cattle has decreased approximately 1.9 times, whereas the number of dairy-cows has decreased by 28%, and the number of pigs by 2.3 times (Table 9).

In 1990 219.3 thousand tons of meat, 1208.0 thousand tons of milk and 547.1 million eggs were produced in Estonia. During the last years the output of animal husbandry has decreased. Nowadays meat is produced 3.2 times, milk - 1.6 times and eggs 1.5 times less than in 1990.

**Table 9.** Number of domestic animals.

| Animal type | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|
| | in 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 | 1,080.4 | 960.0 | 798.6 | 541.1 | 424.3 | 459.8 |
| Poultry | 6,922.5 | 6,536.4 | 5,538.1 | 3,418.1 | 3,226.1 | 3,220.0 |

The share of agriculture in the gross domestic product has decreased. As at the end of Soviet period it formed approximately 20%, during the last years agriculture, hunting and forestry forms only 10-17 % of the gross domestic product. The prognosis for the near future shows the sowing area to be decreased but the yields and products quality to be improved. Animal husbandry production should increase to the level it was in 1990-1991. The most potential articles for export are milk and dairy products.

Due to decreasing production and restructuring of agriculture, GHG emissions from agriculture have decreased. In 1983, when the animal husbandry was on its highest level, methane emission from enteric fermentation and livestock manure management formed 68.2 Gg (Figure 9). By 1990 it had decreased down to 64.1 Gg and at present it is only 35.5 Gg. Ruminants, which include cattle, sheep and goats, have the highest methane emissions among all animal types (Table 10). From the total $CH_4$ emissions 88% come from cattle, and 8.7% from pig husbandry. Methane emission from enteric fermentation formed 87% from total $CH_4$ emissions in agriculture.

The amount of methane produced during decomposition of manure depends on the type and population of animal, manure management etc. Swine manure is the greatest emission source, responsible for about 48 per cent of total methane emissions from livestock manure management.

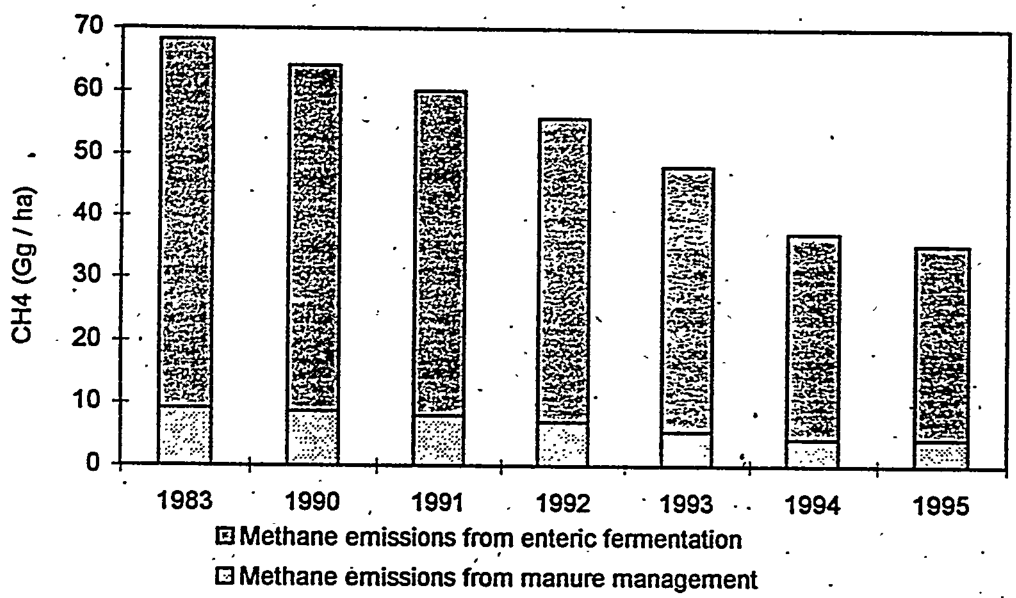


**Figure 9.** Methane emissions from enteric fermentation and livestock manure management

**Table 10.** Total methane emissions from enteric fermentation and livestock manure management in 1990-1992

| Animal type | 1990 | 1991 | 1992 | Average | % |
|---|---|---|---|---|---|
| | CH₄ emissions (Gg / yr) | | | | |
| Dairy cows | 25.6 | 24.4 | 23.0 | 24.3 | 40.6 |
| Non-dairy cattle | 30.7 | 28.6 | 26.6 | 28.6 | 47.8 |
| Sheep | 1.1 | 1.1 | 1.2 | 1.1 | 1.8 |
| Horses | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| Swine | 5.9 | 5.3 | 4.4 | 5.2 | 8.7 |
| Poultry | 0.5 | 0.5 | 0.4 | 0.5 | 0.8 |
| Total | 64.1 | 60.1 | 55.8 | 59.9 | 100.0 |

Nitrogen emissions in Estonian agriculture have decreased during last years (Figure 10). In 1980s, when relatively large amount of complex (both multi-nutrient and nitrogen) and organic fertilizers were used, nitrogen oxide emissions formed on the average emission coefficient level 1000-1200 g $N_2O$-N per hectare. Today nitrous oxide emissions are 2-3 times less. Comparing with the developed agricultural countries the use of fertilizers in Estonia is very low.

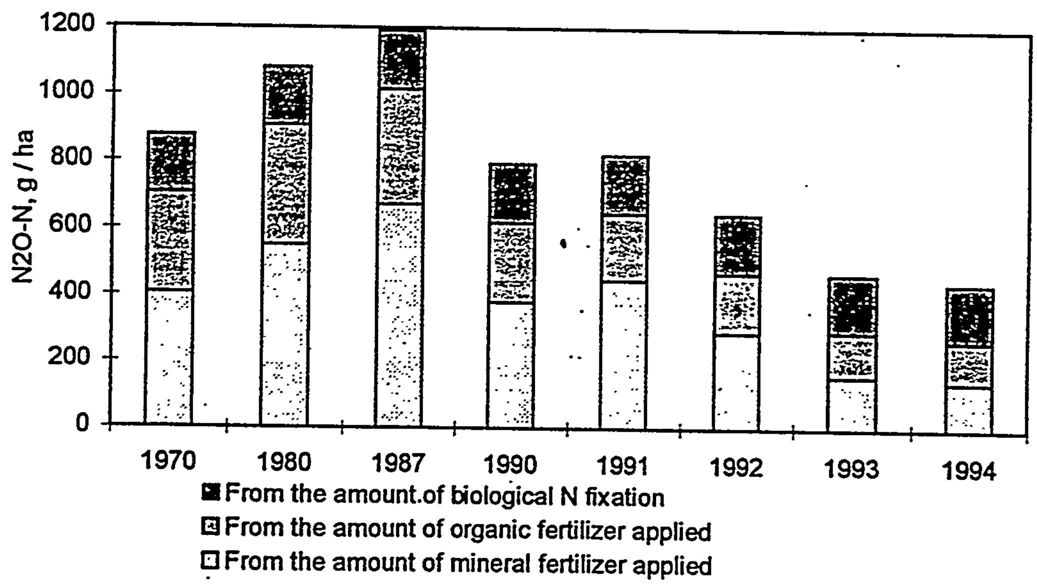


**Figure 10.** Nitrous oxide emissions from fertilizers used on agricultural enterprises and private farms (emission coeficent C=0.0036)

In 1990 approximately 75.2 thousand tons of nitrogen from mineral and 45.4 from organic fertilizers were used. Adding 31 kg of nitrogen per hectare of arable land caused by biological fixation, run-off etc., the total supply of nitrogen used in agriculture was 155.7 thousand tons. Hence total nitrous oxide emissions, depending on its coefficients, were 122.3, 880.9 and 9543.2 Ts $N_2O$-N. At present this level has decreased twice (Table 11).

**Table 11.** Nitrous oxide emission from agricultural soils

| Emission coefficients | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|
| | tons $N_2O$ - N | | | | |
| Low - 0.0005 | 122.3 | 125.9 | 100.5 | 70.5 | 66.3 |
| Medium - 0.0036 | 880.9 | 906.7 | 723.9 | 507.3 | 476.9 |
| High - 0.0390 | 9543.2 | 9822.6 | 7841.8 | 5495.9 | 5166.1 |

Soil-climatic conditions, crop type, management regime and fertilizer application influence the level and reducing possibilities of nitrous emissions from fertilizer use. Scientifically recommended fertilization level enables not only to increase the yield of field crops and profit but also to decrease nitrous oxide emissions to the atmosphere (Table 12).

**Table 12.** Relative nitrous oxide emissions level from soil depending on pedo-climatic conditions and fertilization (emission coefficient = 0.0036)

| Amount of nitrogen fertilizer used | Item | In very favourable pedo-climatic conditions P < 10% | In early sowing time of barley | In later sowing time of barley | In very unfavourable pedo-climatic conditions P > 90% |
|---|---|---|---|---|---|
| Biologically effective amount of fertilizer | N, kg $ha^{-1}$ | 86.0 | 105.0 | 100.0 | 138.0 |
| | Yield, Mg $ha^{-1}$(A) | 4.3 | 3.7 | 2.8 | 2.0 |
| | $N_2O$, g $ha^{-1}$ (B) | 487.0 | 594.0 | 566.0 | 781.0 |
| | B / A | 113.0 | 161.0 | 202.0 | 330.0 |
| Economically recommended amount of fertilizer | N, kg $ha^{-1}$ | 65.0 | 70.0 | 55.0 | 40.0 |
| | Yield, Mg $ha^{-1}$(A) | 4.3 | 3.5 | 2.6 | 1.6 |
| | $N_2O$, g $ha^{-1}$ (B) | 368.0 | 396.0 | 311.0 | 226.0 |
| | B / A | 86.0 | 113.0 | 120.0 | 141.0 |

## 2.6 FORESTRY

Vegetation and soil can be either sources or sinks for atmospheric constituents. The decomposition of soil organic matter releases carbon dioxide into the atmosphere, but the vegetation acts in both as a sink (photosynthesis) and a source (respiration). The budget of $CO_2$ in forest ecosystems is largely depending on the age, density and site types of forests.

On 1 of January 1994, the area of productive forest land was 2,016,600 hectares, of which 1,920,000 hectares was actually forested (Forestry 1994, 1995). Remaining area of productive forest land was made up of clear cut areas, young forest plantations (up to 6...8 years), seed orchards, nurseries, etc. The total forest land area makes up 47.7% of the Estonian land area. During the past half-century the area of forest stands has more than doubled and the growing stock on it has increased 2.4 times.

In 1993 the total volume of standing growing stock in closed forests was reported to be 277 $Mm^3$ sob. Coniferous forests make up 63% of the total area of the Estonian forests and 66% of the total forest yield and deciduous forests 37% and 34% respectively (Statistical Yearbook, 1994).

At the present time 87 native and over 500 introduced tree and shrub species have been recorded in Estonian greenery (Karoles *et al.* 1994). The main coniferous tree species are Scots pine (*Pinus sylvestris* L) and Norway spruce (*Picea abies* /L./Karst.). Deciduous trees are represented by two species of birches (*Betula pendula* Roth, *B. pubescens* Ehrh.), grey alder (*Alnus incana* /L./Moench), aspen (*Populus tremula* L.) and black alder (*Alnus glutinosa* /L./Gaertn.). Other broad-leaved trees, e.g. oak (*Querqus*), ash (*Fraxinus*), linden (*Tilia*), elm (*Ulmus*) make up only 1% of standing volume (Supply, Production and Costs... 1994) (Figure 11).

Boreal forest soil, even excluding wetlands, is a considerable store of organic carbon, estimated to account for 12-13% of world soil carbon pool. However, due to large variation in soil carbon density (t/ha) within the boreal zone, detailed studies of smaller regions are needed for confidently estimating the actual amount. The carbon content in forest soils in Estonia is also varying in different site types depending on soil type. So the soil carbon content may vary from 44 to 192 tonnes per hectare (Kylli, 1988).

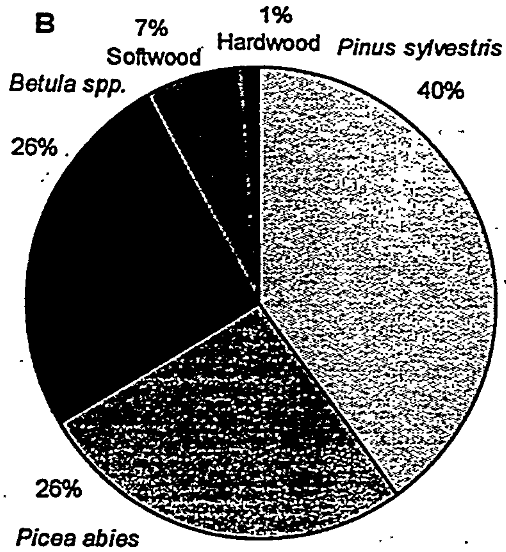


**Figure 11.** The Area of the woodlands by predominant tree species.

As more than half of the forest areas are excessively moist, active forest land drainage for increasing the productivity of forest sites has been carried out since the last century. During recent decades drainage of forests was rather intense, the drainage network now covers over 450,000 ha of forest land (Karoles *et al.*, 1994).

Timber is mostly produced by clear-cuts, mainly restricted cut-over areas in mature stands. Some of the timber comes from maintenance felling of protected or preserved forests, where natural forestry systems are used. The volume of annual final cuts in state forests is 1.2 - 1.5 $Mm^3$ (in all forests 1.6 - 2.0 $Mm^3$) (Karoles *et al.*, 1994). Considering the total volume of Estonian timber resources this is not much. Due to the changes in forest management the volume of fellings in 1994 has increased in comparison with the base year (1990) mainly because of the increased consumption of fuelwood. Accordingly, the total felling in 1994 was 3626.2 thousand $m^3$, out of which 1414.3 thousand $m^3$ were used for fuel. Compared to 1990 the growth in total felling is 24% and in fuel consumption 33%, respectively (Figure 12) (Forestry..., 1995).

The major part of the Estonian productive forest land is owned by the state and managed through 185 Forest Districts - 1,170,000 hectares in 1993. Remaining productive forest land belongs to agriculture cooperations - 780,000 hectares - or private forest owners - 70,000 hectares (Supply, Production and Costs..., 1994). At present there are large uncertainties in the fate of forest land because of continuous process of returning lands to private owners.

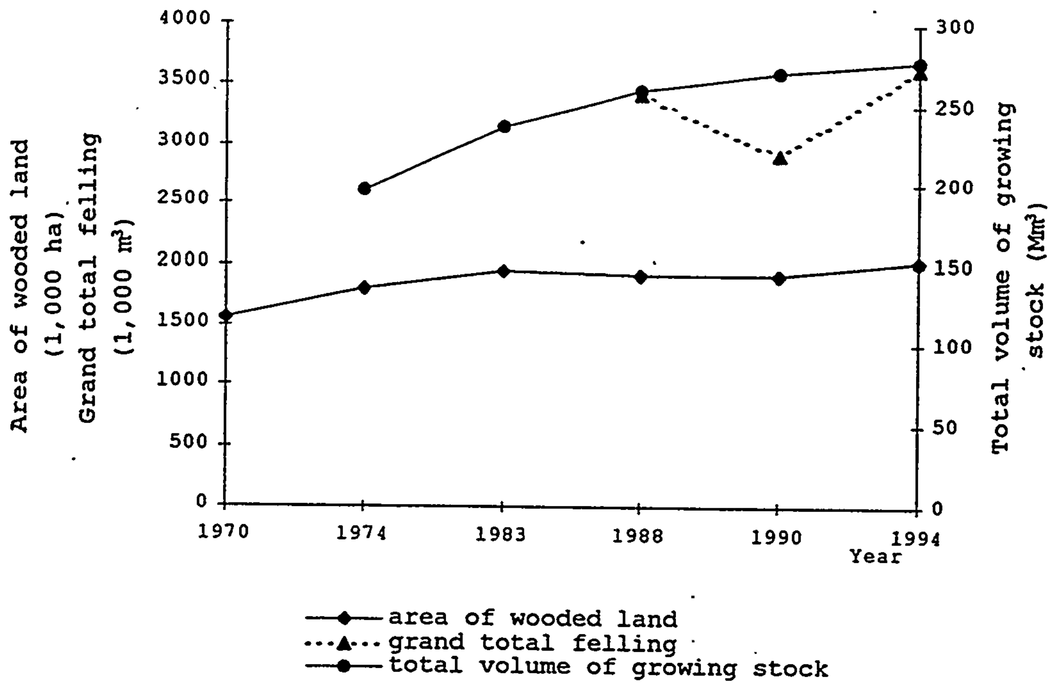


**Figure 12.** Changes in wooded land, volume of growing stock and grand total felling (Karoles *et al.*, 1994, Statistical Yearbook, 1994, Forestry 1994, 1995).

There are large uncertainties in all current methods for estimating fluxes of $CO_2$ and other greenhouse gases from forests and land use change. The simplified method for the estimation of $CO_2$ and other GHG-s fluxes which has been recommended by the IPCC/OECD Programme on the Development of a Methodology for National Inventories of Net Greenhouse Gas Emissions was used in the present study (IPCC Guidelines, 1994). The data of Estonian Forest Department, Estonian Forest Survey Center, Estonian Forest Institute and Faculty of Forestry of Estonian Agricultural University have been used in the inventory calculations. The IPCC Guidelines contain default methodologies and some data for the estimation of greenhouse gas emissions and removals. Average annual statistics on land use change and management activities are used. The assumptions and default datas (recommended by IPCC Guidelines) have been used when national assumption were not available. Here we have to mention that Estonian forests are situating in boreal region and according to methods required only total data about Estonian forests are included into tables.

In the calculations of $CO_2$ budget in Estonian forests the following factors were considered:

**$CO_2$ from:** Changes in forest and other woody biomass stocks

Forest and grassland conversion

Abandonment of managed lands

**$CH_4$, CO, $N_2O$, $NO_X$** from:

On - site burning of cleared forests and woodlands

1990±1 is designated as a base year for calculation of $CO_2$ emission and uptake. According to the methodological requirements current emissions of $CO_2$ from biomass left to decay were estimated over the previous decade (1980-1990). Emissions from soils due to conversions were estimated over previous 25 years (1965-1990). For the immediate release from burning the data of year 1990 were used. In 1994 the forest conversion did not take place and thus immediate release from burning did not occur. To estimate $CO_2$ release from abandoned managed lands for a base year data from 1970-1990 were used and for 1994 the data from 1974-1994.

In the 1990 inventory the areas converted under ditches (1010 ha) have been considered forest conversion. In 1994 the situation was completely changed: under the new economic situation the drainage in forests had stopped. This is due to the uncertainties in the fate of forest land because of the continuous process of returning lands to private owners is under way. Forest conversion did not take place during the period of privatization and ongoing process of restructuring the socioeconomic system offers good possibilities for decreasing $CO_2$ emission.

### *2.6.1 $CO_2$ removals and emissions*

The calculation results showed that $CO_2$ uptake by Estonian forests in 1990 exceeds 3.3 times its emission.

The calculations focus primarily forest conversion processes and abandonment of managed lands. In the calculation $CO_2$ removals or emissions of forests have been taking into account alterations of areas and aboveground biomass changes due to management of forest. So, annual removal of $CO_2$ by Estonian forests was during the inventory year 11346.75 Gg. This figure includes 7438.27 Gg $CO_2$ due to accumulation by total growth increment of managed forests and 3908.48 Gg $CO_2$ due to accumulation by abandonment of managed lands over previous 20 years.

In the processes of forest management a portion of wood may be removed from the conversion site and used as fuelwood or for products. This results 2791.01 Gg of $CO_2$ emission annually to the atmosphere. A portion may be burned on site or converted to slash and decayed to carbon dioxides step by step. The annual rate of soil $CO_2$ emission from forest conversions was estimated 508.75 Gg $CO_2$. Total $CO_2$ emission from forest ecosystem was 3396.31 Gg $CO_2$.

Taking into account emissions and removals of $CO_2$ in forest ecosystem the net $CO_2$ uptake by forest ecosystem in Estonia estimates 7950.44 Gg per year.

### *2.6.2 Non-$CO_2$ trace gases*

Inventory of methane ($CH_4$), carbon monooxide (CO), nitrous oxide ($N_2O$) and oxides of nitrogen ($NO_x$, i.e. NO and $NO_2$) emissions have been carried out in case of burning associated with forest conversion (Table 13).

**Table 13.** The results of estimation of emissions (Gg) of non-$CO_2$ trace gases in Estonian forests.

| $CH_4$ | CO | $N_2O$ | $NO_x$ |
|---|---|---|---|
| 0.1521 | 1.3307 | 0.0010 | 0.0378 |

## *2.7 WETLANDS*

Accounting the importance of wetlands in Estonia and lack of methodical approaches in IPCC Guidlines (1994 and 1995), a special methodology was worked out for inventory of GHG in this sector.

Although the peatlands cover about 1 million ha or ca 22% of Estonian territory the peat accumulation as the main functional pecularity characterizing the virgin state of the peatland is proceeding on much more limited areas. During the last decades our peatlands have been influenced importantly by amelioration activities mostly for agricultural and forestry purposes. Role of peat industry is considered to be somewhat lower.

The inventory aimed to assess the ecological state and values of peatlands is not did in Estonia up to date. Therefore we can't postulate how much of our peatlands and/or wetlands are in virgin state, what part is indirectly affected by the drainage or damaged otherwise than amelioration for agricultural, forestry or peat industry purposes.

The way to get some more realistic picture about the state of Estonian peatlands is to do the expert assessment.

According to official data there is drained for agricultural aims about 120 000 ha, for forestry purposes some 180 000 ha and for industry needs ca 38 000 ha of peatlands. The total value of about 340 000 ha of drained peatlands does not correspond to the actual area of drained or affected by amelioration peatlands for reasons described in following:

1. The data gives information about the area of amelioration systems established, but does not describe the territories bordering the systems which are affected by the activities. Also, there is not accounted with the outflow ditches and other compartments made outside the systems and widering the affected area in its way.
2. It is not accounted with bordering or surrounding ditches made around almost all peatlands during the decades, especially in fifthies and sixties.
3. During the Soviet period many state and collective farms did different kind of amelioration activities outside any official plans. Result to that the most part of peatlands on thin peat layer were drained with the help of only few ditches cut through peatland and reaching the mineral ground below peat deposit.
4. Result of straightening of rivers and streams peatlands locating close to waterflows were drained but not accounted as drained areas.
5. In peat industry the areas bordering peat-fields and affected drastically by peat-cutting are also not taken into account.

6. It is not considered with the influence of oil shale industry on the state of peatlands distributing above the oil shale mines or damaged result to emission of calcium-rich dust from the oil shale industry.

As Nyström (1992) has estimated, in case of drainage for peat mining the area outside the edge ditches influenced by drainage may be from 50 to 130% with average value of 90% of the mined area. Consequently, multiplying the official drainage value with factor 2, we should reach almost realistic data of affected by drainage area for peatlands.

Most drastically are affected fens, swamps and floodplains of which about only 10% are still in virgin state. Less important is drainage influence to bogs. The anthropogenic effect on the state of lakes and marshes has consequenced in the falling down of the water level only in very exceptional cases.

Our data indicate that the peat accumulation in different peatland types is not varying largerly and is between 1.5 and 1.9 t $ha^{-1}$ $y^{-1}$ [Ilomets, 1994]. Here the accounts are based on the mean value of 1.7 t $ha^{-1}$ $y^{-1}$. In lakes the accumulation on organic sediments (gyttja) is differing importantly from 1 to 100 mg $cm^{-2}$ $y^{-1}$, e.a. the mean value is taken as 10 mg $cm^{-2}$ $y^{-1}$ or 1 t $ha^{-1}$ $y^{-1}$ . If consider with 54% carbon content in the dry matter both in peat and lake gyttia then the mean accumulation of $CO_2$-C in the virgin peatlands is about 0.9 t $ha^{-1}$ $y^{-1}$ and in lakes ca 0.324 t $ha^{-1}$ $y^{-1}$ as the ash content in Estonian lake muds is about 40% (Ramst, 1992).

Result to drainage of virgin peatlands the accumulation of organic matter has ceased and due to intensive decay processes the mineralization of the matter has started. For several decades the breakdown of peat deposit and peat losses processes on fenlands ameliorated for agricultural purposes is monitored in Estonia. It is shown that the mineralization of organic matter is about 15 to 20 tons per hectar per year during the first decade after the establishment of amelioration system [Tomberg, 1992]. Later it will be stabilisized and depending on the character of exploitation (crop field, grassland, pasture) may be between 5 and 15 tons per hectar per year. Possible mean level may be about 8 tons per hectar per year or 4.3 t of $CO_2$-C if consider with relative importance of different exploitation ways in Estonia. Franzen (1994) concludes that after drainage the annually decomposed peat lies within the range of 15 to 124 times the mean annual peat accumulation. Also it is shown that the rate of mineralization of the peat on bogs and swamps is quite probably on the same level as on fenlands.

**Table 14.** Carbon bases $CO_2$ and $CH_4$ accumulation and emission on wetlands in 1970.

| Type of wetland | $CO_2$ -C accumulation, Gg | $CO_2$ -C emission, Gg | $CH_4$ emission on virgin wetlands, Gg | $CH_4$ emission on wetlands affected by drainage, Gg |
|---|---|---|---|---|
| Bogs * | 275 | 344 | 0.4 | 0.1 |
| Fens * | 174 | 860 | 6.7 | 0.3 |
| Swamps * | 103 | 215 | 0.2 | 0.05 |
| Marshes * | 5 | unknown | 2.4 | unknown |
| Floodplains* | 32 | 228 | 3.2 | 0.05 |
| Lakes ** | 67 | unknown | 24.2 | unknown |
| TOTAL | 656 | 1,647 | 37.1 | 0.50 |

* $CO_2$-C accumulation on virgin peatlands is approximately 0.9 t C $ha^{-1}$, $CO_2$-C emission is calculated when the annual peat mineralization on drained peatlands is 4.3 t C $ha^{-1}$.
** annual C accumulation in Estonian lakes is taken equal to 324 kg $ha^{-1}$

**Table 15.** Carbon based $CO_2$ and $CH_4$ accumulation and emission on wetlands in 1990.

| Type of wetland | $CO_2$ -C accumu-lation, Gg | $CO_2$ -C emission, Gg | $CH_4$-C emission on virgin wetlands, Gg | $CH_4$-C emiss-ion on affected wetlands, Gg |
|---|---|---|---|---|
| Bogs* | 230 | 559 | 4.9 | 0.1 |
| Fens* | 46 | 1459 | 5.1 | 0.5 |
| Swamps* | 10 | 651 | 1.2 | 0.2 |
| Marshes* | 5 | unknown | 2.4 | unknown |
| Floodplains* | 6 | 353 | 0.5 | 0.1 |
| Lakes** | 67 | unknown | 24.2 | unknown |
| TOTAL | 364 | 3022 | 35.9 | 0.9 |

* $CO_2$-C accumulation on virgin peatlands is approximately 0.9 t C $ha^{-1}$, $CO_2$-C emission is calculated when the annual peat mineralization on drained peatlands is 4.3 t C $ha^{-1}$.
** annual C accumulation in Estonian lakes is taken equal to 324 kg/ha.

Calculations of $CO_2$ and $CH_4$ emissions from wetlands are presented in Appendix 1 and in Worksheets 5-5 in Appendix 2.

Total emission of $CH_4$ and $CO_2$ from wetlands for year 1990 is respectively:

$(35.9+0.9) \times 16 / 12 = 49.1$ Gg of $CH_4$ (not included into total emissions).

and 3022 x 44 / 12) = 11080 Gg of $CO_2$ (included into Forestry and Land-Use Change sector).

## 2.8 WASTE

The most important greenhouse gas produced from disposal and treatment of industrial and municipal wastes is methane. Two major sources of this type of methane production are landfills and wastewater treatment. In Estonia the methane emissions from waste are caused mainly by landfills, by domestic and commercial wastewater treatment and by industrial wastewater.

Organic landfill materials such as yard waste, household garbage, food waste, and paper can decompose and produce methane when organic material in treated and untreated wastewater degrades anaerobically, i.e., without the presence of oxygen. Methane production typically begins one or two years after waste placement in landfill and last long time (over 50 years). Methane may be recovered for use as an energy source.

Amounts of Estonian methane emissions from municipal landfills, municipal and industrial wastewater in 1990 are given in Table 16. Total amount of $CH_4$ emissions from waste in 1990 was 42.1 Gg.

**Table 16.** Methane emissions from waste in 1990

| Source | $CH_4$ Emissions Gg |
|---|---|
| Municipal Landfills | 26.3 |
| Municipal Wastewater | 0.6 |
| Industrial Wastewater | 15.2 |
| **Total Wastes** | 42.1 |

## 2.9 GHG EMISSIONS FOR 1990 AND THEIR RECENT TRENDS IN 1991-1993.

Since 1990 drastic changes haven taken place in Estonian economy, especially in the energy policy. The power-intensive and material-consuming industries that had been subsidized by abnormally low fuel prices collapsed economically during extremly short time. The import of fossil fuels has decreased substantially as prices of imported fuels have rapidly increased and by now reached that of world market level. Figure 13 shows the price increase for different fuels in the period of 1991-1993. As the price increases for different types of fuel varies the changes in the structure of fuel consumption have been significant.

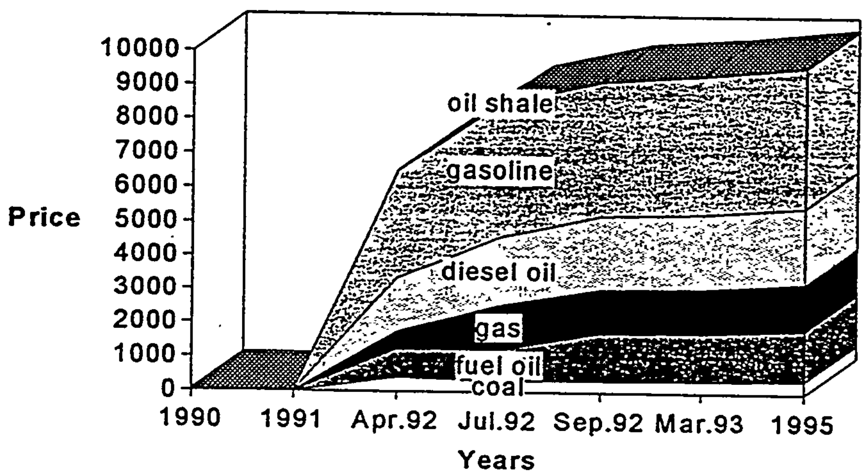


**Figure 13.** The increase of fuel prices 1990-1995.

The export of electric energy decreased sharply: from 8.477 GWh in 1990 to 1.596 GWh in 1993 (Statistical Yearbook, 1994). As a result the total supply of fossil fuels decreased during 1990-1993 by 43,8%, of natural gas by 70,8%, of coal by 68,3%, of liquid fuels by 52,8% and of oil shale by 35,6% (Punning et al.,1995). During these years the total emission of $CO_2$ from energy production and use has decreased by 41,5%. When in 1990 Estonia was in the fifth place in the world by emission of $CO_2$ per capita (after Qatar, Virgin Islands, United Arab Emirates, Luxembourg), then in 1993 the carbon dioxide emission had dropped to 3.9 T per capita (in 1990 this value for USA was 5.26, Canada 4,35, Australia 4,32, global mean 1,15 (United Nation Environmental Data Report, 1994)).

Essential changes have also taken place in agriculture. During the last years the area of total arable land has decreased by 10-20%, the number of cattle by 42,6% and that of pigs by more than 2 times. Due to rapid increase in prices of mineral fertilizers the total amount of nitrogen used in agriculture has decreased by 3,5 times (Punning et al., 1995). As a result of decreased agricultural intensity and its restructuring the emission of methane from enteric fermetation and animal wastes has decreased in 1993, as compared with 1990 by more than 20% and nitrous oxide emission from agricultural soils - about twice.

The area of productive forest land has increased in 1990-1994 by about 5%, mainly due to the abandonment of agricultural lands. Taking into account the changes in the structure of commercial harvest and fuelwood consumption, the emission from Estonian forests has increased by 1%. Annual removal of $CO_2$ to Estonian forest in 1994 was 11,089 Gg, what is only 2% lower than in 1990, although there was alterated balance in $CO_2$ removal between different land use changes and forest categories (Table 17).

**Table 17.** Removals/emissions of $CO_2$ (Gg) due to forestry and land use change in 1990 and 1994.

| | | $CO_2$ (1990) | | $CO_2$ (1994) | |
|---|---|---|---|---|---|
| | | Removal | Emission | Removal | Emission |
| Forest Manage- | Biomass Growth Increment | 7438.27 | - | 8602.47 | - |
| ment | Harvest | - | 2791.01 | - | 2989.14 |
| Forest | On- and off-site Burning | - | 62.73 | - | 0 |
| Conversion | Decay | - | 33.82 | - | 19.32 |
| | Soil | - | 508.75 | - | 420.57 |
| Abandoned Managed | Aboveground Biomass | 1642.70 | - | 1045.04 | - |
| Lands | Soil | 2265.78 | - | 1441.44 | - |
| **Total:** | | 11346.75 | 3396.31 | 11088.95 | 3429.03 |

Net $CO_2$ uptake by Estonian forests in 1994 estimates 7660 Gg that is 3.7 % lower than in 1990.

**Table 18.** Overview of GHG emissions in Estonia in 1990 and 1993

| GHG Source and Sink Categories | Emissions, Gg | | | | | |
|---|---|---|---|---|---|---|
| | $CO_2$ | | $CH_4$ | | $N_2O$ | |
| | 1990 | 1993 | 1990 | 1993 | 1990 | 1993 |
| Fuel Combustion | 37184 | 21751 | 3 | NA | 1.4 | NA |
| Fugitive Fuel Emissions | NO | NO | 217 | 105 | NO | NO |
| Industrial Processes | 613 | NA | NA | NA | NA | NA |
| Agriculture | NO | NO | 60 | 48 | 0.9 | 0.5 |
| Land Use Change & Forestry | -7950 | -7660 | NO | NO | NO | NO |
| Wetlands | 11079 | NA | NO | NO | NO | NO |
| Wastes | NO | NO | 42 | NA | NO | NO |

NA - not available NO - not occuring

The data given in Table 18 demonstrate that, due to economical depression and restructuration the total amount of emitted GHG in Estonia decreased from 1990 to 1993 by about 40%. It must be mentioned that besides direct dropping GHG the emission of other pollutants like $SO_2$, fly ash, aromatic chemical etc. has also decreased.

## *2.10 CONCLUSIONS.*

As radical changes have taken place in the Estonian economy and political life since 1990, strong trends towards the decrease of GHG emission prevailed as the result of which within the last 3-4 years the total emission of GHG in Estonia has diminished by about 40%. Therefore for Estonia the projection of GHG inventory data for the internationally accepted baseline year 1990 on the future and accounting these data as a basis for the assessment of mitigation options or cross-sectoral options in order to produce a national strategy for controlling GHG emissions would be incorrect. At the same time it is obvious that the trend of decreasing of GHG emissions is partly connected with economical slowdown and cannot continue at such rate. After the

~~produce a national strategy for controlling GHG emissions would be incorrect. At the same time it is obvious that the trend of decreasing of GHG emissions is partly connected with economical slowdown and cannot continue at such rate. After the~~ improvment of the economical situation the period of stabilization and an increase in energy use will follow.

When following the policies and measures worked out for the transfer to economically based energy-saving and less energy-consuming production in Estonia the increase in the emission of GHG will not be proportional to that of improvment of the economy. Some measures have already been taken according to new energy policy including that of increased utilization of domestic wood-, peat- and other biofuels. In order to assess potential environmental impacts, and draw up an overall mitigation and monitoring plan, a sectoral Environmental Assessment on the Utilization of Domestic Peat and Wood Raw Material as a Fuel Source for Heating Systems (1994) has been carried out. The analysis of available data shows that it is possible to increase the share of domestic biofuels for heat production up to 12%. The loss of photosynthetically active biomass will be avoided by the improvment of the forests management techniques and only formerly drained peatlands will be utilized. The decrease of oil shale use in energy production will limit the $CO_2$ emission caused by thermal decomposition of its mineral constituent.

There are considerable possibilities of national energy saving. Creation of direct economic stimuli to energy-saving and provision of the consumers with concrete recommendations and credits for the purpose of energy-saving and instructions for saving energy in households will play an important role.

In 1990 the contribution of transport to the total GHG was relatively low. During the last years the number of cars ( private vechicles first of all), has been increasing rapidly. Up to now the second-hand cars (5-10 years old) dominate. In case of income of the inhabitants rising and tax policy changing the renovation of car contingent will grow intensively and probably the future emission from transport will reach the same level as in 1990.

The prognosis by PHARE programme shows certain agriculture level stabilization in the future. This together with better seed selection and-fertilizers' use in agriculture allows to presume that GHG emissions from agriculture will decrase slightly in comparison with 1993.

The methane emissions from landfills in 1990 formed the major part of the total methane emission. The advances in systematic waste management and building of boilerhouses working on biogases derived from waste dumps allows to prognose the stabilization or decrease in methane emissions from landfills.

Summarizing the above-said it seems probable that in 2000 the emissions of GHG will be at the level of 1993 or even less.

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# Appendix 1
# Detailed Description of Methods and Data Used

## 1. Energy

### *1.1 Combustion*

For estimating the emissions of greenhouse gases from energy activities the IPCC top-down method (IPCC Guidelines 1994, 1995) was used. $CO_2$ emissions are produced in the burning of carbon-based fuels. Estonian national emissions estimates were made on the base of the amounts of fuels used and the carbon content of fuels. Fuel amounts were available from national statistics (Statistical Yearbook, 1994), where the energy balance in energy units (PJ) is presented. The data is collected by Estonian Statistical Office and all energy activities excluding military fuel use are covered. In 1990 Estonia had planned economy, where energy resources were centrally controlled and therefore data that is needed for bottom-up approach, is not available in Estonia for year 1990.

For estimation of apparent fuel consumption for each fuel following formula is used:

**Apparent Consumption = Production + Imports - Exports - International Bunkers - Stock Change**

Apparent fuel consumption is converted into carbon content using formula:

**Apparent consumption x Carbon Emission Factor (CEF)**

Carbon emission factors (CEF) of fuels are given in Table 1.

**Table 1.** 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 | 18.9 | 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 | | |
| Lubricants | 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 |

* Calculation of carbon emission factor of oil shale is described on next page.

IPCC Guidelines (1994, 1995) does not contain information about Estonian oil shale and its carbon emission factor. As oil shale is the main indigenous fuel of Estonia therefore its short description is given below.

Estonian oil shale as fuel is characterized by high ash content (45-50%), a moderate content of moisture (11-13%) and of sulphur (1.4-1.8%), a low net caloric value (8.5-9 MJ/kg), a high content of volatile matter in combustible part (up to 90%). The dry matter of Estonian oil shale considered to consist of three main parts: organic, sandy-clay and carbonate.

In 1986 oil shale reserves in the Estonian field made 4,400 million t, while commercial supplies are estimated at 1,200 million t. Oil shale is produced in three open pits and six underground mines and oil shale is mined in two qualities: coarse (grain size 25-250 mm) or crushed (grain size 0-25 mm). Coarse oil shale is processed into oil shale oil. Crushed oil shale (approximately 80%) with caloric value of 8.5-9 MJ/kg is suitable to be used as boiler fuel in big power plants.

From the point of view of greenhouse gase emissions it is important that during combustion of powdered oil shale $CO_2$ has been formed not only as a burning product of organic carbon, but also as a decomposition product of ash carbonate part. Therefore the total quantity of carbon dioxide increases up to 25% in flue gases of oil shale.

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

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

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 pulverised combustion of oil shale)(Kull, et al., 1974).

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

Calculation of oil shale carbon emission factor:

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

## *1.2 Stationary Sources*

Estimation of emissions from stationary source are described using the following basic formula (IPCC Guidelines 1994, 1995):

$$Emissions = \Sigma\ (EF_{abc} \times Activity_{abc}),$$

where **EF** - emission factor, ( kg/TJ );

**Activity** - energy input, ( TJ );

**a** - fuel type;

**b** - sector - activity;

**c** - technology type.

Emission factors for all non-$CO_2$ greenhouse gases from combustion activities vary with fuel type, combustion technology, operating conditions and maintenance and ventage of technology.

In Estonia there are two large power plants: the Estonian - 1610 MW and the Baltic - 1435 MW and other two smaller ones: Kohtla-Järve - 39 MW, and Ahtme - 20 MW. In these power plants pulverised oil shale combustion technology is used. In Iru (190 MW) and in Ülemiste (11 MW) power plants heavy fuel oil and natural gas are used (all figures include only electrical power).

In 1990 there were 3,290 boilerhouses and 7,576 boilers (nearby 40 different types) with total heating capacity 11,272 MW in Estonia. The distribution of heating capacity was: solid fuels - 2327 MW, oil - 6226 MW and natural gas - 2719 MW.

For calculations of emissions of non-$CO_2$ greenhouse gases across activities are not any reliable emission factors in Estonia. Therefore the emission factors from IPCC Guidelines (1995, Volume 3, tables 1-7 ÷ 1-16) were used. But for oil shale boilers in these tables is not any information except oil shale oil boilers (Table 1-7).

Emission factors on non-$CO_2$ greenhouse gases for oil shale power plants and oil shale industry activities were calculated on bases quantities from stationary sources (Gg) 1991 (data from Estonian Institute of Meteorology and Hydrology) and oil shale consumption (PJ) 1991 (Statistical Yearbook, 1994).

**Table 2.** The emission factors for non-$CO_2$ greenhouse gases for oil shale power plants and oil shale industry activities.

| Activities | Consumption, PJ 1991 A | Emissions, Gg 1991 B | | Emission factor, t pollutant/TJ C C=B/A | |
|---|---|---|---|---|---|
| | | $NO_X$ | CO | $NO_X$ | CO |
| **Energy** | | | | | |
| Oil shale (PJ) | 206.221 | 25.7 | 5.3 | 0.1246 | 0.0257 |
| **Industry activities** | | | | | |
| Oil shale (PJ) | 13.779 | 1.7 | 1.2 | 0.1234 | 0.0871 |

### *1.3 Greenhouse Gas Emissions from Mobile Sources*

Estimation of emissions from mobile source is a very complex undertaking that requires consideration of many parameters, including transport class fuel consumed, operating characteristics, emission controls, maintenance procedures, fleet age.

The basic calculation for estimating greenhouse gases emissions can be expressed as:

$$\textbf{Emissions} = \Sigma ( EF_{abc} \times Activity_{abc} )$$

where: EF - emission factor;

Activity - amount of energy consumed for a given mobile source activity;

a - fuel type (diesel, gasoline, LPG, bunker, etc.);

b - vehicle type (e.g. passenger, light-duty or heavy-duty for road vehicles);

c - emission control (in 1990 in Estonia emission control was not used).

In 1990 there in Estonia was 240,900 passenger cars, 7,900 buses, 67,700 lorries and special vehicles, 105,700 motor-cycles, 45,193 tractors, 1695 small excavators, 113 diesel locomotives, 204 merchant ships, 17 passenger ships, 5 merchant ships entered terminally, 8 passenger ships entered terminally (Statistical Yearbook, 1994). Also, amounts of different fuel used (gasoline, diesel oil, natural gas etc.) in transport sector (in PJ) is available from national statistics.

In 1990 vehicles used in Estonia originated mainly from USSR, and no emission factors for these vehicles were available. Therefore detailed calculations according to vehicle type were not carried out, only emissions from vehicles using gasoline or diesel oil were calculated separately. For non-$CO_2$ GHG emission calculations, emission factors from Sweden's National Report (1994) were used (Table 3.) and compared with emission factors in IPCC Guidelines (1995, Volume 3, tables 1-20 ÷ 1-40).

**Table 3.** Emission factors (kg pollutant per PJ) for mobile sources (Sweden's National Report, 1994).

| Fuel | $CH_4$ | $N_2O$ | $NO_X$ | CO | NMVOC |
|---|---|---|---|---|---|
| Oil | 0.54 | 0.001 | 0.91 | 4.8 | 0.64 |

## *1.4 Burning Traditional Biomass Fuels*

For all burning of biomass fuels, IPCC Guidelines requires that net $CO_2$ emissions are treated as zero in the energy sector. Non-$CO_2$ gases are emitted from burning of biomass fuels. Emissions of methane, carbon monoxide, nitrous oxide, and oxides of nitrogen are net emissions and are accounted for as energy emissions.

<u>Step 1:</u> The general equation for estimating carbon emissions is:

**Carbon Released from Biomass Fuel = Total Biomass Consumed (kt dm) × Fraction Oxidised × Carbon Fraction**

<u>Step 2:</u> Non-$CO_2$ trace gas emissions from burning calculation is summarised as follows:

**$CH_4$ Emissions = (carbon released) × (emission ratio) × 16/12**

**CO Emissions = (carbon released) × (emission ratio) × 28/12**

**$N_2O$ Emissions = (carbon released) × (N/C ratio) × (emission ratio) × 44/28**

**$NO_x$ Emissions = (carbon released) × (N/C ratio) × (emission ratio) × 46/14**

In Estonia only wood is used as the biomass fuel. All calculations of emissions from burning Estonian biomass (wood) fuel are carried out using constant from IPCC Guidelines (1994, 1995).

## *1.5 Fugitive Emissions from Oil Shale Mining and Handling Activities*

This section covers fugitive emissions of greenhouse gases from production, processing, handling and utilisation of coal. In Estonia only oil shale is mined and burned for energy generation. For approximate estimations of fugitive emissions from oil shale mining and handling, emission factors for lignite suggested in IPCC Guidelines (1994, 1995) were used.

The structure of the $CH_4$ emissions from mining (underground and surface mining) and post mining activities (underground and surface mining) is (IPCC Guidelines, 1994, 1995):

$$CH_4 \text{ Emissions (Gg)} = CH_4 \text{ Emission Factor } (m^3\ CH_4/\text{ton of oil shale mined}) \times \text{oil shale production (Mt)} \times \text{Conversion Factor } (Gg/10^6\ m^3)$$

Conversion Factor converts the volume of $CH_4$ to a weight measure and is the density of methane at 20°C and 1 atmosphere, namely 0.67 $Gg/10^6\ m^3$.

When consulting with the specialists from Oil Shale Institute in Kohtla-Järve, Estonia, the emission factors of former Soviet Union lignite mining activities ($m^3\ CH_4/t$) were chosen for underground and surface mining and post-mining activities. Estonian experts did not have any estimations of methane emissions from oil shale mining activities. As lignite is similar fuel to oil shale, therefore it's emission factors could be used for approximate estimation of methane emissions.

### *1.6 Fugitive Emissions from Oil Shale and Natural Gas Activities*

Sources of fugitive emissions within oil and gas systems include releases during normal operation, such as emissions associated with venting and flaring, chronic leaks or discharge from process vents, emissions during maintenance, and emissions during system upsets and accidents.

In 1990 liquid fossil fuels and natural gas were mainly imported from Russia. Only oil shale oil was produced in small quantities in Estonia.

The equation for calculating $CH_4$ missions from oil and gas activities is:

$$CH_4 \text{ Emissions } (Gg\ CH_4) = \{\text{Activity (PJ)} \times \text{Emission Factor } (kg\ CH_4/PJ)\} : 10^6$$

Emission factors of oil and gas activities base on data in Table 1-8 of IPCC Guidelines (1994, 1995).

## 2. Industrial Processes

### *2.1 Cement Manufacturing*

Carbon dioxide emitted during the cement production process represents the most important source of global carbon dioxide emissions from industry.

The equation for calculation $CO_2$ emissions from cement manufacturing is:

$$CO_2 \text{ Emissions } (Gg\ CO_2) = \{\text{cement production (t)} \times \text{Emission Factor } (t\ CO_2\ /\ t\ \text{cement})\} : 1000$$

The IPCC Guidelines (1994, 1995) recommended method assumes the average CaO content of cement to be 63.5%, which gives on emission factor of 0.4985 $CO_2$/t cement.

### *2.2 Lime Manufacturing*

For calculation $CO_2$ emissions from lime manufacturing could be used the formula of $CO_2$ emissions from cement production. Emission factor of $CO_2$ for lime manufacturing is taken equal to molecular weight ratio of $CO_2/CaO = 44/56 = 0.7857$

## 3. Agriculture

Animal husbandry and use of fertilizers are the main GHG emission sources in Estonian agriculture. Emissions from burning straw and other plant residues are not calculated in the present inventory as the statistical data are not available. Also in our conditions the burning of plant residues is not essential source of GHG emission. According to US Country Studies Program $CH_4$ and $N_2O$ emissions are more studied and methodologically analysed.

Methane from enteric fermentation is produced in herbivores as a by-product of the digestive process. Micro-organisms in the gastric-intestinal tracts of ruminant and non-ruminant animals in particular form methane when they digest the fodder. The formation of methane that is released depends on the type, age and weight of the animal, the quantity and quality of fodder and the energy expository of the animal. The lower the quality is of the consumed feed, the more methane will be formed.

Methane emission from animal manure depends on the amount of produced manure, and management of the manure. When manure is stored or treated as a liquid, significant quantity of methane is produced.

Methane emissions from enteric fermentation and manure management are calculated according to IPCC methodology (IPCC Guidlines, 1994, 1995), where different emission coefficients were given to different animal types (Table 3).

**$CH_4$ emissions = population of animals x emission coefficient**

**Table 3.** Emission factors for enteric fermentation and manure management.

| Animal type | Enteric Fermentation (kg $CH_4$ head$^{-1}$ yr$^{-1}$) | Manure Management (kg $CH_4$ head$^{-1}$ yr$^{-1}$) |
|---|---|---|
| Dairy cattle | 81 | 6.000 |
| Non-dairy cattle | 56 | 4.000 |
| Sheep | 8 | 0.190 |
| Goats | 5 | 0.120 |
| Horses | 18 | 1.400 |
| Swine | 1.5 | 4.000 |
| Poultry | 0 | 0.078 |

The number of livestock and poultry as well as all statistical data, which were used in these estimations were derived from the publications of the Statistical Office of Estonia (Statistical Yearbook, 1991, 1992, 1993, 1994; Estonian Statistical Bulletin, 1994 No 1-12, 1995 No 1-6).

Nitrous oxide has been produced in soils as the result of microbial processes of denitrification and nitrification. Nitrous oxide production and emissions from soils are affected by such factors as conditions and properties of soils, crop type, management regime, synthetic nitrogen fertilizer and animal manure application, biological nitrogen fixation, etc. Nitrous oxide emissions from agricultural soils was estimated using the methodology of IPCC Guidelines (1994):

$$N_20 \text{ Emissions} = \Sigma (Fmn + Fon + Fbnf) \times C \times 44/28$$

where: **Fmn** - amount of mineral fertilizer applied ($10^3$ t N / yr).

**Fon** - amount of organic fertilizer applied ($10^3$ t N / yr)

**Fbnf** - amount of biological nitrogen fixation applied ($10^3$ t N / yr)

According to the calculations done by scientists of the Research Institute of Agriculture 31 kg of nitrogen per hectare of arable land is fixed symbiotically and non-symbiotically or added by run-off etc. (Kanger, et al., 1994). This figure used for calculating of $N_2O$ emissions.

$C_{low} = 0.0005$

$C_{medium} = 0.0036$

$C_{high} = 0.0390$

# 4. Forestry and Land Use

## 4.1 Changes in Forest and Other Woody Biomass Stocks

Worksheet: 5-1

Goal: Calculate net flux of $CO_2$ due to changes in forest and other woody biomass stocks, including logging, fuelwood harvest and reforestation. Other activities (plantation establishment, urban tree planting) are ignored, because there is not available data and they have no significant effect on $CO_2$ emissions.

Three steps:

1. Estimate annual biomass C uptake due to forest management
2. Estimate annual biomass C removal from roundwood harvest and fuelwood consumption
3. Estimate net C flux (1. - 2.) and convert to $CO_2$ (uptake if net flux > 0; release if net flux < 0)

### *4.1.1 Information requirements*

Forest Management

- **area of managed forests - 1,554,500 ha**

Area of Estonian forest stands in 1970 (Karoles *et al.*, 1994); during 1970-90 increased forest land area have been estimated in "Abandonment of managed lands" to avoid double counting of $CO_2$.

- **annual biomass growth rate of managed forests - 2.9 t dm/ha/yr**

Estimated growth rate of stemwood with branches is 11.5 $Mm^3/yr$ (Supply, Production and Costs..., 1994);

area of productive forest land is 2.0 Mha (Supply, Production and Costs..., 1994);

conversion ratio is 0.5 (default values for converting volume data to tons are 0.65 t $dm/m^3$ for deciduous trees and 0.45 t $dm/m^3$ for conifers (IPCC Guidelines, 1994); 2/3 of the Estonian forests are conifers (Statistical Yearbook, 1994) hence conversion ratio = $2/3 \times 0.45 + 1/3 \times 0.65$);

annual biomass growth rate of managed forests = $11.5/2.0 \times 0.5$.

- **biomass C fraction - 0.45**

Default value (IPCC Guidelines, 1994).

Biomass Removals

- **annual roundwood harvest - 2,356,200 $m^3$/yr**

Industrial wood in 1988 (Karoles *et al.*, 1994).

- **biomass conversion/expansion factor - 0.5**

Default values for converting volume data to tons are 0.65 t dm/$m^3$ for deciduous trees and 0.45 t dm/$m^3$ for conifers (IPCC Guidelines, 1994); 2/3 of the Estonian forests are conifers (Statistical Yearbook, 1994) hence conversion ratio = 2/3×0.45+1/3×0.65.

- **fuelwood consumption - 532,200 t dm/yr**

Estonian fuelwood consumption in 1988 was 1,064,400 $m^3$ (Karoles *et al.*, 1994); conversion factor to convert volume data to tons is 0.5 (see at previous).

- **other wood removals - 0**

Total wood harvested from Estonian forests are distributed as commercial wood or fuelwood.

- **biomass C fraction - 0.45**

Default value (IPCC Guidelines, 1994).

- **wood removed from forest clearing and burned off site - 18,780 t dm/yr**

From forest clearing calculation.

### *4.1.2 Calculation*

1. Annual biomass C uptake (t C/yr):

$$U = (AP \times GP \times CP)$$

where:

AP = area of managed forests (ha)

GP = annual biomass growth rate (t dm/ha/yr)

CP = C fraction for managed forests (t C/t dm)

$$U = (1{,}554{,}500 \times 2.9 \times 0.45) = 2{,}028{,}620 \text{ t C/yr}$$

2. Annual biomass C removal (t C/yr):

$$R = ((RW \times EF) + FW + OW - FC) \times C$$

where:

RW = roundwood harvest ($m^3$/yr)

EF = biomass conversion/expansion factor (t dm/$m^3$)

FW = annual fuelwood consumption (t dm/yr)

OW = other wood use (t dm/yr)

FC = wood removed from forest clearing and burned off-site (t dm/yr)

C = C fraction (t C/t dm)

**R = ((2,356,200 × 0.5) + 532,200 + 0 - 18,780) × 0.45 = 761,190 t C/yr**

3. Net $CO_2$ flux from managed forests (t $CO_2$/yr):

**(U - R) × 44 / 12**

where:

U = annual biomass C uptake (t C/yr) (Step 1)

R = annual biomass C removal (t C/yr) (Step 2)

**(2,028,620 - 761,190) × 44 / 12 =**

**+ 4,647,270 t $CO_2$/yr = +4,647.27 Gg $CO_2$/yr**

## *4.2 Forest and Grassland Conversion*

Worksheet: 5-2

Goal: Calculate $CO_2$ emissions from burning and decay of biomass, and from soils, due to the conversion of forest to permanent cropland, pasture or other land uses.

There has no grassland conversion in Estonia during the inventory period, because of Estonian grasslands have been used very long time as pastures or have in other ways affected by humans or they have been not affected at all. The datas of forest clearing for amelioration works are used in present calculation.

Four major steps:

1. Calculate net C emitted by burning aboveground biomass on site and off site (immediate emissions, occurring in the year of clearing)
2. Calculate net C released by decay of aboveground biomass (delayed emissions, occurring over a 10-year period)
3. Calculate C released from soil (delayed emissions, occurring over a 25-year period)
4. Add 1-3 to arrive at total figure for C released and calculate $CO_2$ from C figure

### *4.2.1 Information requirements*

- **average annual forest areas converted: inventory year, 10- and 25- year averages - 1,010, 1,470 and 1,500 ha/yr**

The numbers include areas converted under ditches and forest roads (Rebane A., personal communication).

- **aboveground biomass per unit of forest area - 92.95 t dm/ha**

Average standing volume of productive forest land in Estonia is 143 $m^3$ per hectare (the figure includs the top) (Statistical Yearbook, 1994);

conversion ratio is 0.5 (default values for converting volume data to tons are 0.65 t dm/$m^3$ for deciduous trees and 0.45 t dm/$m^3$ for conifers /IPCC Guidelines, 1994/; 2/3 of the

Estonian forests are conifers /Statistical Yearbook, 1994/ hence conversion ratio = 2/3×0.45+1/3×0.65);

branches and stumps are forming both 15 % of stemwood (Estonia: Sectoral Environmental..., 1994; Supply, Production and Costs..., 1994), hence they are added to the amount of aboveground biomass;

aboveground biomass = 143×0.5×0.30+143×0.5.

- **aboveground biomass per unit of replacement vegetation - 0**

The areas which are under ditches are not allowed to regrow.

- **fractions of biomass cleared that are burned on-site, burned off-site, and left to decay**

burned on-site = 0.25 - percent of branches and tops (Estonia: Sectoral Environmental..., 1994; Supply, Production and Costs..., 1994);

burned off-site = 0.20 - 1/3 of stemwood (in 1988 1/3 of total fellings was used for fuel /Karoles *et al.*, 1994/)

left to decay = 0.15 - percent of stumps (Estonia: Sectoral Environmental..., 1994; Supply, Production and Costs..., 1994).

- **fraction of biomass oxidized during burning both on- and off-site - 0.90**

Default value (IPCC Guidelines, 1994).

- **C fraction of biomass both on- and off-site - 0.45**

Default value (IPCC Guidelines, 1994).

- **C in soil per unit forest area - 185 t C/ha**

Default value. However in Estonian forests the soil carbon content ranges from 44 to 192 t/ha (Kylli, 1988) the default value recommended by IPCC Guidelines (1994) have been used in calculations.

- **fraction C released from soil following forest conversion - 0.5/25 yrs**

Default value (IPCC Guidelines, 1994).

### *4.2.2 Calculation*

1a. Total C released by burning aboveground biomass on site (t C/yr):

$$CO_n = A \times (BB - BA) \times FB_n \times FO_n \times C$$

where:

A = area converted annually (ha/yr)

BB = biomass density before conversion (t dm/ha)

BA = biomass density after conversion (t dm/ha)

FBn = fraction of biomass burned on site

FOn = fraction of biomass oxidized on site

C = C fraction (t C/t dm)

**COn = 1,010 × (92.95 - 0) × 0.25 × 0.9 × 0.45 = 9,510 t C/yr**

1b. Total C released by burning aboveground biomass off site (t C/yr):

**COf = A × (BB - BA) × FBf × FOf × C**

where:

A = area converted annually (ha/yr)

BB = biomass density before conversion (t dm/ha)

BA = biomass density after conversion (t dm/ha)

FBf = fraction of biomass burned off site

FOf = fraction of biomass oxidized off site

C = C fraction (t C/t dm)

**COf = 1,010 × (92.95 - 0) × 0.2 × 0.9 × 0.45 = 7,600 t C/yr**

1c. Total C released by burning aboveground biomass (t C/yr):

**CB = COn + COf**

where:

COn = amount of C released by on-site burning

COf = amount of C released by off-site burning

**CB = 9,510 + 7,600 = 17,110 t C/yr**

2. Total C released by decay of aboveground biomass (t C/yr):

**CD = AA-10 × (BB - BA) × FD × C**

where:

AA-10 = 10-year average annual area converted (ha/yr)

BB = biomass density before conversion (t dm/ha)

BA = biomass density after conversion (t dm/ha)

FD = fraction left to decay

C = C fraction (t C/t dm)

**CD = 1,470 × (92.95 - 0) × 0.15 × 0.45 = 9,220 t C/yr**

3. Total C released from soil (t C/yr):

**CS = AA-25 × SC × FR**

where:

AA-25 = 25-year average annual area converted (ha/yr)

SC = soil C fraction before conversion (t C/ha)

FR = fraction released over 25 years

**CS = 1,500 × 185 × 0.5 = 138,750 t C/yr**

4. Total $CO_2$ released from forest conversion (t $CO_2$/yr):

**(CB + CD + CS) × 44 / 12**

where:

| | | | |
|---|---|---|---|
| CB | = | total C released by burning aboveground biomass | (Step 1c) |
| CD | = | total C released from decay of aboveground biomass | (Step 2) |
| CS | = | total C released from soil | (Step 3) |

**(17,110 + 9,220 + 138,750) × 44 / 12 =605,300 t $CO_2$/yr = 605.3 Gg $CO_2$/yr**

## *4.3 Non-$CO_2$ Emissions from On-Site Burning of Cleared Forests and Woodlands*

Worksheet: 5-3

Goal: Calculate $CH_4$, CO, $N_2O$, and $NO_x$ emissions

Two steps:

Using total annual C released from on-site burning associated with forest clearing

1. Estimate total annual N released
2. Estimate annual C and N trace gas emissions and convert to full molecular weights

### *4.3.1 Information requirements*

- **annual C released from on-site burning associated with forest clearing - 9,510 t C/yr**

Calculated in Forest Conversion.

- **N/C ratio of biomass burned - 0.01 N/C**

Default value (IPCC Guidelines, 1994).

- **emission ratio of $CH_4$-C to $CO_2$-C released from burning -0.012**

Default value (IPCC Guidelines, 1994).

- **emission ratio of CO-C to $CO_2$-C released from burning -0.06**

Default value (IPCC Guidelines, 1994).

- **emission ratio of $N_2O$-N to N released from burning - 0.007**

Default value (IPCC Guidelines, 1994).

- **emission ratio of $NO_x$-N to N released from burning - 0.121**

Default value (IPCC Guidelines, 1994).

### *4.3.2 Calculation*

1. Total annual N released (t N/yr):

**COn × NC**

where:

COn = annual C released from on-site burning (Step 1a of Forest Conversion)

NC = N/C ratio

**9,510 × 0.01 = 95.1 t N/yr**

2a. Trace gas emissions

**$CH_4$ released (t $CH_4$/yr) = COn × $ER_{CH4}$ × 16 / 12**

**CO released (t CO/yr) = COn × $ER_{CO}$ × 28 / 12**

where:

COn = annual C released from on-site burning (Step 1a of forest conversion)

ER = emission ratio

**$CH_4$ released = 9,510 × 0.012 × 16 / 12 = 152.1 t $CH_4$/yr = 0.1521 Gg $CH_4$/yr**

**CO released = 9,510 × 0.06 × 28 / 12 = 1,330.7 t CO/yr = 1.3307 Gg CO/yr**

2b. Trace gas emissions

**$N_2O$ released (t $N_2O$/yr) = N ×$ER_{N2O}$ ×44 / 28**

**$NO_x$ released (t $NO_x$/yr) = N × $ER_{NOx}$ × 46 / 14**

where:

ER = emission ratio

N = total N released (t N/yr)

**$N_2O$ released = 95.1 × 0.007 × 44 / 28 = 1.000 t $N_2O$/yr = 0.0010 Gg $N_2O$/yr**

**$NO_x$ released = 95.1 × 0.121 × 46 / 14 = 37.8 t $NO_x$/yr = 0.0378 Gg $NO_x$/yr**

## *4.4 Abandonment and Natural Regrowth*

Worksheet: 5-4

Goal: Calculate $CO_2$ uptake in biomass and soils from abandonment and regrowth of cultivated lands and pasture.

Ignores lands abandoned more than 20 years ago because of these are included to Step 1 of Changes in Forest and Other Woody Biomass Stocks.

Three steps:

1. Calculate biomass C uptake on land abandoned during last 20 years
2. Calculate soil uptake on land land abandoned during last 20 years
3. Add 1-2 to estimate total C uptake and convert to $CO_2$

### *4.4.1 Information requirements*

- **C fraction of replacement biomass - 0.45**

Default value (IPCC Guidelines, 1994).

<u>20 years or less</u>

- **total area abandoned and regrown during last 20 years that is regenerating - 343,300 ha**

Changes in forest land area from 1970...1990 (Karoles *et al.*, 1994).

- **annual average biomass accumulation per unit area regenerating - 2.9 t dm/ha/yr**

Estimated growth rate of stemwood with branches is 11.5 $Mm^3$/yr (Supply, Production and Costs..., 1994);

area of productive forest land is 2.0 Mha (Supply, Production and Costs..., 1994);

conversion ratio is 0.5 (default values for converting volume data to tons are 0.65 t dm/$m^3$ for deciduous trees and 0.45 t dm/$m^3$ for conifers /IPCC Guidelines, 1994/; 2/3 of the Estonian forests are conifers /Statistical Yearbook, 1994/ hence conversion ratio = 2/3×0.45+1/3×0.65);

annual biomass growth rate of managed forests = 11.5/2.0×0.5.

It was possible to use here the similar level of growth rate as in Step 1 of Forest Management due to character of forest growth in boreal zones (Tappo, 1982):

1. very low annual accumulation of biomass during the 0-5 year;
2. rapid increase of biomass accumulation in stands with age from 10 to 30;
3. decrease of annual biomass accumulation at the beginning of age 50-60.

- **average annual soil C accumulation per unit area regenerating - 1.8 t C/ha/yr**

Default value (IPCC Guidelines, 1994).

- **aboveground biomass in mature systems - 130 t dm/ha**

Average standing volume of mature forests in Estonia is 227 $m^3$ per hectare (the figure includs the top) (Karoles *et al.*, 1994);

convertion ratio is 0.5 (default values for converting volume data to tons are 0.65 t dm/$m^3$ for deciduous trees and 0.45 t dm/$m^3$ for conifers /IPCC Guidelines, 1994/; 2/3 of the Estonian forests are conifers /Statistical Yearbook, 1994/ hence conversion ratio = 2/3×0.45+1/3×0.65);

branches are forming 15 % of stemwood (Estonia: Sectoral Environmental..., 1994; Supply, Production and Costs..., 1994), hence they are added to the amount of aboveground biomass;

aboveground biomass = 227×0.5×0.15+227×0.5.

### *4.4.2 Calculation*

1. Annual C uptake in aboveground biomass, ≤ 20 years (t C/yr):

   **CBL = AY × RB × C**

where:

AY = total area abandoned and regrown during last 20 years (ha)

RB = annual rate of aboveground biomass accumulation (t dm/ha/yr)

C = C fraction of biomass (t C/t dm)

**CBL = 343,300 × 2.9 × 0.45 = 448,010 t C/yr**

2. Annual C uptake in soils, ≤ 20 years (t C/yr):

**CSL = AY × RS**

where:

AY = total area abandoned and regrown during last 20 years (ha)

RS = annual rate of C uptake in soils (t C/ha/yr)

**CSL = 343,300 × 1.8 = 617,940 t C/yr**

3. Total $CO_2$ uptake from abandonment of managed lands (t $CO_2$/yr):

**(CBL + CSL) × 44 / 12**

where:

CBL = annual C uptake in aboveground biomass, ≤ 20 years (t C/yr) (Step 1)

CSL = annual C uptake in soils, ≤ 20 years (t C/yr). (Step 2)

**(448,010 + 617,940) × 44 / 12 =**

**+ 3,908,470 t $CO_2$/yr = + 3,908.47 Gg $CO_2$/yr**

**Total $CO_2$ flux from land use change and forestry (Gg $CO_2$/yr)**

* $CO_2$ emissions from forest conversion
* $CO_2$ uptake due to abandonment of managed lands
* net $CO_2$ flux from changes in forest and other woody biomass stocks

**-605.3+ 3,908.47 + 4,647.27 = +7,950.44 Gg $CO_2$/yr**

## 5. Wetlands

Goal: To calculate net flux of $CO_2$ due to changes in wetland state result to amelioration activities for forestry, agricultural and industry purposes.

Steps:

1. Estimate total area of different wetland types ameliorated and influenced (peat accumulation stopped) by drainage
2. Calculate annual $CO_2$ emission from peat in drained areas
3. Calculate annual decrease in $CH_4$ emissions from peat in drained areas

**Information requirements**

Wetland drainage

*** area of peatlands - 1,009,101 ha**

Area of Estonian peatlands is 1,009,1001 ha (Orru et al., 1992)

***area of drained peatlands in 1990 - 351,350 ha**

In 1980 the area of lands drained for agricultural purposes was 584,400 ha (Ratt, 1985) of which the peatlands formed about 139,350 ha, In 1987 for forestry purposes was drained about 187,000 ha of peatlands (Valk, 1988), and for industrial need up to 25,000 ha (Ilomets, et al., 1995).

Nyström (1992) has estimated that in case of drainage for peat mining the area outside the edge ditches of a peat field, influenced by drainage, may be from 50 to 130% with average value of 90% of the mined area. Consequently, multiplying the official drainage value with factor 2, we should reach almost realistic data of affected by drainage area for peatlands.

*** area of drained and affected by drainage peatlands in 1990 - 702,700 ha**

area of drained peatlands 351,350 multiply with factor 2 = 702,700 ha

***area of different wetland types in 1990 - expert assessments**

The areas of different types of wetlands drained and influenced by drainage are as the expert assessment values and are presented in Table 4.

**Table 4.** Area of virgin wetlands, and wetlands affected by drainage in 1990 (in $km^2$)

| Wetland type | Virgin state | Affected by drainage | TOTAL |
|---|---|---|---|
| 1. Bogs | 2500 | 1300 | 3800 |
| 2. Fens | 500 | 3392 | 3892 |
| 3. Swamps | 110 | 1515 | 1625 |
| 4. Floodplains | 60 | 820 | 880 |
| 5. Marshes | 50 | - | 50 |
| TOTAL | 3220 | 7027 | 10247 |

***annual peat accumulation per hectar unit - 1.7 ton per ha per year**

annual peat increment in Estonian peatlands varies between 0.15 to 1.7 mm per year with average rate of about 1.2 mm per year. The mean peat bulk density is taken 140 g $dm^{-3}$. So the annual peat accumulation is $1.2 \cdot 10^{-3}$ m $yr^{-1}$ x 140 kg $m^{-3}$ = 0.17 kg $m^{-2}$ $yr^{-1}$ = 1.7 ton per ha per year of dry matter.

*** Carbon content of peat - 54%**

Tolonen et al., (1994) indicate that mean value of carbon content in peat may be taken as 54% from the total dry organic matter.

*** annual emissions from peat in drained wetlands**

It is shown that the mineralization of organic matter is about 15 to 20 tons per hectar per year during the first decade after the establishment of amelioration system [Tomberg, 1992]. Later it will be stabilisized and depending on the character of exploitation (crop field, grassland, pasture) may be between 5 and 15 tons per hectar per year. Possible mean level may be about 8 tons per hectar per year or 4.3 t of $CO_2$-C if consider with relative importance of different exploitation ways in Estonia.

*** annual $CH_4$-C emission rates are given in Table 5**

For $CH_4$-C emissions from drained wetlands the default emission factors from IPCC Guidlines (1995), Reference Manual, page 5.43, are followed, for $CH_4$-C emission rates on natural wetlands the same Reference Manual, Table 5-8 on the page 5.42 is followed. The decrease of methane emissions due to wetland drainage is not reported as antrophogenic sink of methane in Estonian GHG Inventory, because the uncertainty of the source.

**Table 5.** Average methane emission rates of natural and drained wetlands.

| Wetlands category | State | emission rate of $CH_4$-C in | | Production period in days |
|---|---|---|---|---|
| | | mg/m²/day | kg/ha/year | |
| Bog | natural | 11 | 19.6 | 178 |
| | drained | 0.6 | 1.07 | |
| Fens | natural | 60 | 101.4 | 169 |
| | drained | 0.8 | 1.35 | |
| Swamps | natural | 63 | 106.5 | 169 |
| | drained | 0.6 | 1.01 | |
| Floodplains | natural | 75 | 91.5 | 122 |
| | drained | 0.8 | 0.98 | |

## *Calculations*

**1. Annual $CO_2$-C emission (t C/yr)**

$$E_{CO2\text{-}C} = (A_n d \times Erd)$$

where $A_n d$ = area of drained peatland type n (ha)

Erd = $CO_2$-C emission rate in drained peatland type n (kg/ha/yr)

The calculation of $E_{CO2\text{-}C}$ is presented in worksheet 5-5, sheet 1 of 2 (Appendix 2).

In 1990 the emission of $CO_2$ from drained peatlands was 11079.24 Gg. This figure is included into the total $CO_2$ emission/removal figure of Land Use and Forestry sector, in Table 7A - Summary Report for National GHG Inventories (Appendix 3).

**2. Annual $CH_4$-C emission (Gg C/yr)**

$$E_{CH4\text{-}C} = (A_n d \times Erd)$$

where $A_n d$ = area of drained peatland type n (ha)

Erd = decrease of $CH_4$-C emissions in drained wetland type n (kg/ha/yr)

The calculation of $E_{CH4\text{-}C}$ is presented in worksheet 5-5, sheet 2 of 2 (Appendix 2).

In 1990 the decrease of methane emissions due to wetland drainage was estimated to be 36.97 Gg of $CH_4$, but this figure is not included while calculating Estonia's total methane emissions.

# 6. Wastes

## *6.1 Methane Emissions from Landfills*

By IPCC Guidelines (1994, 1995) the determination of annual methane emissions for each country or region can be calculated using formula:

***Methane Emissions (Gg / year) = Total MSW* Landfilled × Fraction DOC** in MSW × Fraction Dissimilated DOC × 0.5g C as $CH_4$/g C as biogas × Conversion Ratio (16/12) - Recovered $CH_4$ (Gg/year)***

where: **MSW*** - Municipal Solid Waste;

**DOC**** - Degradable Organic Carbon.

Total MSW generated can be calculated from:

***Total MSW = Population (thousand persons) × Annual MSW Generation Rate (Gg / thousand persons / year ).***

For calculations of methane emissions from landfills in Estonia DOC of MSW Fraction and Waste Generation were chosen data from Table 6-1 of IPCC Guidelines 1995, line: USSR/E.-Europe.

## *6.2 Methane Emissions from Domestic and Commercial Wastewater Treatment*

In simplified approach for estimation of methane emissions from domestic and commercial wastewater treatment is summarised by next formula of methane emissions calculation (IPCC Guidelines 1995):

***Methane Emissions ( Gg / year ) = Population ( $10^3$ ) × Gg $BOD^*_5$ / person / year × Fraction Treated Anaerobically × 0.22 Gg $CH_4$ / Gg $BOD^*_5$ - Methane Recovered ( Gg )***

* - Biochemical Oxygen Demand

Estimated $BOD_5$ value is chosen from Table 6-2 of IPCC Guidelines 1995 line: N.-America, Europe, Former USSR, Oceania.

Estimated total wastewater fraction anaerobically treated is chosen from Table 6-4 IPCC Guidelines 1995, line: Oceania, N.-America, Europe.

## *6.3 Estimate Methane Emissions from Industrial Wastewater Treatment*

Methane emissions should be estimated for depending on specifity of industrial process. Total emissions from industrial wastewater treatment are the sum of emissions from each industry. Next equation summarises the emissions calculation for industrial wastewater treatment (IPCC Guidelines 1995):

**Methane Emissions (Gg / year) = Σ Wastewater Outflow by Industry (Ml / year) × kg $BOD_5$ / l × Fraction Wastewater Treated Anaerobically × 0.22-$CH_4$ Recovered (Gg/year )**

Annual wastewater outflows were estimated on bases of production (Statistical Yearbook 1994) and medium water consumption per unit of product from IPCC Guidelines 1995, Volume 3, Table 6-6. As in Estonia is not reliable data of water consumption per unit of product at industrial facilities, then methane emissions from industrial wastewater was calculated only for these industrial facilities to whom water consumption per unit of product is given in Table 6-6.

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# Appendix 2

## Worksheets

| | |
|---|---|
| MODULE | ENERGY |
| SUBMODULE | $CO_2$ FROM ENERGY SOURCES (Reference Approach) |
| WORKSHEET | I - I |
| SHEET | I OF 3 |

STEP 1

| Fuel Types | | | A Production TJ | B Imports TJ | C Exports TJ | D International Bunkers, TJ | E Stock Change, TJ | F Apparent Consumption, TJ |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F=(A+B-C-D-E) |
| Liquid Fossil | Primary Fuels | Natural Gas Liquids | 0 | 1524 | 0 | NA | 0 | 1524 |
| | Secondary Fuels | Gasoline | 0 | 23858 | 0 | NA | -752 | 24610 |
| | | Jet Kerosene | 0 | 1583 | 0 | NA | 0 | 1583 |
| | | Other Kerosene | 0 | 4719 | 0 | NA | 0 | 4719 |
| | | Gas/Diesel Oil | 0 | 27024 | 1290 | NA | 0 | 25734 |
| | | Residual Fuel Oil | 0 | 75028 | 1642 | 0 | 842 | 72544 |
| | | LPG | 0 | 1346 | 0 | NA | 0 | 1346 |
| | | Other Oil | 0 | 475 | 0 | NA | 0 | 475 |
| Liquid Fossil Totals | | | | 135557 | 2932 | | 90 | 132535 |
| Solid Fossil | Primary Fuels | Anthracite (Coal) | 0 | 9409 | 0 | 0 | 164 | 9245 |
| | | Oil-Shale | 209596 | 22012 | 850 | 0 | 10310 | 220448 |
| | | Peat | 6155 | 0 | 0 | 0 | -205 | 6360 |
| Solid Fossil Totals | | | 215751 | 31421 | 850 | | 10269 | 236053 |
| Gaseous Fossil | | Natural Gas (Dry) | 0 | 51175 | 0 | 0 | 46 | 51129 |
| TOTAL | | | 215751 | 218153 | 3782 | | 10405 | 419717 |
| Biomass Total | | | 9995 | 0 | 0 | | 0 | 9995 |
| | | Solid Biomass | 9995 | 0 | 0 | 0 | 0 | 9995 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MODULE | | | ENERGY | | | | |
| SUBMODULE | | | $CO_2$ FROM ENERGY SOURCES (Reference Approach) | | | | |
| WORKSHEET | | | I - I | | | | |
| SHEET | | | 2 OF 3 | | | | |
| | | | STEP 2 | | STEP 3 | | |
| Fuel Types | | | G<br>Conversion Factor<br>TJ/Unit | H<br>Apparent Consumption<br>TJ | I<br>Carbon Emission Factor<br>t C/TJ | J<br>Carbon Content<br>t C | K<br>Carbon Content<br>Gg C |
| | | | | H=(FxG) | | J=(HxI) | K=(J/1000) |
| Liquid Fossil | Primary Fuels | Natural Gas Liquids | 1 | 1524 | 17.2 | 26212.8 | 26.213 |
| | Secondary Fuels | Gasoline | 1 | 24610 | 18.9 | 465129.0 | 465.129 |
| | | Jet Kerosene | 1 | 1583 | 19.5 | 30868.5 | 30.869 |
| | | Other Kerosene | 1 | 4719 | 19.6 | 92492.4 | 92.492 |
| | | Gas/Diesel Oil | 1 | 25734 | 20.2 | 519826.8 | 519.827 |
| | | Residual Fuel Oil | 1 | 72544 | 21.1 | 1530678.4 | 1530.678 |
| | | LPG | 1 | 1346 | 17.2 | 23151.2 | 23.151 |
| | | Other Oil | 1 | 475 | 20 | 9500.0 | 9.500 |
| Liquid Fossil Totals | | | | 132535 | | | 2697.859 |
| Solid Fossil | Primary Fuels | Anthracite (Coal) | 1 | 9245 | 26.8 | 247766.0 | 247.766 |
| | | Oil Shale | 1 | 220448 | 29.1 | 6415036.8 | 6415.037 |
| | | Peat | 1 | 6360 | 28.9 | 183804.0 | 183.804 |
| Solid Fossil Totals | | | | 236053 | | | 6846.607 |
| Gaseous Fossil. | | Natural Gas (Dry) | 1 | 51129 | 15.3 | 782273.7 | 782.274 |
| TOTAL | | | | 419717 | | | 10326.740 |
| Biomass Total | | | | 9995 | | | 298.851 |
| | | Solid Biomass | 1 | 9995 | 29.9 | 298850.5 | 298.851 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MODULE | | | ENERGY | | | | |
| SUBMODULE | | | $CO_2$ FROM ENERGY SOURCES (Reference Approach) | | | | |
| WORKSHEET | | | I - I | | | | |
| SHEET | | | 3 OF 3 | | | | |
| | | | STEP 4 | | STEP 5 | | STEP 6 |
| Fuel Types | | | L<br>Carbon Stored<br>Gg C | M<br>Net Carbon Emissions<br>Gg C | N<br>Fraction of Carbon Oxidised | O<br>Actual Carbon Emissions<br>Gg C | P<br>Actual $CO_2$ Emissions<br>Gg C |
| | | | | M=(K-L) | | O=(MxN) | P=(Ox44/12) |
| Liquid Fossil | Primary Fuels | Natural Gas Luquids | 0 | 26.213 | 0.995 | 26.082 | 95.633 |
| | Secondary Fuels | Gasoline | 0 | 465.129 | 0.99 | 460.478 | 1688.418 |
| | | Jet Kerosene | 0 | 30.869 | 0.99 | 30.560 | 112.053 |
| | | Other Kerosene | 0 | 92.492 | 0.99 | 91.567 | 335.747 |
| | | Gas/Diesel Oil | 0 | 519.827 | 0.99 | 514.629 | 1886.971 |
| | | Residual Fuel Oil | 0 | 1530.678 | 0.98 | 1500.065 | 5500.238 |
| | | LPG | 0 | 23.151 | 0.99 | 22.920 | 84.039 |
| | | Other Oil | 0 | 9.500 | 0.9 | 8.550 | 31.350 |
| Liquid Fossil Totals | | | 0 | 2697.859 | | 2654.850 | 9734.449 |
| Solid Fossil | Primary Fuels | Anthracite (Coal) | 0 | 247.766 | 0.98 | 242.811 | 890.306 |
| | | Oil-Shale | 0 | 6415.037 | 0.98 | 6286.736 | 23051.366 |
| | | Peat | 0 | 183.804 | 0.97 | 178.290 | 653.730 |
| Solid Fossil Totals | | | 0 | 6846.607 | | 6707.837 | 24595.401 |
| Gaseous Fossil | | Natural Gas (Dry) | 0 | 782.274 | 0.995 | 778.362 | 2853.995 |
| TOTAL | | | 0 | 10326.740 | | 10141.049 | 37183.845 |
| Biomass Total | | | 0 | 298.851 | | 292.873 | 1073.869 |
| | | Solid Biomass | 0 | 298.851 | 0.98 | 292.873 | 1073.869 |

| MODULE | ENERGY | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SUBMODULE | TRADITIONAL BIOMASS BURNED FOR ENERGY | | | | | | | |
| WORKSHEET | I - 3 | | | | | | | |
| SHEET | 1 OF 3 | | | | | | | |
| | STEP 1 | | | STEP 2 | | STEP 3 | | |
| | A<br>Biomass Consumed<br>kt dm | B<br>Carbon Fraction of Biomass | C<br>Carbon Content<br>kt dm | D<br>Fraction Oxidised | E<br>Total Carbon Released by Biomass Fuels<br>kt C | F<br>C-$CH_4$ Ratio | G<br>Carbon Emitted as $CH_4$<br>kt C | H<br>CH4 Emissions from Biomass Burned<br>Gg $CH_4$ |
| | | | C=(AxB) | | E=(CxD) | | G=(ExF) | H=(Gx16/12) |
| Wood (for direct use) | 532.2 | 0.5 | 266.1 | 0.87 | 231.507 | 0.012 | 2.778 | 3.704 |
| Agricultural Wastes | 0 | | | | | | | |
| Dung | 0 | | | | | | | |
| Charcoal Consumption | 0 | | | | | | | |
| Charcoal Production | | | | | 0 | | | |
| Others (Specify) | 0 | | | | | | | |
| | | | | Total | 231.507 | | | 3.704 |
| **Charcoal Production** | | | | | | | | |
| Input (Wood) | | | | | | | | |
| Input (Other) | | | | | | | | |
| Output (Charcoal) | | | | | | | | |
| Carbon Released | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| MODULE | ENERGY | | | | | | | |
| SUBMODULE | TRADITIONAL BIOMASS BURNED FOR ENERGY | | | | | | | |
| WORKSHEET | I - 3 | | | | | | | |
| SHEET | 2 OF 3 | | | | | | | |
| | STEP 4 | | | STEP 5 | | | | |
| | I<br>C-CO Trace Gas Emission Ratio | J<br>C Emitted as CO<br>kt C | K<br>CO Emitted<br>Gg CO | L<br>Nitrogen-Carbon Fuel Ratio | M<br>Total Nitrogen Released<br>kt N | N<br>$N\text{-}N_2O$ Trace Gas Emission Ratio | O<br>Nitrogen Emitted as $N_2O$<br>kt N | P<br>$N_2O$ Emitted<br>Gg $N_2O$ |
| | | J=(ExI) | K=(Jx28/12) | | M=(ExL) | | O=(MxN) | P=(Ox44/28) |
| Wood | 0.06 | 13.890 | 32.411 | 0.01 | 2.315 | 0.007 | 0.016 | 0.025 |
| Agricultural Wastes | 0 | | | | | | | |
| Dung | 0 | | | | | | | |
| Charcoal Consumption | 0 | | | | | | | |
| Charcoal Production | 0 | | | | | | | |
| Others (Specify) | 0 | | | | | | | |
| | | Total | 32.411 | | | | Total | 0.025 |

| | | | |
|---|---|---|---|
| MODULE | ENERGY | | |
| SUBMODULE | TRADITIONAL BIOMASS BURNED FOR ENERGY | | |
| WORKSHEET | I - 3 | | |
| SHEET | 3 OF 3 | | |
| | STEP 6 | | |
| | Q<br>N - NOx Trace Gas Emissions Ratio | R<br>Nitrogen Emitted as NOx<br>kt N | S<br>NOx Emitted<br>Gg NOx |
| | | R=(MxQ) | S=(Rx46/14) |
| Wood | 0.121 | 0.280 | 0.920 |
| Agricultural Wastes | | | |
| Dung | | | |
| Charcoal Consumption | | | |
| Charcoal Production | | | |
| Others (Specify) | | | |
| | | | |
| | | Total | 0.920 |

| | | | | | | |
|---|---|---|---|---|---|---|
| MODULE | | ENERGY | | | | |
| SUBMODULE | | METHANE EMISSIONS FROM COAL MINING AND HANDLING | | | | |
| WORKSHEET | | I -- 4 | | | | |
| SHEET | | I OF I | | | | |
| | | STEP 1 | | | STEP 2 | |
| | | A | B | C | D | E |
| | | Amount of Oil-Shale Produced (million t) | Emission Factor (m3CH4/t) | Methane Emissions (million m3) | Conversion Factors (0.67 Gg CH4/106 m3) | Methane Emissions (Gg CH4) |
| | | | | C=(AxB) | | E=(CxD) |
| Underground Mines | Mining | 12.593 | 17.50 | 220.378 | 0.67 | 147.653 |
| | Post-Mining | 12.593 | 2.45 | 30.853 | 0.67 | 20.671 |
| Surface Mines | Mining | 13.106 | 1.15 | 15.072 | 0.67 | 10.098 |
| | Post-Mining | 13.106 | 0.10 | 1.311 | 0.67 | 0.878 |
| | | | | | Total | 179.301 |

| | |
|---|---|
| MODULE | ENERGY |
| SUBMODULE | METHANE EMISSIONS FROM OIL AND GAS ACTIVITIES (Tier I Approach) |
| WORKSHEET | I - 5 |
| SHEET | I OF I |

| Category | A<br>Activity | B<br>Emission Factor | C<br>$CH_4$ Emissions<br>kg $CH_4$ | D<br>Emissions $CH_4$<br>Gg $CH_4$ |
|---|---|---|---|---|
| **OIL** | | | C=(AxB) | D=(C/10⁶) |
| Exploration<br>*(Optional if data is locally available)* | *number of wells drilled* | *kg CH4/well drilled* | | |
| Production | *PJ oil produced*<br>15 | *kg CH4/PJ*<br>4000 | 60000 | 0.060 |
| Transport | *PJ oil loaded in tankers*<br>132.535 | *kg CH4/PJ*<br>745 | 98739 | 0.099 |
| Refining | *PJ oil refined*<br>0 | *kg CH4/PJ refined* | | |
| Storage | *PJ oil refined*<br>132.535 | *kg CH4/PJ refined*<br>1400 | 185549 | 0.186 |
| | | | TOTAL $CH_4$ FROM OIL | 0.344 |
| **GAS** | | | | |
| Production/<br>Processing | *PJ gas produced*<br>0 | *kg CH4/PJ* | | |
| Transmission and<br>Distribution | *PJ gas produced*<br>51.129 | *kg CH4/PJ*<br>458000 | 23417082 | 23.417 |
| Other Leakage | *PJ gas consumed*<br>*- Non-residential gas consumed (PJ)*<br>48.58<br>*- Residential gas consumed*<br>2.549 | 279500<br><br>139500 | 13578110<br><br>355586 | 13.578<br><br>0.356 |
| | | | TOTAL $CH_4$ FROM GAS | 37.351 |
| VENTING AND FLARING FROM OIL/GAS PRODUCTION | *PJ oil and gas produced*<br>*- Oil* 15<br>*- Gas* 0<br>*- Combined* 0 | *kg CH4/PJ*<br>4000 | 60000 | 0.060 |
| | | | TOTAL $CH_4$ EMISSIONS FROM OIL AND GAS | 37.755 |

| | |
|---|---|
| MODULE | AGRICULTURE |
| SUBMODULE | METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT, AVERAGE OF YEARS 1990 - 1992 |
| WORKSHEET | 4 - 1 |
| SHEET | 1 OF 1 |

| Livestock Type | A<br>Number of Animals<br>(1000s) | B<br>Emission Factor for Enteric Fermentation<br>(kg/head/year) | C<br>Emissions from Enteric Fermentation<br>(t/year) | D<br>Emission Factor for Manure Management<br>(kg/head/year) | E<br>Emissions from Manure Management<br>(t/year) | F<br>Total Annual Emissions from Domestic Livestock<br>(Gg) |
|---|---|---|---|---|---|---|
| | | | C=(AxB) | | E=(AxD) | F=(C+E)/1000 |
| Dairy Cattle | 279.64 | 81 | 22650.92 | 6 | 1677.85 | 24.33 |
| Non-Dairy Cattle | 477.73 | 56 | 26752.71 | 4 | 1910.91 | 28.66 |
| Buffalo | 0 | | | | | |
| Sheep | 140.96 | 8 | 1127.70 | 0.19 | 26.78 | 1.15 |
| Goats | 0 | | | | | |
| Horses | 8.65 | 18 | 155.66 | 1.4 | 12.11 | 0.17 |
| Mules/Asses | 0 | | | | | |
| Swine | 946.30 | 1.5 | 1419.45 | 4 | 3785.19 | 5.20 |
| Poultry | 6332.40 | | | 0.078 | 493.93 | 0.49 |
| | | Totals | 52106.45 | | 7906.76 | 60.01 |

| Module: Land Use Change and Forestry<br>Sub Module: Changes in Forest and Other Woody Biomass Stocks<br>Worksheet: 5 - 1 | | | | | Module: Land Use Change and Forestry<br>Sub Module: Changes in Forest and Other Woody Biomass Stocks<br>Worksheet: 5 - 1 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STEP 1 | | | | | STEP 2 | | | | | | | |
| A | B | C | D | E | F | G | H | I | J | K | L | M |
| Area of Forest Biomass Stocks (kha) | Annual Growth Rate (t dm/ha) | Annual Biomass Increment (kt dm) | Carbon Fraction of Dry Matter | Total Carbon Uptake Increment (kt C) | Commercial Harvest (1000 m roundwood) | Biomass Conversion Ratio (t dm/m ) | Total Biomass Removed in Commercial Harvest (kt dm) | Total Traditional Fuelwood Consumed (kt dm) | Total Other Wood Use (kt dm) | Total Biomass Con - sumption (kt dm) | Wood Removed From Forest Clearing (kt dm) | Total Biomass Consump-tion From Stocks (kt dm) |
| 1554.5 | 2.9 | 4508.05 | 0.45 | 2028.6225 | 2356.2 | 0.5 | 1178.1 | 532.2 | 0 | 1710.3 | 0.00 | 1710.30 |

Module: Land Use Change and Forestry
Sub Module: Changes in Forest and Other Woody Biomass Stocks
Worksheet: 5 - 1

| STEP 3 | | | |
|---|---|---|---|
| N | O | P | Q |
| Carbon Fraction | Annual Carbon Release (kt C) | Net Annual Carbon Uptake (+) or Release (-) (kt C) | Convert to $CO_2$ Annual Emission (-) or Removal (+) (Gg $CO_2$) |
| 0.45 | 769.64 | 1258.99 | 4616.29 |

| Module: Land Use Change and Forestry<br>Sub Module: Forest and Grassland Conversion<br>Worksheet: 5 - 2<br>Sheet: 1 of 6 | | | | | Module: Land Use Change and Forestry<br>Sub Module: Forest and Grassland Conversion<br>Worksheet: 5 - 2<br>Sheet: 2 of 6 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STEP 1 | | | | | STEP 2 | | | | | |
| A | B | C | D | E | F | G | H | I | J | K |
| Area Converted Annualy (kha) | Biomass Before Conversion (t dm/ha) | Biomass After Conversion (t dm/ha) | Net Change in Biomass Density (t dm/ha) | Annual Loss of Biomass (kt dm) | Fraction of Biomass Burned on Site | Quantity of Biomass Burned on Site (kt dm) | Fraction of Biomass Oxidized on Site | Quantity of Biomass Oxidized on Site (kt dm) | Carbon Fraction of Above-ground Biomass (burned on site) | Quantity of Carbon Released (from biomass burned) (kt C) |
| 1.01 | 92.95 | 0 | 92.95 | 93.88 | 0.25 | 23.47 | 0.9 | 21.12 | 0.45 | 9.51 |

Module: Land Use Change and Forestry
Sub Module: Forest and Grassland Conversion
Worksheet: 5 - 2
Sheet: 3 of 6

| STEP 3 | | | | | | STEP 4 | |
|---|---|---|---|---|---|---|---|
| L | M | N | O | P | Q | R | S |
| Fraction of Biomass Burned Off Site | Quantity of Biomass Burned Off Site (kt dm) | Fraction of Biomass Oxidized Off Site | Quantity of Biomass Oxidized Off Site (kt dm) | Carbon Fraction of Above-ground Biomass (burned off site) | Quantity of Carbon Released (from biomass burned off site) (kt C) | Total Carbon Released (from on and off site burning) (kt C) | Total CO2 Released (from on and off site burning) (kt CO2) |
| 0.2 | 18.78 | 0.9 | 16.90 | 0.45 | 7.60 | 17.11 | 62.73 |

Module: Land Use Change and Forestry
Sub Module: Forest and Grassland Conversion
Worksheet: 5 - 2
Sheet: 4 of 6

| STEP 5 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| A | B | C | D | E | F | G | H | I |
| Average Area Converted (10 Year Average) (kha) | Biomass Before Conversion (t dm/ha) | Biomass After Conversion (t dm/ha) | Net Change in Biomass Density (t dm/ha) | Average Annual Loss of Biomass (kt dm) | Fraction Left to Decay | Quantity of Biomass Left to Decay (kt dm) | Carbon Fraction in Above-ground Biomass | C Released from Decay of Above-ground Biomass (kt C) |
| 1.47 | 92.95 | 0 | 92.95 | 136.64 | 0.15 | 20.50 | 0.45 | 9.22 |

| Module: Land Use Change and Forestry<br>Sub Module: Forest and Grassland Conversion<br>Worksheet: 5 - 2<br>Sheet: 5 of 6 | | | | | Module: Land Use Change and Forestry<br>Sub Module: Forest and Grassland Conversion<br>Worksheet: 5 - 2<br>Sheet: 6 of 6 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| STEP 6 | | | | | STEP 7 | | | | |
| A | B | C | D | E | A | B | C | D | E |
| Average Annual Forest/ Grassland Converted (25 year average) (kha) | Carbon Content of Soil Before onversio (t/ha) | Total Annual Potential Soil Carbon Losses (kt C) | Fraction of Carbon Released over 25 years | Carbon Release from Soil (kt C) | Immediate Release from Burning (kt C) | Delayed Emissions from Decay (10-year average) (kt C) | Long Term Emissions from Soil (25-year average) (kt C) | Total Annual Carbon Release (kt C) | Total Annual CO2 Release (Gg CO2 ) |
| 1.50 | 185 | 277.5 | 0.5 | 138.75 | 17.11 | 9.22 | 138.75 | 165.08 | 605.30 |

Module: Land Use Change and Forestry
Sub Module: On-site Burning of Forests
Worksheet: 5 - 3
Sheet: 1 of 1

| STEP 1 | | | STEP 2 | | | | |
|---|---|---|---|---|---|---|---|
| A | B | C | | D | E | F | G |
| Quantity of Carbon Released (kt C) | Nitrogen-Carbon Ratio | Total Nitrogen Released (kt N) | | Trace Gas Emissions Ratios | Trace Gas Emissions (kt C) | Conversion Ratio | Trace Gas Emissions from Burning of Cleared Forests (Gg $CH_4$, CO) |
| 9.51 | | | $CH_4$ | 0.012 | 0.1141 | 16/12 | 0.1522 |
| 9.51 | | | CO | 0.06 | 0.5706 | 28/12 | 1.3314 |
| | | | | | (kt N) | | (Gg $N_2O$, $NO_x$) |
| 9.51 | 0.01 | 0.0951 | $N_2O$ | 0.007 | 0.0007 | 44/28 | 0.0010 |
| 9.51 | 0.01 | 0.0951 | $NO_x$ | 0.121 | 0.0115 | 46/14 | 0.0378 |

| Module: Land Use Change and Forestry<br>Sub Module: Abandonment of Managed Lands<br>Worksheet: 5 - 4<br>Sheet: 1 of 3 | | | | | Module: Land Use Change and Forestry<br>Sub Module: Abandonment of Managed Lands<br>Worksheet: 5 - 4<br>Sheet: 2 of 3 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| STEP 1 | | | | | STEP 2 | | STEP 3 | | | | |
| A | B | C | D | E | F | G | H | I | J | K | L |
| 20 Year Total Abandoned and Regrowing (kha) | Annual Rate of Above-ground Biomass Growth (t dm/ha) | Annual Above-ground Biomass Growth (kt dm) | Carbon Fraction of Above-ground Biomass | Annual Carbon Uptake in Above-ground Biomass (kt C) | Annual Rate of Uptake of Carbon in Soils (t C/ha) | Total Annual Carbon Uptake in Soils (less than 20 years) (kt C) | Total Area Abandoned More than Twenty Years (kha) | Annual Rate of Above-ground Biomass Growth (t dm/ha) | Annual Above-ground Biomass Growth (kt dm) | Carbon Fraction of Above-ground Biomass | Annual Carbon Uptake in Above-ground Biomass (kt C) |
| 343.3 | 2.9 | 995.57 | 0.45 | 448.01 | 1.8 | 617.94 | 0 | 0 | 0 | 0 | 0 |

Module: Land Use Change and Forestry
Sub Module: Abandonment of Managed Lands
Worksheet: 5 - 4
Sheet: 3 of 3

| STEP 4 | | STEP 5 | |
|---|---|---|---|
| M | N | O | P |
| Annual Rate of Uptake of Carbon in Soils (t C/ha) | Total Annual Carbon Uptake in Soils (kt C) | Total Carbon Uptake from Abandoned Lands (kt C) | Total Carbon Dioxide Uptake (Gg CO2) |
| 0 | 0 | 1065.95 | 3908.47 |

Module: Land Use Change and Forestry
Submodule: Wetland drainage
Worksheet: 5 - 5
Sheet: 1 of 2

| STEP 1 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Different wetland types | Area, $km^2$ | | | Emission rate of $CO_2$-C in drained wetlands | $CO_2$-C emissions due to drainage | $CO_2$ emissions due to drainage |
| | total | natural | drained | kg/ha/yr | Gg/yr | Gg/yr |
| | A | B | C | D | $E=C*D/10^4$ | $F=E*44/12$ |
| Bogs | 3800 | 2500 | 1300 | 4300 | 559.00 | 2049.67 |
| Fens | 3892 | 500 | 3392 | 4300 | 1458.56 | 5348.05 |
| Swamps | 1625 | 110 | 1515 | 4300 | 651.45 | 2388.65 |
| Floodplain | 880 | 60 | 820 | 4300 | 352.60 | 1292.87 |
| TOTAL | 10197 | 3170 | 7027 | | 3021.61 | 11079.24 |

Module: Land Use Change and Forestry
Submodule: Wetland drainage
Worksheet: 5 - 5
Sheet: 2 of 2

| | STEP 1 | | | | | | | | | | | STEP 2 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Different wetland types | Area, $km^2$ | | | Production period | Emission rate of $CH_4$-C | | | | Decrease in $CH_4$-C emissions due to wetland drainage | | Sink of $CH_4$ due to drainage | Emissions of $CH_4$-C in virgin wetlands | Emissions of $CH_4$ in virgin wetlands |
| | | | | days | $mg/m^2/day$ | | kg/ha/yr | | kg/ha/yr | Gg/yr | Gg/yr | Gg/yr | Gg/yr |
| | total | natural | drained | | natural | drained | natural | drained | | | | | |
| | A | B | C | D | E | F | G=D*E/100 | H=D*F/100 | I=H-G | $J=C*I/10^4$ | K=J*16/12 | $K=B*G/10^4$ | L=K*16/12 |
| Bogs | 3800 | 2500 | 1300 | 178 | 11 | 0.6 | 20 | 1.1 | 10.4 | 1.35 | 1.8 | 4.9 | 6.5 |
| Fens | 3892 | 500 | 3392 | 169 | 60 | 0.8 | 101 | 1.4 | 59.2 | 20.08 | 26.8 | 5.1 | 6.8 |
| Swamps | 1625 | 110 | 1515 | 169 | 63 | 0.6 | 106 | 1.0 | 62.4 | 9.45 | 12.6 | 1.2 | 1.6 |
| Floodplains | 880 | 60 | 820 | 122 | 75 | 0.8 | 92 | 1.0 | 74.2 | 6.08 | 8.1 | 0.5 | 0.7 |
| TOTAL | 10197 | 3170 | 7027 | | | | | | | 36.97 | 49.3 | 11.7 | 15.6 |

| MODULE | WASTE |
|---|---|
| SUBMODULE | METHANE EMISSIONS FROM INDUSTRIAL LANDFILLS |
| WORKSHEET | 6 - 1 |
| SHEET | 1 OF 1 |

| STEP 1 | STEP 2 | | | | STEP 3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A<br>Annual MSW Landfilled<br>Gg | B<br>Fraction DOC | C<br>Annual DOC Landfilled<br>Gg | D<br>Faction Which Actually Degrades | E<br>Annual Carbon Released as Blogas<br>Gg C | F<br>Fraction C-CH4 to C-Blogas | G<br>Annual Carbon Released as CH4<br>Gg C | H<br>Conver-sation Ratio<br>(16/12) | I<br>CH4 Released<br>Gg CH4 | J<br>CH4 Recove-red<br>Gg CH4 | K<br>Net CH4 Emissions<br>Gg CH4 |
| | | C=(AxB) | | E=(CxD) | | G=(ExF) | | I=(GxH) | | K=(I-J) |
| 292.56 | 0.175 | 51.20 | 0.77 | 39.42 | 0.5 | 19.71 | 1.333 | 26.28 | 0 | 26.28 |

| MODULE | WASTE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SUBMODULE | METHANE EMISSIONS FROM DOMESTIC AND COMMERCIAL WASTEWATER TREATMENT | | | | | | | |
| WORKSHEET | 6 - 2 | | | | | | | |
| SHEET | 1 OF 1 | | | | | | | |
| STEP 1 | | | STEP 2 | | | | STEP 3 | |
| A<br>Population (1000 persons) | B<br>Wastewater BOD Value $Gg\ BOD_5$ / 1000 per- -sons / year | C<br>Annual BOD ($Gg\ BOD_5$) | D<br>Fraction Wastewater Anaerobically Treated | E<br>Quantity of BOD from Anaerobically Treated Wastewater ($Gg\ BOD_5$) | F<br>Methane Emission Factor ($Gg\ CH_4$ / $Gg\ BOD_5$) | G<br>Total $CH_4$ Released ($Gg\ CH_4$) | H<br>Methane Recovered ($Gg\ CH_4$) | I<br>Net $CH_4$ Emissions ($Gg\ CH_4$) |
| | | C=(A x B) | | E=(C x D) | | G=(E x F) | | I=(G - H) |
| 1571.648 | 0.0182 | 28.6 | 0.1 | 2.86 | 0.22 | 0.629 | 0 | 0.629 |

| | |
|---|---|
| MODULE | WASTE |
| SUBMODULE | METHANE EMISSIONS FROM INDUSTRIAL WASTEWATER TREATMENT |
| WORKSHEET | 6 - 3 |
| SHEET | 1 OF 1 |

| | | STEP 1 | | | STEP 2 | | | STEP 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A<br>Annual Waste-water Outflow<br>$10^6$ litres | B<br>BOD Concent-ration<br>kg / litre | C<br>Total BOD Concent-ration<br>Gg BOD | D<br>Fraction of Waste-water Treated Anaerobically | E<br>Quantity of BOD from Anaerobically Treated WW<br>Gg BOD | F<br>$CH_4$ Emission Factor<br>Gg $CH_4$ / Gg $BOD_5$ | G<br>Total $CH_4$ Released<br>Gg $CH_5$ | H<br>$CH_4$ Recove-red<br>Gg $CH_4$ | I<br>Net $CH_4$ Emissions<br>Gg $CH_4$ |
| | | | | C=(AxB) | | E=(CxD) | | G=(ExF) | | I=(G-H) |
| Iron and steel | | 0 | | | | | | | | |
| Non-ferrous metals | | 0 | | | | | | | | |
| Fertilizer | | NE | NA | | | | | | | |
| Food & Beverages | Canneries | NE | NA | | | | | | | |
| | Beer | 4380 | 0.085 | 372.3 | 0.1 | 37.23 | 0.22 | 8.191 | 0 | 8.191 |
| | Wine | 66.6 | 0.135 | 8.99 | 0.1 | 0.899 | 0.22 | 0.198 | 0 | 0.198 |
| | Meat packing | 3256.2 | 0.02 | 65.12 | 0.1 | 6.512 | 0.22 | 1.433 | 0 | 1.433 |
| | Dairy products | NE | NA | | | | | | | |
| | Sugar | 0 | | | | | | | | |
| | Fish processing | NE | NA | | | | | | | |
| | Oil & Grease | 0 | | | | | | | | |
| | Coffee | 0 | | | | | | | | |
| | Soft drinks | NE | NA | | | | | | | |
| | Other | NE | NA | | | | | | | |
| Pulp and paper | Pulp | 44802 | 0.004 | 179.21 | 0.1 | 17.92 | 0.22 | 3.943 | 0 | 3.943 |
| | Paper | 16420 | 0.004 | 65.68 | 0.1 | 6.568 | 0.22 | 1.445 | 0 | 1.445 |
| | Other | 0 | | | | | | | | |
| Petroleum refining / Petrochemicals | | 0 | | | | | | | | |
| Textiles | Bleaching | 0 | | | | | | | | |
| | Dying | 0 | | | | | | | | |
| | Other | 0 | | | | | | | | |
| Rubber | | 0 | | | | | | | | |
| Other | | 0 | | | | | | | | |
| Totals | | | | | | | | 15.21 | 0 | 15.21 |

# Appendix 3

## Standard Data Tables

## Standard Data Table 1

### Energy: 1A Fuel Combustion Activities - Detailed Technology Based Calculation

| Source And Sink Categories | Activity Data | Emission Estimates | | | | | | Aggregate Emission Factors | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector Specific Data (units) | A<br>Apparent Consumpt. (PJ) | B<br>(Gg of full mass of pollutatnt) | | | | | | C=B/A<br>(kg(pollutant)/GJ) | | | | | |
| | | $CO_2$ | $CH_4$ | $N_2O$ | $NO_x$ | CO | NMVOC | $CO_2$ | $CH_4$ | $N_2O$ | $NO_x$ | CO | NMVOC |
| **I A Fuel Combust. Activities *** | 419.717 | 37183.85 | 2.610 | 1.417 | 93.029 | 183.549 | 22.925 | 88.593 | 0.006 | 0.003 | 0.222 | 0.437 | 0.055 |
| Oil | 132.535 | 9734.45 | 2.054 | 1.227 | 50.021 | 173.437 | 22.925 | 73.448 | 0.015 | 0.009 | 0.377 | 1.309 | 0.173 |
| Gas | 51.129 | 2854.00 | 0.017 | 0.010 | 11.584 | 0.920 | NA | 55.819 | 0.000 | 0.000 | 0.227 | 0.018 | NA |
| Coal | 9.245 | 890.31 | 0.034 | 0.163 | 2.642 | 1.771 | NA | 96.301 | 0.004 | 0.018 | 0.286 | 0.192 | NA |
| Oil-Shale | 220.448 | 23051.37 | NA | NA | 27.451 | 6.514 | NA | 104.566 | NA | NA | 0.125 | 0.030 | NA |
| Peat | 6.36 | 653.73 | NA | NA | NA | NA | NA | 102.788 | NA | NA | NA | NA | NA |
| Biomass | 9.995 | 1073.87 | 0.504 | 0.017 | 1.331 | 0.907 | NA | 107.441 | 0.050 | 0.002 | 0.133 | 0.091 | NA |
| **I A 1 Energy and Transformation Activities** | 308.902 | 28460.97 | 0.047 | 0.002 | 49.397 | 7.329 | NA | 92.136 | 0.000 | 0.000 | 0.160 | 0.024 | NA |
| Oil | 58.05 | 4263.66 | 0.041 | NA | 11.668 | 0.871 | NA | 73.448 | 0.001 | NA | 0.201 | 0.015 | NA |
| Gas | 41.201 | 2299.82 | 0.004 | NA | 11.001 | 0.783 | NA | 55.819 | 0.000 | NA | 0.267 | 0.019 | NA |
| Coal | 3.01 | 289.87 | 0.002 | 0.002 | 0.981 | 0.364 | NA | 96.302 | 0.001 | 0.001 | 0.326 | 0.121 | NA |
| Oil-Shale | 206.641 | 21607.62 | NA | NA | 25.747 | 5.311 | NA | 104.566 | NA | NA | 0.125 | 0.026 | NA |
| **I A 2 Industry** | 34.267 | 2897.54 | 0.051 | NA | 4.812 | 1.676 | NA | 84.558 | 0.001 | NA | 0.140 | 0.049 | NA |
| Oil | 12.97 | 952.62 | 0.038 | NA | 2.088 | 0.195 | NA | 73.448 | 0.003 | NA | 0.161 | 0.015 | NA |
| Gas | 5.446 | 303.99 | 0.008 | NA | 0.365 | 0.093 | NA | 55.820 | 0.001 | NA | 0.067 | 0.017 | NA |
| Coal | 1.991 | 191.74 | 0.005 | NA | 0.655 | 0.185 | NA. | 96.301 | 0.003 | NA | 0.329 | 0.093 | NA |
| Oil-Shale | 13.807 | 1443.74 | NA | NA | 1.704 | 1.203 | NA | 104.566 | NA | NA | 0.123 | 0.087 | NA |
| Peat | 0.053 | 5.45 | NA | NA | NA | NA | NA | 102.792 | NA | NA | NA | NA | NA |
| **I A 3 Transport** | 36.147 | 2655.55 | 1.935 | 0.036 | 32.646 | 171.950 | 22.925 | 73.465 | 0.054 | 0.001 | 0.903 | 4.757 | NA |
| Oil | 35.82 | 2630.91 | 1.934 | 0.036 | 32.596 | 171.936 | 22.925 | 73.448 | 0.054 | 0.001 | 0.910 | 4.800 | 0.640 |
| Gas | 0.175 | 9.77 | 0.0002 | NA | 0.012 | 0.003 | NA | 55.817 | 0.001 | NA | 0.069 | 0.017 | NA |
| Coal | 0.117 | 11.27 | 0.0003 | NA | 0.038 | 0.011 | NA | 96.299 | 0.003 | NA | 0.325 | 0.094 | NA |
| Peat | 0.035 | 3.60 | NA | NA | NA | NA | NA | 102.800 | NA | NA | NA | NA | NA |
| **I A 4a Commercial/Industrial *** | 21.096 | 1581.13 | 0.116 | 0.954 | 3.131 | 1.625 | NA | 74.949 | 0.005 | 0.045 | 0.148 | 0.077 | NA |
| Oil | 16.601 | 1219.31 | 0.027 | 0.772 | 2.273 | 0.282 | NA | 73.448 | 0.002 | 0.047 | 0.137 | 0.017 | NA |
| Gas | 1.758 | 98.13 | 0.002 | 0.004 | 0.084 | 0.017 | NA | 55.820 | 0.001 | 0.002 | 0.048 | 0.010 | NA |
| Coal | 2.72 | 261.94 | 0.027 | 0.161 | 0.642 | 0.530 | NA | 96.301 | 0.010 | 0.059 | 0.236 | 0.195 | NA |
| Peat | 0.017 | 1.75 | NA | NA | NA | NA | NA | 102.765 | NA | NA | NA | NA | NA |
| Biomass | 3.998 | 429.55 | 0.060 | 0.017 | 0.132 | 0.796 | NA | 107.441 | 0.015 | 0.004 | 0.033 | 0.199 | NA |
| **I A 4b Residential *** | 19.305 | 1588.65 | 0.461 | 0.425 | 3.043 | 0.969 | NA | 82.292 | 0.024 | 0.022 | 0.158 | 0.050 | NA |
| Oil | 9.094 | 667.94 | 0.014 | 0.419 | 1.396 | 0.153 | NA | 73.448 | 0.002 | 0.046 | 0.154 | 0.017 | NA |
| Gas | 2.549 | 142.28 | 0.003 | 0.006 | 0.122 | 0.024 | NA | 55.820 | 0.001 | 0.002 | 0.048 | 0.009 | NA |
| Coal | 1.407 | 135.50 | NA | NA | 0.326 | 0.681 | NA | 96.301 | NA | NA | 0.232 | 0.484 | NA |
| Peat | 6.255 | 642.94 | NA | NA | NA | NA | NA | 102.788 | NA | NA | NA | NA | NA |
| Biomass | 5.997 | 644.32 | 0.444 | NA | 1.199 | 0.111 | NA | 107.441 | 0.074 | NA | 0.200 | 0.019 | NA |

* Biomass is not included to the totals

## Standard Data Table 1

**Energy: 1A Fuel Combustion Activities - Traditional Biomass Burned for Energy**

| Sector Specific Data | Activity Data | Emission Estimates | | | | | | Aggregate Emission Factors | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector Specific Data (units) | A Apparent Consumption (kt dm) | B Quantities Emitted (Gg) | | | | | | C Emission Factor (t / t dm) C=B/A | | | | | |
| | | CO2 | CH4 | N2O | NOx | CO | NMVOC | CO2 | CH4 | N2O | NOx | CO | NMVOC |
| Fuelwood | 532.2 | 1073.87 | 0.504 | 0.017 | 1.331 | 0.907 | N/A | 2.02 | 0.000947 | 0.00003 | 0.0025 | 0.0017 | N/A |
| Agricultural Wastes | | | | | | | | | | | | | |
| Dung | | | | | | | | | | | | | |
| Charocal Consumption | | | | | | | | | | | | | |
| Charocal Production | | | | | | | | | | | | | |
| Other (specify) | | | | | | | | | | | | | |

# Standard Data Table 1

## Energy: 1B1 Fugitive Emissions from Fuels (Oil Shale Mining)

| SOURCE AND SINK CATEGORIES | ACTIVITY DATA<br>A<br>Production<br>(Mt) | METHANE EMISSIONS<br>B<br>(million m³) | EMISSION FACTOR<br>C<br>(m³/t) |
|---|---|---|---|
| | | | C=B/A |
| 1B1 Solid Fuels | | | |
| 1B1 a Coal Mining | | | |
| 1B1 a I Underground Mines | | | |
| Underground activities | 12.593 | 220.378 | 17.50 |
| Post-mining activities | 12.593 | 30.853 | 2.45 |
| 1B1a II Surface Mines | | | |
| Surface activities | 13.106 | 15.072 | 1.15 |
| Post-mining activities | 13.106 | 1.311 | 0.10 |
| 1B1 b Solid Fuel Transformation | | | |
| 1B1 c Other | | | |

# Standard Data Table 1

## Energy: 1B2 Fugitive Emissions from Fuels (Oil and Natural Gas)

| SOURCE AND SINK CATEGORIES | | ACTIVITY DATA | EMISSIONS ESTIMATES | | | AGGREGATE EMISSION FACTORS | | |
|---|---|---|---|---|---|---|---|---|
| | | Fuel Quantity (PJ) | $CH_4$ (Gg) | $CO_2$ (Gg) | NMVOC (Gg) | $CH_4$ (kg/GJ) | $CO_2$ (kg/GJ) | NMVOC (kg/GJ) |
| I B 2 a Oil | | | | | | | | |
| i Exploration | (no. of wells drilled) | | | | | | | |
| ii Production of Crude Oil | | 15 | 0.06 | | | 4 | | |
| iii Transport of Crude Oil | (Qnty. loaded on tankers) | 132.535 | 0.1 | | | 0.755 | | |
| iv Refining/Storage | (Qnty. refined) | 132.535 | 0.19 | | | 1.434 | | |
| v Distribution of Oil Products | (Qnty. consumed) | | | | | | | |
| vi Other | | | | | | | | |
| I B 2 b Natural Gas | | | | | | | | |
| i Production/Processing | (Qnty. produced) | | | | | | | |
| ii Transmission/Distribution | (Qnty. consumed) | 51.129 | 23.4 | | | 458 | | |
| iii Other Leakage | (Qnty. consumed) | | | | | | | |
| I B 2 c Venting and Flaring | | | | | | | | |
| i Oil | (Qnty. produced) | 15 | 0.06 | | | 4 | | |
| ii Natural Gas | (Qnty. produced) | | | | | | | |
| iii Combined | (Qnty. produced) | | | | | | | |

# Standard Data Table 2

## Industrial Processes

| Source and Sink Categories | Activity Data | Emission Estimates | | | | | | | | | Aggregate Emission Factors | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector Specific Data (units) | A<br>Production quantity (kt) | B<br>Full Mass of Pollutant (Gg) | | | | | | | | | C=B/A<br>Pollutant per tonne of product (kg / t) | | | | | | | | |
| | | $CO_2$ | CO | $CH_4$ | $N_2O$ | $NO_X$ | NMVOC | HFCs | PFCs | $SF_6$ | $CO_2$ | CO | $CH_4$ | $N_2O$ | $NO_X$ | NMVOC | HFCs | PFCs | $SF_6$ |
| A Iron and Steel | 0 | | | | | | | | | | | | | | | | | | |
| B Non-Ferrous Metals | 0 | | | | | | | | | | | | | | | | | | |
| Aluminium Production | | | | | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | | | | | |
| C Inorganic Chemicals (excepting solvent use) | 0 | | | | | | | | | | | | | | | | | | |
| Nitric Acid | | | | | | | | | | | | | | | | | | | |
| Fertiliser Production | | | | | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | | | | | |
| D Organic Chemicals | 0 | | | | | | | | | | | | | | | | | | |
| Adipic Acid | | | | | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | | | | | |
| E Non-Metallic Mineral Products | | | | | | | | | | | | | | | | | | | |
| Cement | 938 | 467.593 | | | | | | | | | 0.4985 | | | | | | | | |
| Lime | 185 | 145.355 | | | | | | | | | 0.7857 | | | | | | | | |
| Other | | | | | | | | | | | | | | | | | | | |
| F Other ( ISIC ) | 0 | | | | | | | | | | | | | | | | | | |
| TOTAL | 1123 | 612.948 | NA | NA | NA | NA | NA | NA | NA | NA | 0.54581 | | | | | | | | |

# Standard Data Table 4

## Agriculture: 4A & B Enteric Fermentation & Manure Management

| Source and Sink Categories | Activity Data | Emission Estimates | | Aggregate Emission Factor | |
|---|---|---|---|---|---|
| | A | B | | C | |
| | Number of Animals | Enteric Fermentation | Manure Management | Enteric Fermentation | Animal Wastes |
| | (1000) | (Gg $CH_4$) | | (kg $CH_4$ per animal) | |
| | | | | C=(B/A)x1000 | |
| 1 Cattle | 757.4 | | | | |
| I Beef | 477.7 | 26.75 | 1.91 | 56.0 | 71.4 |
| II Diary | 279.6 | 22.65 | 1.68 | 81.0 | 74.2 |
| 2 Buffalo | 0 | | | | |
| 3 Sheep | 141.0 | 1.13 | 0.03 | 8.0 | 26.5 |
| 4 Goats | 0 | | | | |
| 6 Horses | 8.6 | 0.16 | 0.01 | 18.5 | 62.5 |
| 7 Mules/Asses | 0 | | | | |
| 8 Swine | 946.3 | 1.42 | 3.79 | 1.5 | 2669.0 |
| 9 Poultry | 6332.4 | NO | 0.49 | NO | 0.1 |
| TOTAL | | 52.11 | 7.91 | | |

## Agriculture: 4D Agricultural Soils

| Source and Sink Categories | Activity Data | | Emission Estimates | Aggregate Emission Factor | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| Crop Type | Amount of N applied in fertilizer and manure (t N) | Area Cultivated (th. ha) | (Gg N2O) | tonnes N2O-N released per tonne t N applied (kg N) | Amount of Biol. fixation of N (t N) |
| Total arable land | 125200 | 1132 | 0.907 | 0.0036 | 35100 |

| | |
|---|---|
| Title of Inventory | Estonian Greenhouse Gas Emissions Inventory |
| Contact Name | J. M. Punning |
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## 5 A I Forest Clearing: $CO_2$ Release from Burning Aboveground Biomass

| ACTIVITY DATA | | | EMISSIONS ESTIMATES | AGGREGATE EMISSIONS FACTOR |
|---|---|---|---|---|
| A | B | C | D | E |
| Area Cleared (kha) | Total Biomass Change (kt dm) | Quintity of Biomass Burned (on and off-site) (kt dm) | Quantity of $CO_2$ Released (Gg $CO_2$) | (Mg $CO_2$/kt dm burned) |
| 1.01 | 93.88 | 42.25 | 62.7300 | 1.4847 |

## 5 A 2 On-Site Burning of Cleared Forests

| ACTIVITY DATA | | EMISSIONS ESTIMATES | | | | AGGREGATE EMISSION RATIOS | | | |
|---|---|---|---|---|---|---|---|---|---|
| A | B | C | | | | D | | | |
| Carbon Release Gg | Nitrogen Release Gg | Emissions Estimates Gg | | | | Aggregate Emissions Ratios | | | |
| | | $CH_4$ | CO | $N_2O$ | $NO_x$ | $CH_4$ | CO | $N_2O$ | $NO_x$ |
| 9.51 | 0.0951 | 0.0152 | 1.3307 | 0.0010 | 0.0378 | 0.0016 | 0.1399 | 0.0105 | 0.3975 |

Forest Clearing: $CO_2$ Release from Decay of Aboveground Biomass

| ACTIVITY DATA | | | EMISSIONS ESTIMATES | AGGREGATE EMISSIONS FACTOR |
|---|---|---|---|---|
| A | B | C | D | E |
| 10-Year Average Area Cleared (kha) | 10-Year Average Actual Loss of Biomass (kt dm) | Average Quantity of Biomass to Decay (kt dm) | $CO_2$ Emissions (Gg $CO_2$) | Emissions Factor (Mg $CO_2$ /kt dm) |
| 1.47 | 136.64 | 20.50 | 33.8250 | 1.6500 |

## 5 A 4 Forest Clearing: Soil Carbon Release

| ACTIVITY DATA | | EMISSIONS ESTIMATES | AGGREGATE EMISSIONS FACTOR |
|---|---|---|---|
| A | B | C | D |
| Average Annual Forest Converted to Pasture or Crops over 25 Years (kha) | Soil Carbon Content of Land Before Clearing (t C/ha) | $CO_2$ Released from Soil (Gg $CO_2$) | Aggregate Emissions Factor from Soil Carbon (Mg/ha) |
| 1.5 | 185 | 508.7500 | 339.1667 |

## 5 A 5 Total $CO_2$ Emissions from Forest Clearing

| CATEGORY | EMISSIONS (Gg) |
|---|---|
| $CO_2$ from Burning of Cleared Biomass | 62.7300 |
| $CO_2$ from Decay of Cleared Biomass | 33.8250 |
| $CO_2$ from Soil Carbon Release | 508.7500 |
| TOTAL | 605.3050 |

## 5 C 1 Abandonment of Managed Lands

(Annual Carbon Uptake from Lands Abandoned Over the Previous 20 Years)

| ACTIVITY DATA | | | CARBON UPTAKE ESTIMATES | | | AGGREGATE REMOVAL ESTIMATES | |
|---|---|---|---|---|---|---|---|
| A | B | C | D | E | F | G | H |
| Total Area Abandoned (Previous 20 Years) (kha) | Aboveground Biomass in Mature Systems (t dm/ha) | Soil Carbon in Mature Systems (t C/ha) | Aboveground Biomass (Gg C) | Soils (Gg C) | Total | Carbon Removal in Aboveground Biomass (Mg/ha) | Carbon Removal in Soils (Mg/ha) |
| 343.3 | 130 | 185 | 448.01 | 617.94 | 1065.95 | 1.3050 | 1.8000 |

## 5 C 3 Abandonment of Managed Lands - Total $CO_2$ Removals

| SINK CATEGORY | A | B |
|---|---|---|
| | Carbon Removals (Gg C) | CO2 Removals (Gg CO2) |
| Lands Abandoned Over the Previous 20 Years | 1065.95 | 3908.48 |
| Lands Abandoned More than 20 Years Previously | 0 | 0.00 |
| TOTAL | 1065.95 | 3908.48 |

## 5 D 1 Managed Forests (Part I): Annual Growth Increment

| ACTIVITY DATA | EMISSIONS/ REMOVALS ESTIMATES | AGGREGATE REMOVALS FACTORS |
|---|---|---|
| A | B | C |
| Area of Managed Forest (kha) | Carbon Removal (Gg C) | Carbon Removal Factor (Mg C) |
| 1554.5 | 2028.62 | 1.3050 |

## 5 D 2 Managed Forests (Part II): Harvest

| SOURCE AND SINK CATEGORIES | ACTIVITY DATA | EMISSION ESTIMATES | AGGREGATE EMISSION FACTORS |
|---|---|---|---|
| | A | B | C |
| | Amount of Biomass Harvested (kt dm) | Carbon Emission/Removal Estimates (Gg C) | Carbon Emissions Factors (Mg C/t dm) |
| Commercial Timber | 1178.1 | 530.15 | 0.45 |
| Fuelwood | 513.42 | 231.04 | 0.45 |
| Other | 0 | 0 | 0 |

## 5 D 3 Managed Forests: Net Emissions/Removals (Summary)

| CATEGORY | EMISSIONS/REMOVALS ($CO_2$ (Gg)) |
|---|---|
| Total Growth Increment | 7438.2733 |
| Total Harvest | 2791.0080 |
| NET EMISSIONS (+) OR REMOVALS (-) | 4647.2653 |

## Standard Data Table 6

### 6 A Waste: Landfills

| Source and Sink Categories | Activity Data | | Emission Estimates | Aggregate Emission Factors | |
|---|---|---|---|---|---|
| Disposal Method | A<br>Total MSW<br>(kg per year) | B<br>MSW Landfilled<br>( Gg ) | C<br>CH4 Emissions<br>( Gg ) | D<br>Emission Factor<br>(kg CH4/kg MSW landfilled) | E<br>Qty of CH4 recovered<br>(kg CH4) |
| | | | | D=C/B | |
| A Landfills | | 292.56 | 26.28 | 0.0898 | |

### 6 B Waste: Sewage Treatment

| Source and Sink Categories | | Activity Data | | Emission Estimates | Aggregate Emission Factors | |
|---|---|---|---|---|---|---|
| Wastewater Type | | A<br>Quantity BOD in Wastewater<br>( Gg ) | B<br>Quantity of CH4 Anaerobically Digested<br>( kg CH4 ) | C<br>CH4 Emissions<br>( Gg ) | D<br>Emission Factor.<br>( kg CH4/ kg BOD ) | E<br>Quantity of $CH_4$ Recovered<br>( kg CH4 ) |
| | | | | | D=C/A | |
| B Wastewater | Municipal | 28.6 | | 0.629 | 0.022 | |
| | Industrial | 691.302 | | 15.21 | 0.022 | |
| C Other | | | | | | |

# Standard Data Table 7B Short Summary Report for National GHG Inventories

| Short Summary Report for National Greenhouse Gas Inventories (Gg) | | | | | | | |
|---|---|---|---|---|---|---|---|
| GHG Source and Sink Categories | $CO_2$ Emissions | $CO_2$ Removals | $CH_4$ | $N_2O$ | $NO_X$ | CO | NMVOC |
| Total National Emissions and Sinks | 40925 | 0 | 322 | 2 | 93 | 185 | 23 |
| 1 All Energy (Fuel Combustion + Fugitive) | 37184 | 0 | 220 | 1 | 93 | 184 | 23 |
| A Fuel Combustion | 37184 | 0 | 3 | 1 | 93 | 184 | 23 |
| B Fugitive Fuel Emission | 0 | 0 | 217 | NO | NO | NO | NA |
| 2 Industrial Processes | 613 | 0 | NA | NA | NA | NA | NA |
| 3 Solvent and Other Product Use | NA | 0 | NO | NO | NO | NO | NA |
| 4 Agriculture | 0 | 0 | 60 | 1 | NO | NO | NO |
| 5 Land Use Change & Forestry | 3128 | NE | 0 | 0 | 0 | 1 | NO |
| 6 Waste | 0 | 0 | 42 | NO | NO | NO | NO |
| International Bunkers | NA | 0 | NA | NA | NA | NA | NA |