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ESTONIAN GREENHOUSE GAS
EMISSIONS INVENTORY REPORT

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Appendix 1: Detailed Description of Methods and Data Used

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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 Sovereignty of the Estonian SSR was passed, which marked the beginning of the "new awakening", a peaceful struggle to regain independence. In May, 1989, the country declared economic independence. On August 20, 1991, the Supreme Council of 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 deterioration of the national economy. However, several political, institutional, legal, and economic changes have recently been successfully implemented and thus improving conditions for future development.

Further 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 Sustainable 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 conventions:

- 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 compiling 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 km², of which 4,132 km² (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 exceeds evaporation approximately twice, 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 km², 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 (CO₂, SO₂, 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 vehicles. A lot of used old cars and lorries are imported

from abroad. Therefore the total emissions from transport vehicles 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 km² (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 km², 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 CO₂ and CH₄. 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 km²; 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 importance in European and worldwide size and therefore it is necessary 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/km².

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 CO₂ emissions from energy sources are given in Table 3.

In energy sector the main contributor of CO₂ emissions is the use of oil shale. In 1990 total CO₂ emissions from fossil fuel consumption were 37,183.8 Gg.

Biomass fuel was used in form of fuelwood and wood waste. For 1990 CO₂ emissions from biomass consumption were 1,073.9 Gg.

Approximately 68% of Estonian CO₂ 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 CO₂ emissions. Sectorial emissions of carbon dioxide in energy consumption were: industrial - 33%, transportation - 30%, residential - 19% and commercial - 18%.

In Table 5 non-CO₂ gases emissions from fuel combustion activities are given for 1990. In Estonia the biggest amount of non-CO₂ emissions was coming from transport sector.

Table 3. CO₂ from energy sources (Reference Approach).

Fuel Types	CO₂ 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 CO₂ 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-CO₂ gas emissions from fuel combustion activities.

Sector	Emissions Estimates, Gg				
	CH ₄	N ₂ O	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 (CaCO₃) from limestone, chalk or other calcium-rich materials calcium oxide (CaO) and carbon dioxide (CO₂) are formed. Total CO₂ emissions from cement and lime production in Estonia were 612.948 Gg in 1990 (the Table 7).

Table 7. Sources of CO₂ 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 CH₄ emissions 88% come from cattle, and 8.7% from pig husbandry. Methane emission from enteric fermentation formed 87% from total CH₄ 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	%
	CH ₄ 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 N₂O-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 coefficient 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 N₂O-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 ₂ O - 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 ₂ O, 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 ₂ O, 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 CO₂ 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 Mm³ 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 (*Quercus*), 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 Mm³ (in all forests 1.6 - 2.0 Mm³) (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 m³, out of which 1414.3 thousand m³ 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 coöperations - 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 CO₂ and other greenhouse gases from forests and land use change. The simplified method for the estimation of CO₂ 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 CO₂ budget in Estonian forests the following factors were considered:

CO₂ from: Changes in forest and other woody biomass stocks

Forest and grassland conversion

Abandonment of managed lands

CH₄, CO, N₂O, NO_x from:

On - site burning of cleared forests and woodlands

1990±1 is designated as a base year for calculation of CO₂ emission and uptake. According to the methodological requirements current emissions of CO₂ 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 CO₂ 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 CO₂ emission.

2.6.1 CO₂ removals and emissions

The calculation results showed that CO₂ 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 CO₂ 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 CO₂ by Estonian forests was during the inventory year 11346.75 Gg. This figure includes 7438.27 Gg CO₂ due to accumulation by total growth

increment of managed forests and 3908.48 Gg CO₂ 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 CO₂ 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 CO₂ emission from forest conversions was estimated 508.75 Gg CO₂. Total CO₂ emission from forest ecosystem was 3396.31 Gg CO₂.

Taking into account emissions and removals of CO₂ in forest ecosystem the net CO₂ uptake by forest ecosystem in Estonia estimates 7950.44 Gg per year.

2.6.2 Non-CO₂ trace gases

Inventory of methane (CH₄), carbon monoxide (CO), nitrous oxide (N₂O) and oxides of nitrogen (NO_x, i.e. NO and NO₂) 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-CO₂ trace gases in Estonian forests.

CH ₄	CO	N ₂ O	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 Guidelines (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 peculiarity 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 widening 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 fifties 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 largely and is between 1.5 and $1.9 \text{ t ha}^{-1} \text{ y}^{-1}$ [Ilomets, 1994]. Here the accounts are based on the mean value of $1.7 \text{ t ha}^{-1} \text{ y}^{-1}$. In lakes the accumulation on organic sediments (gyttja) is differing importantly from 1 to $100 \text{ mg cm}^{-2} \text{ y}^{-1}$, e.a. the mean value is taken as $10 \text{ mg cm}^{-2} \text{ y}^{-1}$ or $1 \text{ t ha}^{-1} \text{ y}^{-1}$. If consider with 54% carbon content in the dry matter both in peat and lake gyttja then the mean accumulation of $\text{CO}_2\text{-C}$ in the virgin peatlands is about $0.9 \text{ t ha}^{-1} \text{ y}^{-1}$ and in lakes ca $0.324 \text{ t ha}^{-1} \text{ y}^{-1}$ 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 hectare per year during the first decade after the establishment of amelioration system [Tomberg, 1992]. Later it will be stabilised and depending on the character of exploitation (crop field, grassland, pasture) may be between 5 and 15 tons per hectare per year. Possible mean level may be about 8 tons per hectare per year or 4.3 t of $\text{CO}_2\text{-C}$ 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 CO₂ and CH₄ 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

* CO₂-C accumulation on virgin peatlands is approximately 0.9 t C ha⁻¹, CO₂-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 CO₂ and CH₄ accumulation and emission on wetlands in 1990.

Type of wetland	CO ₂ -C accumulation, Gg	CO ₂ -C emission, Gg	CH ₄ -C emission on virgin wetlands, Gg	CH ₄ -C emission 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

* CO₂-C accumulation on virgin peatlands is approximately 0.9 t C ha⁻¹, CO₂-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 CO₂ and CH₄ emissions from wetlands are presented in Appendix 1 and in Worksheets 5-5 in Appendix 2.

Total emission of CH₄ and CO₂ from wetlands for year 1990 is respectively:

$$(35.9+0.9) \times 16 / 12 = 49.1 \text{ Gg of CH}_4 \text{ (not included into total emissions).}$$

and $3022 \times 44 / 12 = 11080$ Gg of CO₂ (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 is 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 CH₄ 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 extremely 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 CO₂ 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 CO₂ 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 fermentation 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 CO₂ to Estonian forest in 1994 was 11,089 Gg, what is only 2% lower than in 1990, although there was altered balance in CO₂ removal between different land use changes and forest categories (Table 17).

Table 17. Removals/emissions of CO₂ (Gg) due to forestry and land use change in 1990 and 1994.

		CO ₂ (1990)		CO ₂ (1994)	
		Removal	Emission	Removal	Emission
Forest Management	Biomass Growth				
	Increment	7438.27	-	8602.47	-
	Harvest	-	2791.01	-	2989.14
Forest Conversion	On- and off-site Burning	-	62.73	-	0
	Decay	-	33.82	-	19.32
	Soil	-	508.75	-	420.57
Abandoned Managed Lands	Aboveground Biomass	1642.70	-	1045.04	-
	Soil	2265.78	-	1441.44	-
Total:		11346.75	3396.31	11088.95	3429.03

Net CO₂ 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 ₂ O	
	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 occurring

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 SO₂, 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 CO₂ 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 decrease 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.

References

1. *Eesti majandusülevaade / Overview of Estonian Economy*. 1994-1995, Tallinn, 1995, 129 pp.
2. *Environment, 1994*. Ministry of Environment of Estonia, Environmental Information Centre, Tallinn, 112 pp.
3. *Estonia: Sector Environmental Assessment on the Utilization of Domestic Peat and Wood Chips as a Fuel for Heating Systems*. Stockholm and Tallinn, 1994. 102 pp.
4. *Estonian Statistics Bulletin*. 1994. No 1-12. Statistical Office of Estonia. Tallinn.
5. *Estonian Statistics Bulletin*. 1995. No 1-6. Statistical Office of Estonia. Tallinn.
6. *Estonia's first National communication under the United Nations Framework Convention on Climate Change*. Ministry of Environment of the Republic of Estonia, 1995. Tallinn, 38 pp.
7. *Forestry 1994*. 1995. Statistical Office of Estonia. Tallinn.
8. Franzen, L. G. 1994. Are Wetlands the Key to the Ice-age Cycle Enigma? *AMBIO*, vol. 23, pp. 300 - 308.
9. Ilomets, M., Animägi, J., Kallas, R., 1995. *Estonian Peatlands. A brief review of their development, state, conservation, peat resources and management*. - Tallinn, 48 p.
10. Ilomets, M. 1994. Why Preserve Our Mires? *Estonian Nature*, Vol. 3: 1994.

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. CO₂ 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:

$$\text{Apparent Consumption} = \text{Production} + \text{Imports} - \text{Exports} - \text{International Bunkers} - \text{Stock Change}$$

Apparent fuel consumption is converted into carbon content using formula:

$$\text{Apparent consumption} \times \text{Carbon Emission Factor (CEF)}$$

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 gas emissions it is important that during combustion of powdered oil shale CO₂ 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:

$$CEF_{oil\ shale} = 10 \frac{C'_t + k(CO_2)'_M \cdot 12/44}{Q'_I} \quad (tC/TJ)$$

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

C'_t - carbon content of oil shale as it burned, %;

$(CO_2)'_M$ - 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):

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

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

$Activity$ - energy input, (TJ);

a - fuel type;

b - sector - activity;

c - technology type.

Emission factors for all non-CO₂ 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 (nearly 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-CO₂ 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-CO₂ 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-CO₂ 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:

$$\text{Emissions} = \sum (EF_{abc} \times \text{Activity}_{abc})$$

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-CO₂ 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 ₂ O	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 CO₂ emissions are treated as zero in the energy sector. Non-CO₂ 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.

Step 1: The general equation for estimating carbon emissions is:

$$\text{Carbon Released from Biomass Fuel} = \text{Total Biomass Consumed (kt dm)} \times \text{Fraction Oxidised} \times \text{Carbon Fraction}$$

Step 2: Non-CO₂ trace gas emissions from burning calculation is summarised as follows:

$$\text{CH}_4 \text{ Emissions} = (\text{carbon released}) \times (\text{emission ratio}) \times 16/12$$

$$\text{CO Emissions} = (\text{carbon released}) \times (\text{emission ratio}) \times 28/12$$

$$\text{N}_2\text{O Emissions} = (\text{carbon released}) \times (\text{N/C ratio}) \times (\text{emission ratio}) \times 44/28$$

$$\text{NO}_x \text{ Emissions} = (\text{carbon released}) \times (\text{N/C ratio}) \times (\text{emission ratio}) \times 46/14$$

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 CH₄ emissions from mining (underground and surface mining) and post mining activities (underground and surface mining) is (IPCC Guidelines, 1994, 1995):

$$\text{CH}_4 \text{ Emissions (Gg)} = \text{CH}_4 \text{ Emission Factor (m}^3 \text{ CH}_4\text{/ton of oil shale mined)} \times \text{oil shale production (Mt)} \times \text{Conversion Factor (Gg/10}^6 \text{ m}^3\text{)}$$

Conversion Factor converts the volume of CH₄ to a weight measure and is the density of methane at 20°C and 1 atmosphere, namely 0.67 Gg/10⁶ m³.

When consulting with the specialists from Oil Shale Institute in Kohtla-Järve, Estonia, the emission factors of former Soviet Union lignite mining activities (m³ CH₄/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 CH₄ missions from oil and gas activities is:

$$\text{CH}_4 \text{ Emissions (Gg CH}_4\text{)} = \{\text{Activity (PJ)} \times \text{Emission Factor (kg CH}_4\text{/PJ)}\} : 10^6$$

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 CO₂ emissions from cement manufacturing is:

$$\text{CO}_2 \text{ Emissions (Gg CO}_2\text{)} = \{\text{cement production (t)} \times \text{Emission Factor (t CO}_2\text{ / t cement)}\} : 1000$$

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 CO₂/t cement.

2.2 Lime Manufacturing

For calculation CO₂ emissions from lime manufacturing could be used the formula of CO₂ emissions from cement production: Emission factor of CO₂ for lime manufacturing is taken equal to molecular weight ratio of CO₂/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 CH₄ and N₂O 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 Guidelines, 1994, 1995), where different emission coefficients were given to different animal types (Table 3).

$$\text{CH}_4 \text{ emissions} = \text{population of animals} \times \text{emission coefficient}$$

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):

$$\text{N}_2\text{O Emissions} = \Sigma (\text{Fmn} + \text{Fon} + \text{Fbnf}) \times \text{C} \times 44/28$$

where: Fmn - amount of mineral fertilizer applied (10³ t N / yr) .

Fon - amount of organic fertilizer applied (10³ t N / yr)

Fbnf - amount of biological nitrogen fixation applied (10³ 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 N₂O emissions.

$$C_{\text{low}} = 0.0005$$

$$C_{\text{medium}} = 0.0036$$

$$C_{\text{high}} = 0.0390$$

4. Forestry and Land Use

4.1 Changes in Forest and Other Woody Biomass Stocks

Worksheet: 5-1

Goal: Calculate net flux of CO₂ 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 CO₂ 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 CO₂ (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 CO₂.

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

Estimated growth rate of stemwood with branches is 11.5 Mm³/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/m³ for deciduous trees and 0.45 t dm/m³ for conifers (IPCC Guidelines, 1994); 2/3 of the Estonian forests are conifers (Statistical Yearbook, 1994) hence conversion ratio = $\frac{2}{3} \times 0.45 + \frac{1}{3} \times 0.65$;

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 m³/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/m³ for deciduous trees and 0.45 t dm/m³ for conifers (IPCC Guidelines, 1994); 2/3 of the Estonian forests are conifers (Statistical Yearbook, 1994) hence conversion ratio = $2/3 \times 0.45 + 1/3 \times 0.65$.

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

Estonian fuelwood consumption in 1988 was 1,064,400 m³ (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 (m³/yr)

EF = biomass conversion/expansion factor (t dm/m³)

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)

$$R = ((2,356,200 \times 0.5) + 532,200 + 0 - 18,780) \times 0.45 = 761,190 \text{ t C/yr}$$

3. Net CO₂ flux from managed forests (t CO₂/yr):

$$(U - R) \times 44 / 12$$

where:

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

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

$$(2,028,620 - 761,190) \times 44 / 12 =$$

$$+ 4,647,270 \text{ t CO}_2/\text{yr} = +4,647.27 \text{ Gg CO}_2/\text{yr}$$

4.2 Forest and Grassland Conversion

Worksheet: 5-2

Goal: Calculate CO₂ 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 CO₂ 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 m³ per hectare (the figure includes the top) (Statistical Yearbook, 1994);

conversion ratio is 0.5 (default values for converting volume data to tons are 0.65 t dm/m³ for deciduous trees and 0.45 t dm/m³ for conifers /IPCC Guidelines, 1994/; 2/3 of the

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

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 = $143 \times 0.5 \times 0.30 + 143 \times 0.5$.

- **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)

FB_n = fraction of biomass burned on site

FOn = fraction of biomass oxidized on site

C = C fraction (t C/t dm)

$$CO_n = 1,010 \times (92.95 - 0) \times 0.25 \times 0.9 \times 0.45 = 9,510 \text{ t C/yr}$$

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

$$CO_f = A \times (BB - BA) \times FB_f \times FO_f \times C$$

where:

A = area converted annually (ha/yr)

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

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

FBf = fraction of biomass burned off site

FOf = fraction of biomass oxidized off site

C = C fraction (t C/t dm)

$$CO_f = 1,010 \times (92.95 - 0) \times 0.2 \times 0.9 \times 0.45 = 7,600 \text{ t C/yr}$$

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

$$CB = CO_n + CO_f$$

where:

CO_n = amount of C released by on-site burning

CO_f = amount of C released by off-site burning

$$CB = 9,510 + 7,600 = 17,110 \text{ t C/yr}$$

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

$$CD = AA-10 \times (BB - BA) \times FD \times C$$

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)

$$CD = 1,470 \times (92.95 - 0) \times 0.15 \times 0.45 = 9,220 \text{ t C/yr}$$

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

$$CS = AA-25 \times SC \times FR$$

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

$$CS = 1,500 \times 185 \times 0.5 = 138,750 \text{ t C/yr}$$

4. Total CO₂ released from forest conversion (t CO₂/yr):

$$(CB + CD + CS) \times 44 / 12$$

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)

$$(17,110 + 9,220 + 138,750) \times 44 / 12 = 605,300 \text{ t CO}_2/\text{yr} = 605.3 \text{ Gg CO}_2/\text{yr}$$

4.3 Non-CO₂ Emissions from On-Site Burning of Cleared Forests and Woodlands

Worksheet: 5-3

Goal: Calculate CH₄, CO, N₂O, 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 CH₄-C to CO₂-C released from burning -0.012

Default value (IPCC Guidelines, 1994).

- emission ratio of CO-C to CO₂-C released from burning -0.06

Default value (IPCC Guidelines, 1994).

- emission ratio of N₂O-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):

$$COn \times NC$$

where:

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

NC = N/C ratio

$$9,510 \times 0.01 = 95.1 \text{ t N/yr}$$

- 2a. Trace gas emissions

$$CH_4 \text{ released (t } CH_4/\text{yr)} = COn \times ER_{CH_4} \times 16 / 12$$

$$CO \text{ released (t } CO/\text{yr)} = COn \times ER_{CO} \times 28 / 12$$

where:

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

ER = emission ratio

$$CH_4 \text{ released} = 9,510 \times 0.012 \times 16 / 12 = 152.1 \text{ t } CH_4/\text{yr} = 0.1521 \text{ Gg } CH_4/\text{yr}$$

$$CO \text{ released} = 9,510 \times 0.06 \times 28 / 12 = 1,330.7 \text{ t } CO/\text{yr} = 1.3307 \text{ Gg } CO/\text{yr}$$

- 2b. Trace gas emissions

$$N_2O \text{ released (t } N_2O/\text{yr)} = N \times ER_{N_2O} \times 44 / 28$$

$$NO_x \text{ released (t } NO_x/\text{yr)} = N \times ER_{NO_x} \times 46 / 14$$

where:

ER = emission ratio

N = total N released (t N/yr)

$$N_2O \text{ released} = 95.1 \times 0.007 \times 44 / 28 = 1.000 \text{ t } N_2O/\text{yr} = 0.0010 \text{ Gg } N_2O/\text{yr}$$

$$NO_x \text{ released} = 95.1 \times 0.121 \times 46 / 14 = 37.8 \text{ t } NO_x/\text{yr} = 0.0378 \text{ Gg } NO_x/\text{yr}$$

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).

20 years or less

- total area abandoned and regrown during last 20 years that is regenerating -

343,300 ha

Changes in forest land area from 1970...1990 (Károles *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 Mm³/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/m³ for deciduous trees and 0.45 t dm/m³ 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 = $11.5 / 2.0 \times 0.5$.

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 m³ per hectare (the figure includes the top) (Károles *et al.*, 1994);

conversion ratio is 0.5 (default values for converting volume data to tons are 0.65 t dm/m³ for deciduous trees and 0.45 t dm/m³ for conifers /IPCC Guidelines, 1994/; 2/3 of the Estonian forests are conifers /Statistical Yearbook, 1994/ hence conversion ratio = $2/3 \times 0.45 + 1/3 \times 0.65$);

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 = $227 \times 0.5 \times 0.15 + 227 \times 0.5$.

4.4.2 Calculation

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

$$\text{CBL} = \text{AY} \times \text{RB} \times \text{C}$$

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)

$$\text{CBL} = 343,300 \times 2.9 \times 0.45 = 448,010 \text{ t C/yr}$$

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

$$\text{CSL} = \text{AY} \times \text{RS}$$

where:

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

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

$$\text{CSL} = 343,300 \times 1.8 = 617,940 \text{ t C/yr}$$

3. Total CO₂ uptake from abandonment of managed lands (t CO₂/yr):

$$(\text{CBL} + \text{CSL}) \times 44 / 12$$

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)

$$(448,010 + 617,940) \times 44 / 12 =$$

$$+ 3,908,470 \text{ t CO}_2/\text{yr} = + 3,908.47 \text{ Gg CO}_2/\text{yr}$$

Total CO₂ flux from land use change and forestry (Gg CO₂/yr)

* CO₂ emissions from forest conversion

* CO₂ uptake due to abandonment of managed lands

* net CO₂ flux from changes in forest and other woody biomass stocks

$$-605.3 + 3,908.47 + 4,647.27 = +7,950.44 \text{ Gg CO}_2/\text{yr}$$

5. Wetlands

Goal: To calculate net flux of CO₂ 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 CO₂ emission from peat in drained areas
3. Calculate annual decrease in CH₄ 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 (Oru 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 km²)

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 hectare 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 $1.2 \cdot 10^{-3} \text{ m yr}^{-1} \times 140 \text{ kg m}^{-3} = 0.17 \text{ kg m}^{-2} \text{ yr}^{-1} = 1.7 \text{ ton per ha per year of dry matter}$.

*** 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 hectare per year during the first decade after the establishment of amelioration system [Tomberg, 1992]. Later it will be stabilized and depending on the character of exploitation (crop field, grassland, pasture) may be between 5 and 15 tons per hectare per year. Possible mean level may be about 8 tons per hectare per year or 4.3 t of CO₂-C if consider with relative importance of different exploitation ways in Estonia.

*** annual CH₄-C emission rates are given in Table 5**

For CH₄-C emissions from drained wetlands the default emission factors from IPCC Guidelines (1995), Reference Manual, page 5.43, are followed, for CH₄-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 anthropogenic 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/m ² /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 CO₂-C emission (t C/yr)

$$E_{CO_2-C} = (A_n d \times Erd)$$

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

Erd = CO₂-C emission rate in drained peatland type n (kg/ha/yr)

The calculation of E_{CO_2-C} is presented in worksheet 5-5, sheet 1 of 2 (Appendix 2).

In 1990 the emission of CO₂ from drained peatlands was 11079.24 Gg. This figure is included into the total CO₂ emission/removal figure of Land Use and Forestry sector, in Table 7A - Summary Report for National GHG Inventories (Appendix 3).

2. Annual CH₄-C emission (Gg C/yr)

$$E_{CH_4-C} = (A_n d \times Erd)$$

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

Erd = decrease of CH₄-C emissions in drained wetland type n (kg/ha/yr)

The calculation of E_{CH_4-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 CH₄, 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:

$$\text{Methane Emissions (Gg / year)} = \text{Total MSW* Landfilled} \times \text{Fraction DOC** in MSW} \times \text{Fraction Dissimilated DOC} \times 0.5 \text{g C as CH}_4/\text{g C as biogas} \times \text{Conversion Ratio (16/12)} - \text{Recovered CH}_4 \text{ (Gg/year)}$$

where: MSW* - Municipal Solid Waste;

DOC** - Degradable Organic Carbon.

Total MSW generated can be calculated from:

$$\text{Total MSW} = \text{Population (thousand persons)} \times \text{Annual MSW Generation Rate (Gg / thousand persons / year)}.$$

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):

$$\text{Methane Emissions (Gg / year)} = \text{Population (10}^3\text{)} \times \text{Gg BOD}_5^* / \text{person / year} \times \text{Fraction Treated Anaerobically} \times 0.22 \text{ Gg CH}_4 / \text{Gg BOD}_5^* - \text{Methane Recovered (Gg)}$$

* - Biochemical Oxygen Demand

Estimated BOD₅ 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 specificity 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):

$$\text{Methane Emissions (Gg / year)} = \sum \text{Wastewater Outflow by Industry (MI / year)} \times \text{kg BOD}_5 / \text{l} \times \text{Fraction Wastewater Treated Anaerobically} \times 0.22 \text{ CH}_4 \text{ Recovered (Gg/year)}$$

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	H	I	J	K
			Conversion Factor TJ/Unit	Apparent Consumption TJ	Carbon Emission Factor t C/TJ	Carbon Content t C	Carbon Content Gg C
				H=(F×G)		J=(H×I)	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	M	N	O	P
			Carbon Stored Gg C	Net Carbon Emissions Gg C	Fraction of Carbon Oxidised	Actual Carbon Emissions Gg C	Actual CO ₂ Emissions Gg C
				M=(K-L)		O=(MxN)	P=(Ox44/12)
Liquid Fossil	Primary Fuels	Natural Gas Liquids	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	91,587	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	
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

[illegible]

MODULE	ENERGY										
SUBMODULE	TRADITIONAL BIOMASS BURNED FOR ENERGY										
WORKSHEET	I - 3										
SHEET	2 OF 3										
	STEP 4					STEP 5					
	I	J	K	L	M	N	O	P			
	C-CO Trace Gas Emission Ratio	C Emitted as CO kt C J=(Exl)	CO Emitted Gg CO K=(Jx28/12)	Nitrogen-Carbon Fuel Ratio	Total Nitrogen Released kt N M=(ExL)	N-N ₂ O Trace Gas Emission Ratio	Nitrogen Emitted as N ₂ O kt N O=(MxN)	N ₂ O Emitted Gg N ₂ O P=(Ox44/28)			
Wood	0.06	13.890	32.411	0.01	2.315	0.007	0.018	0.025			
Agricultural Wastes	0										
Dung	0										
Charcoal Consumption	0										
Charcoal Production	0										
Others (Specify)	0										
	Total	13.890	32.411		2.315	0.007	0.018	0.025	Total		0.025

MODULE	ENERGY		
SUBMODULE	TRADITIONAL BIOMASS BURNED FOR ENERGY		
WORKSHEET	1 - 3		
SHEET	3 OF 3		
	STEP 6		
	Q N - NOx Trace Gas Emissions Ratio	R Nitrogen Emitted as NOx kt N $R=(M \times Q)$	S NOx Emitted Gg NOx $S=(R \times 46/14)$
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 Amount of Oil-Shale Produced (million t)	B Emission Factor (m ³ CH ₄ /t)	C Methane Emissions (million m ³) C=(AxB)	D Conversion Factors (0.67 Gg CH ₄ /106 m ³)	E Methane Emissions (Gg CH ₄) E=(Cx D)
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	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 Number of Animals (1000s)	B Emission Factor for Enteric Fermentation (kg/head/year)	C Emissions from Enteric Fermentation (t/year) C=(AxB)	D Emission Factor for Manure Management (kg/head/year)	E Emissions from Manure Management (t/year) E=(AxD)	F Total Annual Emissions from Domestic Livestock (Gg) 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 Sub Module: Changes in Forest and Other Woody Biomass Stocks Worksheet: 5 - 1					Module: Land Use Change and Forestry Sub Module: Changes in Forest and Other Woody Biomass Stocks 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	Annual Growth Rate	Annual Biomass Increment	Carbon Fraction of Dry Matter	Total Carbon Uptake Increment	Commercial Harvest	Biomass Conversion Ratio	Total Biomass Removed in Commercial Harvest	Total Traditional Fuelwood Consumed	Total Other Wood Use	Total Biomass Consumption	Wood Removed From Forest Clearing	Total Biomass Consumption From Stocks
(kha)	(t dm/ha)	(kt dm)		(kt C)	(1000 m roundwood)	(t dm/m)	(kt dm)	(kt dm)	(kt dm)	(kt dm)	(kt dm)	(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 CO2 Annual Emission (-) or Removal (+) (Gg CO2)
0.45	769.64	1258.99	4616.29

Module: Land Use Change and Forestry Sub Module: Forest and Grassland Conversion Worksheet: 5 - 2 Sheet: 1 of 6					Module: Land Use Change and Forestry Sub Module: Forest and Grassland Conversion Worksheet: 5 - 2 Sheet: 2 of 6					
STEP 1					STEP 2					
A	B	C	D	E	F	G	H	I	J	K
Area Converted Annually	Biomass Before Conversion	Biomass After Conversion	Net Change in Biomass Density	Annual Loss of Biomass	Fraction of Biomass Burned on Site	Quantity of Biomass Burned on Site	Fraction of Biomass Oxidized on Site	Quantity of Biomass Oxidized on Site	Carbon Fraction of Above- ground Biomass (burned on site)	Quantity of Carbon Released (from biomass burned)
(kha)	(t dm/ha)	(t dm/ha)	(t dm/ha)	(kt dm)		(kt dm)		(kt dm)		(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)	Biomass Before Conversion	Biomass After Conversion	Net Change in Biomass Density	Average Annual Loss of Biomass	Fraction Left to Decay	Quantity of Biomass Left to Decay	Carbon Fraction in Above- ground Biomass	C Released from Decay of Above- ground Biomass (kt C)
(kha)	(t dm/ha)	(t dm/ha)	(t dm/ha)	(kt dm)		(kt dm)		
1.47	92.95	0	92.95	136.64	0.15	20.50	0.45	9.22

Module: Land Use Change and Forestry Sub Module: Forest and Grassland Conversion Worksheet: 5 - 2 Sheet: 5 of 6					Module: Land Use Change and Forestry Sub Module: Forest and Grassland Conversion Worksheet: 5 - 2 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 conversion (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	Nitrogen- Carbon Ratio	Total Nitrogen Released		Trace Gas Emissions Ratios	Trace Gas Emissions	Conversion Ratio	Trace Gas Emissions from Burning of Cleared Forests (Gg CH ₄ , CO)
(kt C)		(kt N)			(kt C)		
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 ₂ O, NO _x)
9.51	0.01	0.0951	N ₂ O	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 Sub Module: Abandonment of Managed Lands Worksheet: 5 - 4 Sheet: 1 of 3					Module: Land Use Change and Forestry Sub Module: Abandonment of Managed Lands Worksheet: 5 - 4 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 CO ₂)
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	$E=C \cdot D / 10^4$	$F=E \cdot 44 / 12$
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	$G=D \cdot E/100$	$H=D \cdot F/100$	$I=H-G$	$J=C \cdot I/10^4$	$K=J \cdot 16/12$	$K=B \cdot G/10^4$	$L=K \cdot 16/12$
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 Annual MSW Landfilled Gg	B Fraction DOC	C Annual DOC Landfilled Gg	D Faction Which Actually Degrades	E Annual Carbon Released as Biogas Gg C	F Fraction C-CH4 to C-Biogas	G Annual Carbon Released as CH4 Gg C	H Conver- sation Ratio (16/12)	I CH4 Released Gg CH4	J CH4 Recove- red Gg CH4	K Net CH4 Emissions Gg CH4
		C=(AxB)		E=(Cx D)		G=(Ex F)		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 Population (1000 persons)	B Wastewater BOD Value Gg BOD ₅ / 1000 per- -sons / year	C Annual BOD (Gg BOD ₅)	D Fraction Wastewater Anaerobically Treated	E Quantity of BOD from Anaerobically Treated Wastewater (Gg BOD ₅)	F Methane Emission Factor (Gg CH ₄ / Gg BOD ₅)	G Total CH ₄ Released (Gg CH ₄)	H Methane Recovered (Gg CH ₄)	I Net CH ₄ Emissions (Gg CH ₄)
		$C=(A \times B)$		$E=(C \times D)$		$G=(E \times F)$		$I=(G - H)$
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	B	C	D	E	F	G	H	I
		Annual Waste-water Outflow 10 ⁶ litres	BOD Concentration kg / litre	Total BOD Concentration Gg BOD	Fraction of Waste-water Treated Anaerobically	Quantity of BOD from Anaerobically Treated WW Gg BOD	CH ₄ Emission Factor Gg CH ₄ / Gg BOD ₅	Total CH ₄ Released Gg CH ₄	CH ₄ Recovered Gg CH ₄	Net CH ₄ Emissions 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								
	Dyeing	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 Apparent Consumpt. (PJ)	B						C=B/A					
		(Gg of full mass of pollutant)						(kg(pollutant)/GJ)					
		CO ₂	CH ₄	N ₂ O	NO _x	CO	NM VOC	CO ₂	CH ₄	N ₂ O	NO _x	CO	NM VOC
1 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
Blomass	9.995	1073.87	0.504	0.017	1.331	0.907	NA	107.441	0.050	0.002	0.133	0.091	NA
1 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
1 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
1 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
1 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
Blomass	3.998	429.55	0.060	0.017	0.132	0.796	NA	107.441	0.015	0.004	0.033	0.199	NA
1 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	0.048	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
Blomass	5.997	644.32	0.444	NA	1.199	0.111	NA	107.441	0.074	NA	0.200	0.019	NA

* Blomass is not included to the totals

Standard Data Table 1

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

[illegible]

Standard Data Table 1

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

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	METHANE EMISSIONS	EMISSION FACTOR
	A	B	C
	Production (Mt)	(million m ³)	(m ³ /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 (Qty. loaded on tankers)	132.535	0.1			0.755		
iv Refining/Storage (Qty. refined)	132.535	0.19			1.434		
v Distribution of Oil Products (Qty. consumed)							
vi Other							
I B 2 b Natural Gas							
i Production/Processing (Qty. produced)							
ii Transmission/Distribution (Qty. consumed)	51.129	23.4			458		
iii Other Leakage (Qty. consumed)							
I B 2 c Venting and Flaring							
i Oil (Qty. produced)	15	0.06			4		
ii Natural Gas (Qty. produced)							
iii Combined (Qty. produced)							

Standard Data Table 2

Industrial Processes

Source and Sink Categories Sector Specific Data (units)	Activity Data	Emission Estimates										Aggregate Emission Factors									
	A Production quantity (kt)	B Full Mass of Pollutant (Gg)										C=B/A Pollutant per tonne of product (kg / t)									
		CO ₂	CO	CH ₄	N ₂ O	NO _x	NM VOC	HFCs	PFCs	SF ₆	CO ₂	CO	CH ₄	N ₂ O	NO _x	NM VOC	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	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 Dairy	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	48.5	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	
Crop Type	A	B	C	D	E
	Amount of N applied in fertilizer and manure (t N)	Area Cultivated (th. ha)	(Gg N ₂ O)	tonnes N ₂ O-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
Title	Director
Organization	Institute of Ecology
Address	Kevade 2, Tallinn EE0001 Estonia
Phone	372-245-1634
Fax	372-245-3748
E-Mail	eco@eco.edu.ee

Standard Data Tables 5 Land Use Change and Forestry

5 A 1 Forest Clearing: CO2 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)	Quantity of Biomass Burned (on and off-site) (kt dm)	Quantity of CO2 Released (Gg CO2)	(Mg CO2/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			
		CH4	CO	N2O	NOx	CH4	CO	N2O	NOx
9.51	0.0951	0.0152	1.3307	0.0010	0.0378	0.0016	0.1399	0.0105	0.3975

5 A 3 Forest Clearing: CO₂ 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 CO₂ 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 CO₂ Removals

SINK CATEGORY	A	B
	Carbon Removals (Gg C)	CO ₂ Removals (Gg CO ₂)
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 (CO2 (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 Total MSW (kg per year)	B MSW Landfilled (Gg)	C CH ₄ Emissions (Gg)	D Emission Factor (kg CH ₄ /kg MSW landfilled) D=C/B	E Qty of CH ₄ recovered (kg CH ₄)
A Landfills		292.56	26.26	0.0898	

6 B Waste: Sewage Treatment

Source and Sink Categories	Activity Data		Emission Estimates	Aggregate Emission Factors	
Wastewater Type	A Quantity BOD In Wastewater (Gg)	B Quantity of CH ₄ Anaerobically Digested (kg CH ₄)	C CH ₄ Emissions (Gg)	D Emission Factor (kg CH ₄ / kg BOD) D=C/A	E Quantity of CH ₄ Recovered (kg CH ₄)
B Wastewater	28.6		0.629	0.022	
Municipal	691.302		15.21	0.022	
C Other					
Industrial					

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 ₂ O	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