RUSSIAN FEDERAL SERVICE FOR HYDROMETEOROLOGY
AND ENVIRONMENTAL MONITORING

RUSSIAN FEDERATION CLIMATE CHANGE COUNTRY STUDY

(COOPERATIVE AGREEMENT DE-FCO2-93PO10118)

FINAL REPORT

volume 1

Inventory of technogenic GHG emissions

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Introduction

In accordance with the Russian Federation Climate Change Country Study Workplan, Report on Task 1 includes the description of data collected and estimates of emissions of three direct and most important greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Emissions of indirect greenhouse gases: carbon monoxide (CO), oxides of nitrogen (NO_x) and non-methane volatile organic compounds are included if available from statistics or if can be estimated basing on national statistics data. According to the UN Framework Convention on Climate Change regulations, halogenated and other species controlled by the Montreal Protocol are not considered to avoid parallel reporting.

Using IPCC classification, technogenic emissions were calculated in the following sectors of GHG-related activities:

- ***Energy*** - emissions of all GHGs from energy activities (fuel combustion as well as fugitive fuel emissions);
- ***Industrial Processes*** - emissions from industrial processes where GHGs are by-product of the various production processes. Emissions exclude GHGs from the combustion of energy used during the production processes which are included in the energy sector;
- ***Waste*** - emissions from waste management, excluding GHGs from the combustion of energy used during the processes of waste management. Emissions from animal wastes (manure) are discussed in Volume 2 of the Report, together with emissions from ruminants.

Atmospheric formation of N_2O, not considered by the IPCC reporting instructions as emission source, is estimated in a separate chapter.

Emissions were estimated mainly on the base of 1990 activity data, only in some cases which are discussed in the corresponding sections of the Report 1991 or later data were used. The following sources of information were used: official statistical data, scientific publications and primary data of organizations taking part in the Study. Alternative or multi-variant estimates of emissions are included and discussed when possible.

The authors of Volume 1 represent seven organizations which participated in work on this task of the Study, including Ministries, State agencies, scientific and research organizations.

The Study was carried out under the guidance of the Federal Service of the Russian Federation for Hydrometeorology and Enviroment Monitoring (Roshydromet) and the U.S. Country Study Management Team. Roshydromet is responsible for coordination of national efforts in the field of climate change, including activity of special Interagency Commission of the Russian Federation on Climate Change Problems. The Commission keeps permanent contacts with all organizations of the Russian Federation connected with preparation of the National Communications and other obligations of the UN Framework Convention on Climate Change. Institute of Global Climate and Ecology under Roshydromet and Russian Academy of Science was responsible for the Study coordination and technical preparation of the Reports.

The U.S. Country Study Management Team provided Project with wide range of assistance including financial and methodological support, computer equipment and possibility to participate in international workshop and conferences.

1. State of Official Statistical Information Concerning the Inventory of Technogenic Emissions

The Russian Federation includes 89 subjects of the Federation: republics, lands, oblasts, autonomous districts, and federal cities, united (from economical, but not administrative viewpoint) in 11 economic regions.

These regions are (see Figure 1.1):

- Economic regions of European Russia:
  - ∗ North, (including Kaliningrad district), North-West, Central, Volga-Vyatka, Central-Chernozem (Central Black-Earth), Volga and North-Caucasus;
- Economic regions of Asian Russia:
  - ∗ West-Siberia, East-Siberia and Far East;
- Ural economic region situated both in Europe and Asia:

Traditionally, but not always, statistical and other data on the North-West region incorporate also data on Kaliningrad oblast, which is separated from the main territory of the Russian Federation by Lithuania. In other cases data on Kaliningrad oblast are listed separately.

Territories and population of economic regions are presented in Table 1.1.

Table 1.1

Territory and Population of Economic Regions

Region	Territory (10^3 sq. km)	Population (end of 1990) (10^3 persons)	
		Total	Urban
North	1466.3	6161	4746
North-West	211.5	9192	7909
Central	485.1	30478	25249
Volga-Vyatka	263.3	8480	5902
Central-Chernozem	167.7	7761	4747
Volga	536.4	16586	12225
North-Caucasus	355.1	17030	9823
Ural	824.0	20397	15310
West-Siberia	2427.2	15158	11090
East-Siberia	4122.8	9243	6652
Far East	6215.9	8057	6146
Total	**17075.4**	**148543**	**109799**

In accordance with existing legislation, all enterprises and institutions located over the territory of Russian Federation irrespective of their organization-legal forms and property types must compile and present state statistic accounts to local statistic bodies (departments and committees of Goskomstat of Russia). Release from the accounts allotment is prohibited.

Figure 1.1

Economic regions and fuel basins of Russian Federation

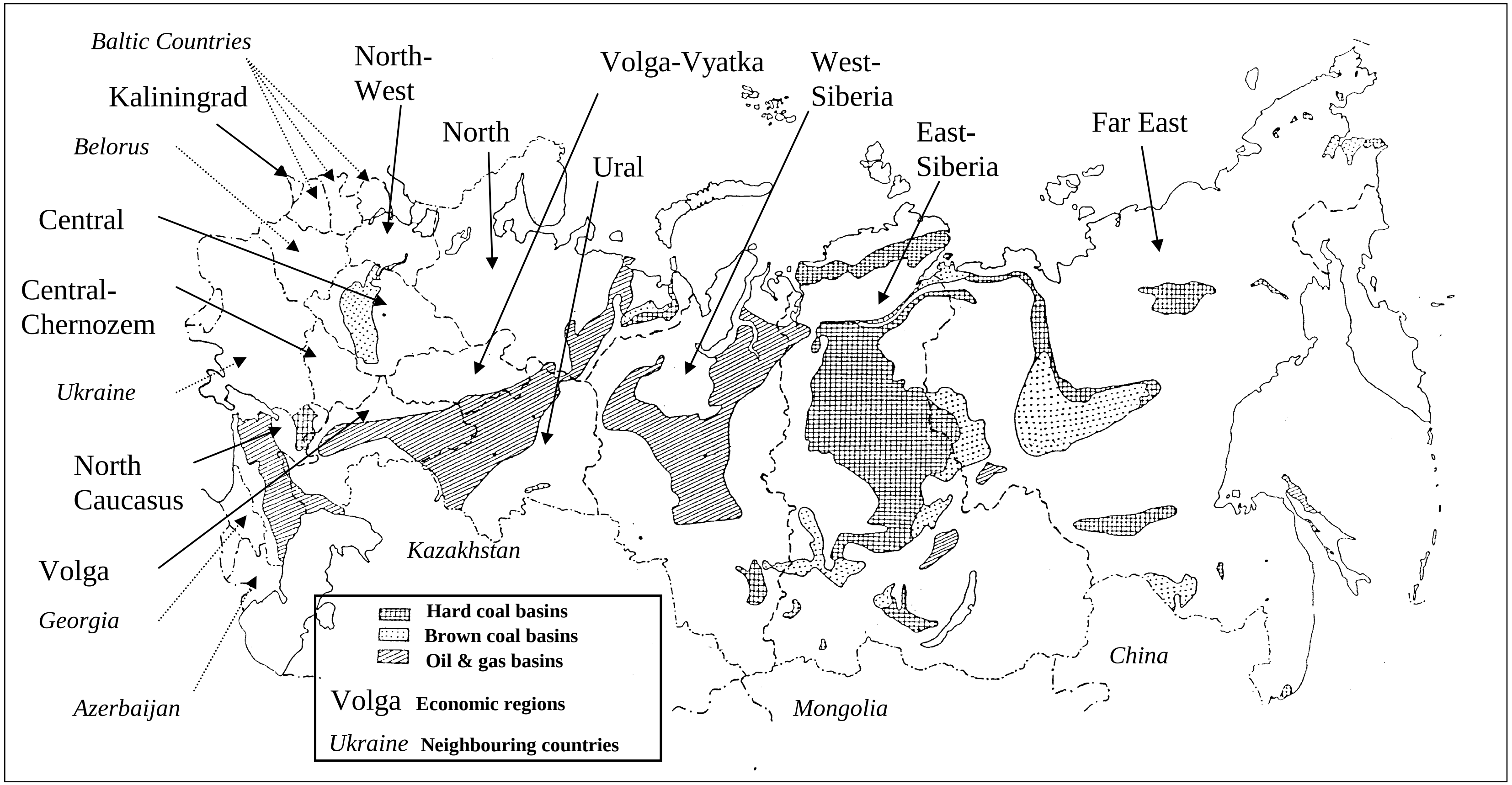
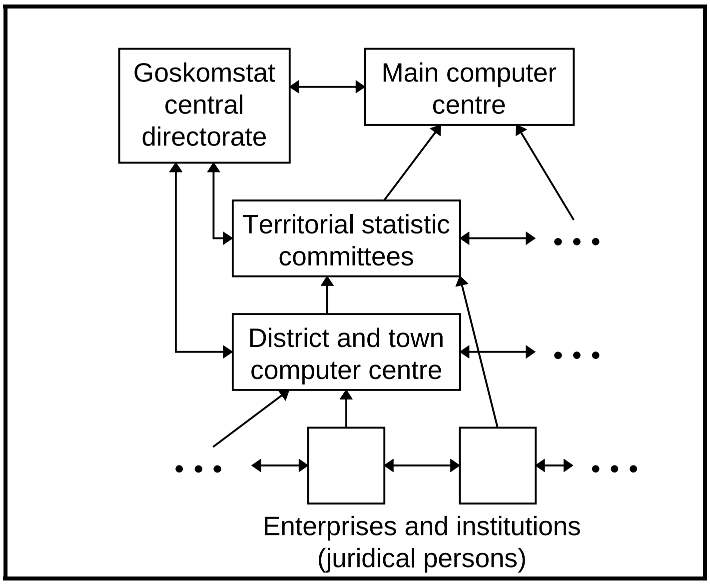


Diagram of obtaining and processing of statistic information is shown in Figure 1.2. In 1990 the sources of information were about 20 thousand enterprises and institutions. In 1993 their number was risen to 1.5 million, and at the end of 1994 it have reached 6 million.

Figure 1.2

Collection and Processing of Statistical Information in the Goskomstat RF System



Due to especial system of encoding of obtained data, the Main Computer Center provides information on the following directions:

- over the whole Russian Federation and its individual areas (republics included in Russian Federation, administrative territories, regions, districts, towns) - SOATO system;
- within departments (ministries, committees) - SOOGU system;
- within branches of national economy - OKONH system.

Central staff of Goskomstat of Russia works out methodology of obtaining and processing of information on all levels, containing indices of statistic accounts, approval of instructions, working out of the mathematical support of obtaining and processing of information - KEOI system.

Goskomstat of Russia disposes of the following information for 1990 concerning inventory of technogenic GHG emissions:

- On extraction, transportation and internal consumption of fuel and energy.
- On generation, use and storage of liquid and solid wastes.
- On emission of pollutants to the atmosphere from stationary sources (including emissions of indirect greenhouse gases: CO, NO_x, hydrocarbons; see Table 6.1).

  (For example, the total amounts of the most important pollutants emitted to the atmosphere from 38.4 thousand enterprises of Russia and the former USSR in 1990 are listed in Table 1.2)
- Statistical data concerning transport.

Distribution of information concerning estimation of the GHG emission is carried out by Departments of Industry, Ecology, Transport and Communications of the central staff of Goskomstat of Russia.

The State Program for changing the system of statistics and accounting to make it close to the accepted one in the market-economy countries was developed for the 1993-1995 period. One of the central problems of statistics is working out the State Cadastre of enterprises and institutions of all types of property and introducing into practice new All-Russian Classifier of types of economic activity, production and utilities, harmonized with international systems. Items necessary for the Inventory of GHG emissions are expedient to be taken into account when making this changes.

Statistic information on branches of national economy is also available from ministries. From the point of view of inventory of GHG emission, the most widely used were data providing by Ministry of Fuel and Power and by Ministry of Transport of Russian Federation (including information on the results of pilot investigations which are absent in Goskomstat of Russia).

2. Emissions From Energy Activities

2.1. Emission-Related Activities

2.1.1. General Data

Data collected are shown in Tables 2.1–2.5. According to the Russian national standard all quantitative data on primary and secondary fuels in these Tables are in 10^3 t of coal equivalent (c.e.). Net calorific value for coal equivalent is 7.0 Mcal/kg or 29.3 GJ/t.

Table 2.1 includes data on production, export, import, stock changes and using as international bunkers of primary and secondary fossil fuels and biomass fuels from Ministry of Fuel and Power of the Russian Federation, Table 2.2 includes the similar data obtained from State Committee of the Russian Federation for Statistics. Exports and imports are considered both to/from the Community of Independent States (CIS) countries and Baltic countries (being the republics of the former USSR in 1990), and for the “far” foreign countries.

Analyzing data from Tables 2.1–2.2 one must take into consideration the following peculiarities of Russian energy sector and statistical system:

Special collection of data on natural gas liquids is not provided by the Russian statistics. All data on natural gas liquids are included into the crude oil data.

Naphta and conformable to naphta by its properties secondary fuels produced in Russia are used as solvents rather than for combustion. Export, import and stock change are negligible and not reported by national statistics.

Import and export of lubricants outside the USSR in 1990 are considered negligible. There is no data available on trade or exchange of lubricants between Russia and other republics of the former USSR in 1990, and there is no reasons to suppose that exchange negligible.

Ethane is not accounted separately by the national statistics. Data are included into the total LPG statistics.

Other Oil line in Table 2.1 includes:

- fractions of oil distilled at the place of oil production
- fuel oil
- naval oil
- household fuel oil
- motor fuel oil for low-speed diesel engines
- other liquid secondary fuels

Export, import and stock change data on the anthracite and coking coal in Table 2.2 includes also the lignite.

Fuelwood is the only type of traditional biomass fuels used in Russia.

Table 2.1

Elements of 1990 Fossil Fuel Balance of Russia Obtained from Ministry of Fuel and Power of the Russian Federation

			Production	Imports	Exports	Internat Bunkers[1)]	Stock Change
Liquid Fossil	Primary Fuels	Crude Oil	738343	70315	264343		-3987
		Natural Gas Liquids					
	Secondary Fuels	Gasoline		1839	13956	NA	-2116
		Jet Kerosene		0	0	NA	NA
		Other Kerosene		79	1909	NA	- 45
		Gas/Diesel Oil		1418	28651	NA	- 245
		Residual Fuel Oil		NA	NA	NA	
		LPG		921	3913		-1749
		Ethane					
		Naphta		NA	NA		NA
		Bitumen		42	645		+ 7
		Lubricants		NA	NA	NA	NA
		Petroleum Coke		280	113		+ 63
		Refinery Feedstocks					
		Other Oil		3668	41390		- 808
Liquid Fossil Totals			738343	78562	354920	NA	-8880
Solid Fossil	Primary fuels	Anthracite	107022	3727	25024		-2197
		Coking Coal	65115	7136	22800		- 579
		Other bit. Coal				NA	
		Sub-bit. Coal	24560	139	3175	NA	- 375
		Lignite	64698		5328		- 93
		Peat	1851		152		- 370
	Secondary fuels	BKB & Patent Fuel					
		Coke					
Solid Fossil Totals			263246	11002	56479	NA	-3614
Gaseous Fossil		Natural gas (dry)	737488	106159	250414		+5889
Total			1739077	195723	605334	—	-6605
Biomass Total			NA	NA	NA		NA
		Solid biomass (Fuelwood)	NA	NA	NA		NA
		Liquid biomass	NA	NA	NA		NA
		Gas biomass	NA	NA	NA		NA

1) - for complete data on international bunkers please see section 2.1.4. 2) NA-data not available

Table 2.2

Elements of 1990 Fossil Fuel Balance of Russia Obtained from State Committee of the Russian Federation for Statistics

			Production	Imports	Exports	Internat.Bunkers[1)]	Stock Change
Liquid Fossil	Primary Fuels	Crude Oil	738297	70315	264343		-3987
		Natural Gas Liquids					
	Secondary Fuels	Gasoline		1839	13956	NA	-2116
		Jet Kerosene				1400	NA
		Other Kerosene		79	1909	NA	- 45
		Gas/Diesel Oil		1418	28651	NA	- 245
		Residual Fuel Oil		2441	33870	NA	+ 468
		LPG		921	3913		-1749
		Ethane					
		Naphta		NA	NA		NA
		Bitumen		42	645		+ 7
		Lubricants		NA	NA	NA	NA
		Petroleum Coke		280	113		+ 63
		Refinery Feedstocks		NA	NA		NA
		Naval Oil		159	4741	NA	- 175
		Other Oil		NA	NA		NA
Liquid Fossil Totals			738297				
Solid Fossil	Primary fuels	Anthracite	118640	32543	48633		-3174
		Coking Coal	84955				
		Other bit. Coal	NA	NA	NA	NA	NA
		Sub-bit. Coal	NA	NA	NA	NA	NA
		Lignite	62206	NA	NA		NA
		Peat	1724	1	0		- 370
	Secondary fuels	BKB & Patent Fuel		49	320		- 74
		Coke		3698	2591		- 204
Solid Fossil Totals							
Gaseous Fossil		Natural gas (dry)	736651	106159	250414		+5889
Total							
Biomass Total			18986	0	178		- 541
		Solid biomass (Fuelwood)	18986	0	178		- 541
		Liquid biomass	NA	NA	NA		NA
		Gas biomass	NA	NA	NA		NA

1) - for complete data on international bunkers please see section 2.1.4. 2) NA-data not available

Table 2.3

Conversion factors, carbon emission factors and fractions of carbon oxidized

			Conversion Factor (TJ/Unit)	Carbon Emission Factor (t C/TJ)	Fraction of Carbon Oxidized
Fuel Types					
Liquid Fossil	Primary Fuels	Crude Oil	$29.3*10^3$	20.0	0.99
		Natural Gas Liquids		17.2	0.99
	Secondary Fuels	Gasoline		18.9	0.99
		Jet Kerosene		19.5	0.99
		Other Kerosene		19.6	0.99
		Gas/Diesel Oil		20.2	0.99
		Residual Fuel Oil		21.1	0.99
		LPG		17.2	0.99
		Ethane		16.8	0.99
		Naphta		(20.0)	0.99
		Bitumen		22.0	0.99
		Lubricants		(20.0)	0.99
		Petroleum Coke		27.5	0.99
		Refinery Feedstocks		(20.0)	0.99
		Other Oil		(20.0)	0.99
Liquid Fossil Totals			$29.3*10^3$		
Solid Fossil	Primary fuels	Anthracite	$29.3*10^3$	26.8	0.85
		Coking Coal		25.8	0.96
		Other bit. Coal		25.8	
		Sub-bit. Coal		26.2	0.97
		Lignite		27.6	0.98
		Peat		28.9	0.98
	Secondary fuels	BKB & Patent Fuel		(25.8)	
		Coke		29.5	
Solid Fossil Totals			$29.3*10^3$		
Gaseous Fossil		Natural gas (dry)	$29.3*10^3$	15.3	0.995
Total			$29.3*10^3$		
Biomass Total			$29.3*10^3$		
		Solid biomass (Fuelwood)	$29.3*10^3$	29.9	
		Liquid biomass		(20.0)	
		Gas biomass		(30.6)	

Official data included in Tables 2.1 and 2.2 possibly not account for local fuelwood production by individuals and small enterprises. Alternative way to calculating fuelwood production is throughan independent estimate consumption by population, based on:

- data on population number using wood fuel for heating and other purposes (about 20 per cent of the RF population);
- data on mean wood fuel consumption per capita of this category of population.

According to this estimate, the total consumption of wood fuel by Russian population is within the range of 80-120 Mm^3 per year. Since 1 m^3 of wood (for tree species typical for Russia) corresponds to 0.5 metric ton of dry biomass, multiplying fuel consumption (in m^3) by this value and then dividing by $\hat{E}_q$, one can obtain wood consumption in coal equivalent units. ($\hat{E}_q = 7000/4750$ is a ratio between coal equivalent and low calorific value of wood fuel, i.e., it is factor to recalculate coal equivalent to wood mass).

Fuelwood consumption estimate resulting from this approach is 27.1-40.7 Mt.c.e.

On the whole, most data in Tables 2.1 and 2.2 are in a full or close agreement. Distinctions concern primarily the degree of detalization of secondary liquid fuels and primary solid fuels. The latter being the result of a difference between Russian national system of coal classification and that used by the IPCC.

Conversion factors, carbon emission factors and fractions of carbon oxidized for different fuels including specific for Russia fractions

of carbon oxidized for coking coal, anthracite, sub-bit coal, lignite and peat obtained from experimental data and reports of power stations (references to be included into next Progress reports) are shown in Table 2.3.

Table 2.4

Data for Estimation Carbon Stored in Products (Ministry of Fuel and Power data)

		Estimated fuel Quantities	Conversion Factor (TJ/Unit)	Carbon Emission Factor (t C/TJ)	Fraction of Carbon Stored
Fuel Types					
Naphta		NA	$29.3*10^3$	(20.0)	0.80
Lubricants		6465.1		(20.0)	0.50
Bitumen		4792.0		22.0	1.00
Coal Oils and Tars (from Coking Coal)				25.8	0.75
Natural Gas		82554.0		15.3	0.33
Gas/Diesel Oil		460.0		20.2	0.50
LPG		4373.0		17.2	0.80
Other Fuels	Oil distilled at the place of production	764.0		17.2	0.80
	Petroleum Coke	947.0		22.0	1.00

Table 2.4 based on the Ministry of Fuel and Power data and Table 2.5 using State Committee for Statistics data include necessary information for estimating carbon stored in products. The disagreement in data on a bitumen is probably due

to the better completeness of the State Committee for Statistics data, collected in all branches of national economy, not only in fuel & energy sectors. Other data are in a good agreement or intercomplementary.

Table 2.5

Data for Estimation Carbon Stored in Products (State Committee for Statistics data)

Fuel Types	Estimated fuel Quantities	Conversion Factor (TJ/Unit)	Carbon Emission Factor (t C/TJ)	Fraction of Carbon Stored
Naphta	12437	$29.3*10^3$	(20.0)	0.80
Lubricants	6462		(20.0)	0.50
Bitumen	15266		22.0	1.00
Coal Oils and Tars (from Coking Coal)	NA		25.8	0.75
Natural Gas	86444		15.3	0.33
Gas/Diesel Oil	NA		20.2	0.50
LPG	NA		17.2	0.80
Other Fuels	NA			

2.1.2. Mobile Combustion

Data on a number of fleet of road vehicles in Russian Federation in 1990 are presented in Tables 2.6–2.7. The number of the fleet by types of motor vehicles is given in accordance with data of the State Automobile Inspection under the Ministry of Internal Affairs of Russia. Statistical reports on the total number of registered motor vehicles are compiled by the organs of the State Automobile Inspection under the Ministry of Internal Affairs of Russia.

Besides, a certain portion of the motor vehicle fleet is registered by the organs of Military Automobile Inspection under the Russian Federation Ministry of Defense, Customs Committee (automobiles imported by foreign citizens for the use on the Russian territory for a period up to one year) and Roskommash (off-road vehicles, wheel tractors, etc).

Table 2.6

Road transport fleet by year, (10^3 units)

	Years		
	1990	1991	1992
Passenger Cars	8959	9127	9880
Buses	432	501	517
Trucks and heavy-duty Vehicles	3623	3380	3506
Motorcycles	10111	10110	9230

The same is the situation with some number of ships, river boats and aircraft (military, sports, etc.). Data on these mobile sources was not available in the direct form and not included in the following tables.

Table 2.7

Road transport fleet, 1993 data, (10^3 units)

Type	Number by fuel type							
	Gaso-line	Dies. Oil	Gas	Other	Total	Aver Age (yr)	Average Fuel Consumpt. (liter/100 km)[1)]	Average Activity (10^3 km/yr)[1)]
Passenger Cars	11719	60	2.7	0	11782	6	7.8	7.3
Urban and Highway Buses	445	145	8.0	0	598	10	32.0	50.0
Light Trucks (<3.5 t)	951	4	5.0	0	960	8	18.0	108.0
Heavy-Duty Vehicles (>3.5 t)	1859	1176	90.0	0	3125	8	30.0	36.0
Motor-cycles	10726			0	10726	NA	NA	NA

1) - Expert estimate
NA - data not available

Division of the fleet of road vehicles into the groups in respect to fuel used (1993 data) was carried out in accordance with estimates made by experts from All-Russian Scientific and Research Institute of Complex Fuel and Energetic Problems under the Ministry of Fuel and Energetic. The mean age of the fleet and the mean fuel consumption were calculated based of data of selective investigations and estimates of experts from the State Scientific and Research Institute of Automobile Transport under the Ministry of Transport of the Russian Federation, Moscow Auto-Road Institute, the State Automobile Inspection, and All-Russian Scientific and Research Institute of Complex Fuel and Energetic Problems.

Presently exhaust control systems for road vehicles are not used in the Russian Federation because of the wide use of leaded gasoline.

Published data on number of locomotives in Russia in early 1993 are presented in Table 2.8.

Diesel locomotives are 35% of the cargo-carrying engines fleet, 38% of the passenger engines fleet, and 78% of the shunting engines ones. Other locomotives are electric-powered.

In early 1993 the total number of river boats fleet (based on data of the Department of River Transport under the Ministry of Transport of the Russian Federation) was equal to 8.5 thousand (see Table 2.9).

Table 2.8

Locomotives, (10^3 units)

	Cargo-carrying Engines[1)]	Passenger Engines	Shunting Engines
Number	4.6	1.2	5.8

1) - Not includes “industrial” locmotives in the possession of industrial enterprises used for local transportation only.

Table 2.9

River Boat Fleet (10^3 units)

	Passenger Vessels& Passenger-Cargo Ships	Tankers	Dry-Cargo Ships	Cargo Ships & Others
Number	1.5	0.65	2.05	4.30

In 1993 28 passenger vessels and more than 400 cargo ships formed the marine transport of Russia.

The number of flying stock of the civil aviation of the CIS countries was equal to 3240 units in 1993, the share of Russia makes about 65%.

Data on fuel consumption (1990 year) by different types of transport are presented in Table 2.10.

Table 2.10

Fuel Consumption by Transport

Type	Fuel Consumption (10^3t)
Passenger Cars	3797
Urban and Road Buses	6037
Light Trucks	9583
Heavy-Duty Vehicles	27177
Road Transport Totals	46594
Passenger Locomotives	574
Cargo Locomotives	5270
“Industrial” Cargo Locomotives[1)]	90
Railway Transport Totals	5934
Internal River Transport	1907
Marine Transport	998
Civil Aviation	16528
Transport Totals	**71961**

1) - Expert estimates

Table 2.11 shows data on consumption of different types of fuel by passenger cars and other automobiles.

Table 2.11

Fuel Consumption by Cars and Vehicles

Fuel Types		Fuel Consumption (10^3t)	
		Passenger Cars	Other vehicles
Gasoline	Leaded	2998	20896
	Non-Leaded	749	3757
Diesel Oil		43	17819
LPG & High-Pressure Natural Gas		7	325
Other Fuels		0	0
Fuel Totals		**3797**	**42797**

2.1.3. Bunker Fuels

The Russian maritime transport in 1990 have used 95% of internally consumpted motor fuel and 90% of naval oil.

The share of maritime transport in total freight turnover is 12-13%. About 90% of Russian maritime transport freight turnover falls on foreign navigation (exports, imports, cargo transportation for foreign freighters).

The freight volumes and turnover from Russian ports to Russian ports, from/to Russian ports to/from foreign ports and also between foreign ports are shown at the Table 2.12 The share of Russia in the world freight sea shipping is shown at the Table 2.13. Data on fuel consumption by marine for internal and international transportation on condition that refueling will be provided on the Russian territory are shown in Tables 2.14-2.15.

Table 2.12

Freight Volume and Turnover by Marine Transport

Kind of sea shipping		Year		
		1989	1990	1991
Cabotage	(kt)	51955.6	46619.3	16993.2
	(mln.t-miles)	33183.2	30099.2	17020.9
Foreign Trade	Export (kt)	86194.5	77350.2	19307.1
	Import (kt)	41472.7	33657.8	3269.4
	Between Foreign Ports (kt)	6783.5	4385.6	167.9
Foreign Trade Totals (kt)		134450.7	115393.6	33703.8
Foreign Charters	(kt)	41568.6	50430.8	42372.6
Foreign Navigation Totals	(kt)	176019.3	165824.4	70717.1
	(mln. ton-miles)	496495.9	478008.1	194256.5

Cabotage - sea shipping from Russian ports to Russian port;
Foreign navigation - sea shipping from/to Russian ports, to/from foreign ports, between foreign ports, by foreign freighters (including CIS countries)
Source: Goscomstat RF, operational reports of the Maritime Transport Department, archives of the Ministry of Marine of the Soviet Union;

Table 2.13

Share of Russia in the World Freight Sea Shipping in 1992, %

Transport type	Country				
	Russia	US	Great Britain	Germany	Japan
Marine and "Sea-River" Water Transport	21.1	12.2	3.3	6.6	19.4

Table 2.14

Fuel Consumption by Russian Ships in International Navigation with Bunkering in Russian Ports (kt)

Fuel Type	Year		
	1989	1990	1991

Diesel oil	620	600	550
Motor fuel and naval oil	1250	1170	1065
Fuel Oil	1250	1220	1115
Total	**3120**	**2990**	**2730**

Table 2.15

Fuel Consumption by Foreign Ships with Bunkering in Russian Ports (kt)

Fuel Type	Year		
	1989	1990	1991
Diesel oil	40	35	30
Motor fuel and naval oil	35	30	20
Fuel Oil	30	25	20
Total	**105**	**90**	**70**

Summing up 1990 data from Tables 2.14 and 2.15 and recalulating it to coal equivalent results in the following estimates of marine bunker fuel consumption:

- diesel oil - 939 kt.c.e.;
- residual fuel oil (sum of motor fuel, naval oil and fuel oil) - 3354 kt.c.e.

Fuel use by international bunkering of aircraft (jet kerosene only was used in 1990) was approximately estimated by Goscomstat at 1400 kt.c.e. (24.0 PJ) level.

2.2. Estimates of Emission

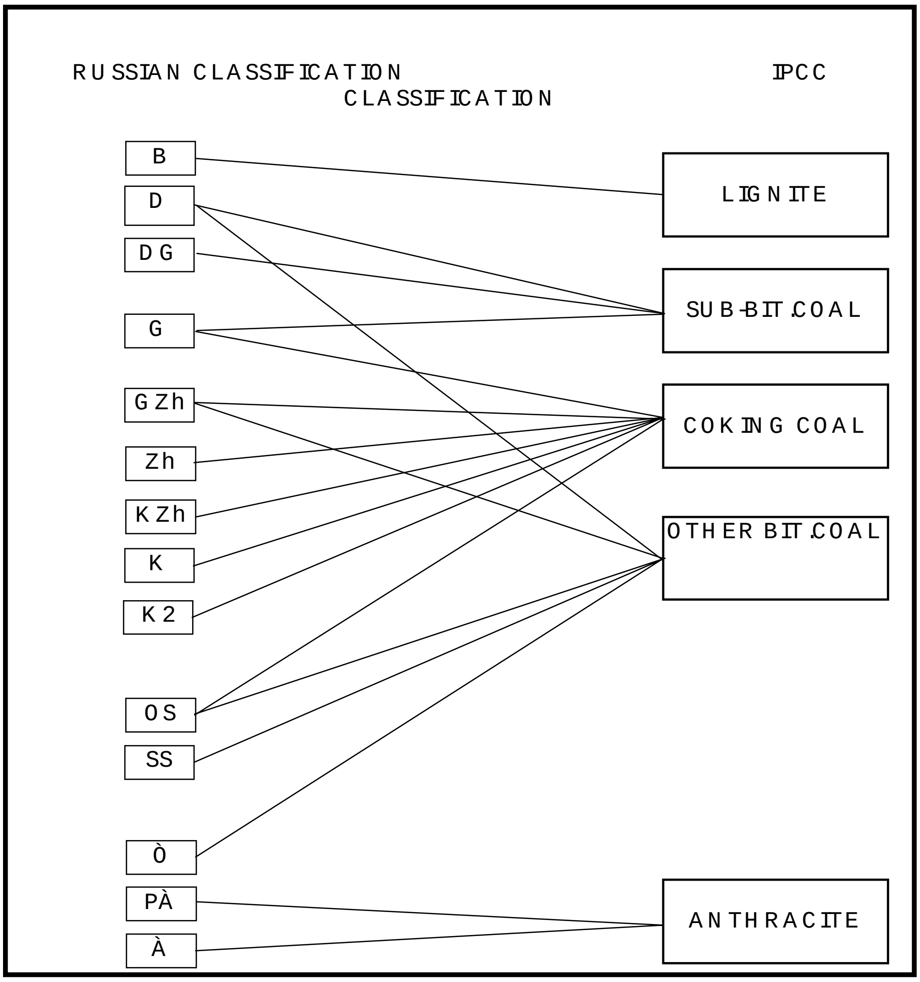
2.2.1. CO_2 Emissions from Energy

Data on fossil fuel adopted for calculation of emission (based on the Section 2.1.1 primary data) are listed in Table 2.16. These data are presented in units 10^3 t of coal equivalent (c.e.).

To calculating emissions from coal, classes of coal adopted in Russia and those presented in IPCC (1995) were cross referenced (Figure 2.1). The IPCC classifies coals as lignite, sub-bituminous coal, coking coal, bituminous coal, and anthracite.

Figure 2.1

Reduction Russian Coal Classification to the IPCC-Used Classification



In Russian statistical publications coal is divided either into two classes (power-generating coal, and coking one), or into three classes (brown coal, black coal, anthracite), or into 10-14 classes depending on the coal basin. In practice, each basin in Russia use its own industrial classification. The coal of the same class from different basins can differ in its composition and properties, e.g., in its coking properties.

These individual classifications include the following classes: brown coal (B1 B2 B3 differing in its moisture), long-flame (D), long-flame gas one (DG), gas coal (G), gas-fat coal (GZh), ñoking coal (K), coking-fat one (KZh), coking 2 (K2), fat coal (Zh), lean-ñoking coal (SchS/OS), badly coking one (SS), lean coal (T), half-anthracite (TA, or PA) and anthracite (A).

The basis of IPCC (1995) classification is the USA classification (ASTM D388-64) with the addition of “coking coal”, i.e. the coal used for coke production. Only two parameters of this classification coincide with those of Russian industrial classification (the yield of volatile material, and the coking ability). So, to compare the classifications, additional data characterizing the calorific value of different coal ranks are used. They are available from reference books on coal usage for power generation.

The CO_2 emissions from fossil fuel are calculated using carbon emission factors (Table 2.17) and carbon stored (Table 2.18), and results are presented in Table 2.19. It was concluded the total emission is equal to 2.40 Gt of CO_2. Emission from liquid fossil combustion is 0.87 Gt, emission from solid fossil combustion - 0.62 Gt, from natural gas combustion - 0.91 Gt.

The next step, however not considered by the IPCC methodology, was to exclude carbon stored by fuel leaks and other losses. This losses are estimated (data was taken mainly from *Energy.., 1995*) as following:

- primary liquid fuels - 20.3 Mtc.e.;
- no data available for secondary liquid fuels;
- solid fuels - 17.1 Mtc.e.;
- natural gas - 29.9 Mtc.e.

Treating this fuels in the same manner, as when estimating carbon stored in products, results in:

- 9.52 MtC stored by losses of liquid fuel (fraction of carbon stored applied was 0.8 to allow for entional and occasional burning some fraction of leaking in accidents oil);
- 13.3 MtC stored by losses of solid fuel (fraction of carbon stored 1.0);
- 13.4 MtC from natural gas escaped to the atmosphere by leakages (and considered as fugitive emission of CH_4).

Resulting estimate of CO_2 emission is 617 MtC (228 MtC from liquid fuel, 153 MtC from solid, 236 MtC from natural gas). More 2.5 MtC must be added to the emission from solid fuel as a result of coal dumps burning, and 0.5 MtC as a result of release of CO_2 from underground coal mines (*Djunko et al., 1996*). Release of CO_2 from non-coal mines is expected to be negligible. At last, adding 4.9 MtC of emission from partial flaring of natural gas accompanying oil production (approximately 11.4 Mtc.e. of accompanying gas was flared in 1990), final estimate of CO_2 emission - 625 MtC can be obtained.

Thus, according to our estimation, CO_2 emission from fossil fuel combustion in Russia in 1990 was equal to about 8.2 per cent it's global anthropogenic emission (*IPCC, 1995)*, while, e.g., the population of Russia was only about 2.8 per cent of the world population in 1990.

- Uncertainty of this estimates can be described as moderate because of two main factors which has influenced accuracy of calculating the apparent consumption of fuels, namely: incomplete data on exports/imports of fuels from Russia to other republics of the former USSR in 1990, especially on secondary liquid fuels;

Table 2.16

The 1990 Balance of Fossil Fuels in Russia in 10^3 t of coal equivalent

			Production	Imports	Exports	Internat Bunkers	Stock Change	Apparent Consumption
Liquid Fossil	Primary Fuels	Crude Oil	738343	70315	264343		-3987	548302
		Natural Gas Liquids						
	Secondary Fuels	Gasoline		1839	13956	0	-2116	-10001
		Jet Kerosene		NA	NA	1400	NA	-1400
		Other Kerosene		79	1909	0	-45	-1785
		Gas/Diesel Oil		1418	28651	939	-245	-27927
		Residual Fuel Oil		2600	38611	3354	293	-39658
		LPG		921	3913		-1749	-1243
		Ethane						
		Naphta		0	0		0	0
		Bitumen		42	645		7	-610
		Lubricants		NA	NA		NA	NA
		Petroleum Coke		280	113		63	104
		Refinery Feedstocks		0	0		0	0
		Other Oil		0	0		0	0
Liquid Fossil Totals			738343	77494	352141	4480	-7779	466995
Solid Fossil	Primary fuels	Anthracite	20593	7471	11334		340	16390
		Coking Coal	81172	32379	68852		-502	45201
		Other bit. Coal	72432	64404	66360		-2873	73349
		Sub-bit. Coal	28741	15744	17870		-346	26961
		Lignite	66670	17120	21624		1322	60844
		Peat	1552	211	98		-323	1988
	Secondary fuels	BKB & Patent Fuel		49	320		-74	-197
		Coke		3698	2591		-204	1311
Solid Fossil Totals			271160	141076	189049	0	-2660	225847
Gaseous Fossil		Natural gas (dry)	737488	106159	250414		5889	587344
Total			**1746991**	**324729**	**791604**	**4480**	**-4550**	**1280186**

NA-data not available

Table 2.17

Estimation of Carbon Content in Fuels

			Conversion Factor (TJ/kt.e.f.)	Apparent Consumption (TJ)	Carbon Emis.Factor (tC/TJ)	Carbon Content (tC)	Carbon Content (TgC)
Liquid Fossil	Primary Fuels	Crude Oil	29.3	16065248.6	20.0	321304972.0	321.3
		Natural Gas Liquids					
	Secondary Fuels	Gasoline	29.3	-293029.3	18.9	-5538253.8	-5.5
		Jet Kerosene	29.3	-41020	19.5	-799890.0	-0.8
		Other Kerosene	29.3	-52300.5	19.6	-1025089.8	-1.0
		Gas/Diesel Oil	29.3	-809353.9	20.2	-16348948.8	-16.3
		Residual Fuel Oil	29.3	-1135345.7	21.1	-23955794.3	-24.0
		LPG	29.3	-36419.9	17.2	-626422.3	-0.6
		Ethane	29.3	0	16.8	0	0.0
		Naphta	29.3	0	20.0	0	0.0
		Bitumen	29.3	-17873	22.0	-393206.0	-0.4
		Lubricants	29.3	0	20.0	0	0.0
		Petroleum Coke	29.3	3047.2	27.5	83798.0	0.1
		Refinery Feedstocks	29.3	0	20.0	0	0.0
		Other Oil	29.3	0	20.2	0	0.0
Liquid Fossil Totals				13682953.5		272701165.1	272.7
Solid fossil	Primary fuels	Anthracite	29.3	480227	26.8	12870083.6	12.9
		Coking Coal	29.3	1324389.3	25.8	34169243.94	34.2
		Other bit. Coal	29.3	2149125.7	25.8	55447443.06	55.4
		Sub-bit. Coal	29.3	789957.3	26.2	20696881.3	20.7
		Lignite	29.3	1782729.2	27.6	49203325.9	49.2
		Peat	29.3	58248.4	28.9	1683378.8	1.7
	Secondary fuels	BKB & Patent Fuel	29.3	-5772.1	25.8	-148920.2	-0.1
		Coke	29.3	38412.3	29.5	1133162.9	1.1
Solid Fossil Totals				6617317.1		175054599.2	175.1
Gaseous Fossil		Natural gas (dry)	29.3	17209179.2	15.3	263300441.8	263.3
Total				**37509449.8**		**711056206.1**	**711.1**

Table 2.18

Amount of Carbon Stored

Fuel Type		Estimated fuel Quantities (kt.e.f.)	Conversion Factor (TJ/kt.e.f)	Estimated Fuel Quantities (TJ)	Carbon Emission Factor (t C/TJ)	Carbon Content (tC)	Carbon Content (TgC)	Fraction of Carbon Stored	Carbon Stored (Tg C)
Crude Oil Natural Gas Liquids		28833	29.3	844806.9	20.0	16,896,138.0	16.90	0.75	12.67
Naphta		12437	29.3	364404.1	20.0	7,288,082.0	7.29	0.80	5.83
Lubricants		6465	29.3	189424.5	20.0	3,788,490.0	3.79	0.50	1.89
Bitumen		15266	29.3	447293.8	22.0	9,840,463.6	9.84	1.00	9.84
Natural Gas		86444	29.3	2532809.2	15.3	38,751,980.8	38.75	0.33	12.79
Gas/Diesel Oil		460	29.3	13478.0	20.2	272,255.6	0.27	0.50	0.14
LPG		4373	29.3	128128.9	17.2	2,203,817.1	2.20	0.80	1.76
Other Fuels	Oil, distilled at the place of production	764	29.3	22385.2	17.2	385,025.4	0.39	0.80	0.31
	Petroleum Coke	947	29.3	27747.1	22.0	610,436.2	0.61	1.00	0.61
Total		**127156**		**3725671**		**63140550.7**	**63.14**		**45.84**

Table 2.19

The 1990 CO_2 Emissions From Fossil Fuel in the Russian Federation

			Carbon Stored (Tg C)	Net Carbon Emissions (Tg C)	Fraction of Carbon Oxidised	Actual Carbon Emissions (Tg C)	Actual Emissions (Tg C)
Liquid Fossil	Primary Fuels	Crude Oil	12.7	308.6	0.99	305.5	1,120.3
		Natural Gas Liquids					
	Secondary Fuels	Gasoline	0	-5.5	0.99	-5.5	-20.1
		Jet Kerosene	0	-0.8	0.99	0.8	2.9
		Other Kerosene	0	-1.0	0.99	1.0	3.7
		Gas/Diesel Oil	0.1	-16.5	0.99	-16.3	-59.8
		Residual Fuel Oil	0	-24.0	0.99	-23.7	-87.0
		LPG	1.8	-2.4	0.99	-2.4	-8.7
		Ethane					
		Naphta	5.8	-5.8	0.99	-5.8	-21.2
		Bitumen	9.8	-10.2	0.99	-10.1	37.1
		Lubricants	1.9	-1.9	0.99	-0.5	-1.9
		Petroleum Coke	0.6	-0.5	0.99	-0.5	1.9
		Refinery Feedstocks	0	0.0	0.99	0.0	0.0
		Other Oil	0.3	-0.3	0.99	-0.3	-1.1
Liquid Fossil Totals			*33.1*	239.6		237.2	869.9
Solid fossil	Primary fuels	Anthracite	0	12.9	0.92	11.8	43.4
		Coking Coal	0	34.2	0.99	33.8	124.0
		Other bit. Coal	0	55.4	0.95	52.7	193.1
		Sub-bit. Coal	0	20.7	0.95	19.7	72.1
		Lignite	0	49.2	0.96	47.2	173.2
		Peat	0	1.7	0.97	1.6	6.0
	Secondary fuels	BKB & Patent Fuel	0	-0.1	0.98	-0.15	-0.5
		Coke	0	1.1	0.98	1.1	4.1
Solid Fossil Totals			*0*	175.1		167.8	615.4
Gaseous Fossil		Natural gas (dry)	12.8	250.8	0.995	249.3	914.0
Total			**45.8**	**665.2**		**654.3**	**2,399.3**

- it is not clear, because of lack of data, if Russian-produced fuels consumed by military forces of the former Soviet Union, deployed abroad in 1990, was completely or partially included in the fuel consumption data used in this Study. It can be noted, however, that the whole problem of possible including emissions from Soviet military activities abroad is far beyond the scope of the Study.

The obtained results allows to calculate an important value - empirical carbon dioxide emission factor per GJ of apparent fuel consumption. For apparent consumption of liquid fuel this factor is 0.49 tC/tc.e., for this of solid fuel - 0.69 tC/tc.e, for natural gas - 0.41 tC/tc.e. Using these factors may help in preliminary estimations of CO_2 emissions in for the next years. Strictly speaking, the factors obtained in such a way, do not take into account carbon stored because it is included in the apparent consumption. However, this error appears to be relatively small because the amount of carbon stored in Russia is less than 5 per cent of the total carbon fraction of liquid, solid and gaseous fossil fuels in emissions.

Treating bunker fuels consumed (see Section 2.1.3) in the same manner as other fossil fuels (Tables 2.16-2.19) results in the following approximate estimates of CO_2 emissions from bunker fuels in 1990:

- maritime liquid fuels - 2.7 MtC, including 0.6 MtC from diesel oil and 2.1 MtC from residual fuel oil;
- aircraft liquid fuel (jet kerosene) - 0.8 MtC.

According to the IPCC methodology, bunker fuels were excluded from internal fuels consumption when calculating total CO_2 emission (see Table 2.16).

2.2.2. Fugitive Emissions from Coal Mining and Handling Activities

Data on CH_4 fugitive emissions from solid fuel-related activities are presented in Table 2.20. The calculation was carried out for each coal rank and when was summed up for all coals mined in the considered economic region (separately for underground and surface mining). Emissions from peat and shales were also taken into consideration and the steam coals were divided into two ranks - other bituminious and anthracite i.e. ranks of coals were reduced to IPCC-used classification.

Comparing the composition and properties of coals produced in each economic region with indexes of Russian and U.S. classifications we have obtained the following values of CH_4 production (cub. meters CH_4 per 1 t of dry ash-free coal produced):

- Underground production: lignite (shale) - 4; sub. bit. coal - 10; coking coal - 22; other bit. coal - 28; anthracite - 32;
- Surface production: pet - 3; lignite (shale) - 1; sub. bit. coal - 2; coking coal - 6.5; other bit. coal - 7.0.

The emission coefficients for post-mining activities were taken from IPCC Manual.

Table 2.20

CH_4 Emissions from Coal Mining and Handling Activities in Economic Regions of Russian Federation

Source		Amount of Coal Produced (Mt)	Emission Factor (m^3 CH_4/t)	Methane Emission (Mm^3)	Convers. Factors ($GgCH_4/Mm^3$)	Methane Emission (Gg CH_4)
North						
Underground	Mining	22.857	21.0	480	0.67	321.6
Mines	Post-Mining	22.857	4.0	91.4		61.2
Surface Mines	Mining	0	0	0		0
	Post-Mining	0	0	0		0
Total						**382.8**
North-West						
Underground	Mining	0	0	0	0.67	0
Mines	Post-Mining	0	0	0		0
Surface Mines	Mining	1.440	1.0	1.4		1.0
	Post-Mining	1.440	0.2	0.28		0.2
Total						**1.2**
Central						
Underground	Mining	3.689	4.6	17.0	0.67	11.4
Mines	Post-Mining	3.689	1.0	3.7		2.5
Surface Mines	Mining	2.783	1.8	5.0		3.4
	Post-Mining	2.783	0.2	0.56		0.4
Total						**17.7**
Volga-Vyatka						
Underground	Mining	0	0	0	0.67	0
Mines	Post-Mining	0	0	0		0
Surface Mines	Mining	0.523	3.0	1.5		1.0
	Post-Mining	0.523	0.2	0.1		0.1
Total						**1.1**
Central-Chernozem						
Underground	Mining	0	0	0	0.67	0
Mines	Post-Mining	0	0	0		0
Surface Mines	Mining	1.112	3.0	3.3		2.2
	Post-Mining	1.112	0.2	0.2		0.14
Total						**2.34**

Table 2.20 (continued)

Volga						
Underground	Mining	0.05	4.0	0.2	0.67	0.14
Mines	Post-	0.05	1.0	0.05		0.04

	Mining					
Surface Mines	Mining	0	0	0		0
	Post-Mining	0	0	0		0
Total						**0.18**
North-Caucasus						
Underground	Mining	18.66	31.0	578.6	0.67	387.7
Mines	Post-Mining	18.66	4.0	74.6		50.0
Surface Mines	Mining	0	0	0		0
	Post-Mining	0	0	0		0
Total						**437.7**
Ural						
Underground	Mining	3.6	21.0	75.6	0.67	50.6
Mines	Post-Mining	3.6	4.0	14.4		9.6
Surface Mines	Mining	7.057	1.3	9.2		6.1
	Post-Mining	7.057	0.2	1.4		0.9
Total						**67.2**
West-Siberia						
Underground	Mining	83.515	24.3	2033.4	0.67	1362.1
Mines	Post-Mining	83.515	4.0	334.1		223.8
Surface Mines	Mining	19.116	5.9	112.8		75.6
	Post-Mining	19.116	0.2	3.8		2.6
Total						**1664.4**
East-Siberia						
Underground	Mining	5.863	10.0	58.6	0.67	39.3
Mines	Post-Mining	5.863	4.0	23.4		15.7
Surface Mines	Mining	54.397	1.1	59.9		40.1
	Post-Mining	54.397	0.2	10.8		7.2
Total						**102.3**
Far East						
Underground	Mining	9.387	21.0	197.1	0.67	132.0
Mines	Post-Mining	9.387	4.0	37.5		25.1
Surface Mines	Mining	19.094	2.9	55.9		37.4
	Post-Mining	19.094	0.2	3.8		2.5
Total						**197.0**

Table 2.20 (continued)

RUSSIA						
Underground	Mining					2305
Mines	Post-Mining					388
Surface Mines	Mining					167
	Post-Mining					14
Total						**2874**

2.2.3. *Fugitive Emissions from Oil and Natural Gas*

The main source of methane emissions in Russia is natural and oil gas production, transportation, storage and distribution. The greater part of uncertainty in the emissions estimation is also connected with natural and oil gas. This situation is explained by lack of reliable statistical data and by the large uncertainty of emission factors. Perhaps, one can consider that the uncertainty of the total emission estimation in Russia will be nearly wholly determined by this one in the gas sector. In Figure 2.2 the amounts of gas fluxes in Russian economy are shown, as well as the types of emissions from each branch of the gas sector. Applying to this amounts the IPCC-recommended emission factors we obtain total estimation of methane emission at 11.8-26.5 Mt CH_4 including:

- production - routine maintenance emission - 4.9 (3.0-6.8) Mt CH_4/yr;
- production - venting and flaring - 0.4 (0.1-0.7) Mt CH_4/yr;
- transportation, storage, processing and distribution - 9.9 (6.2-13.6) Mt CH_4/yr;
- consumption - leakage at industrial plants and power stations - 3.8 (2.4-5,2) Mt CH_4/yr;
- consumption - leakage in the residential and commertial sector - 0.17 (0.10-0.23) Mt CH_4/yr.

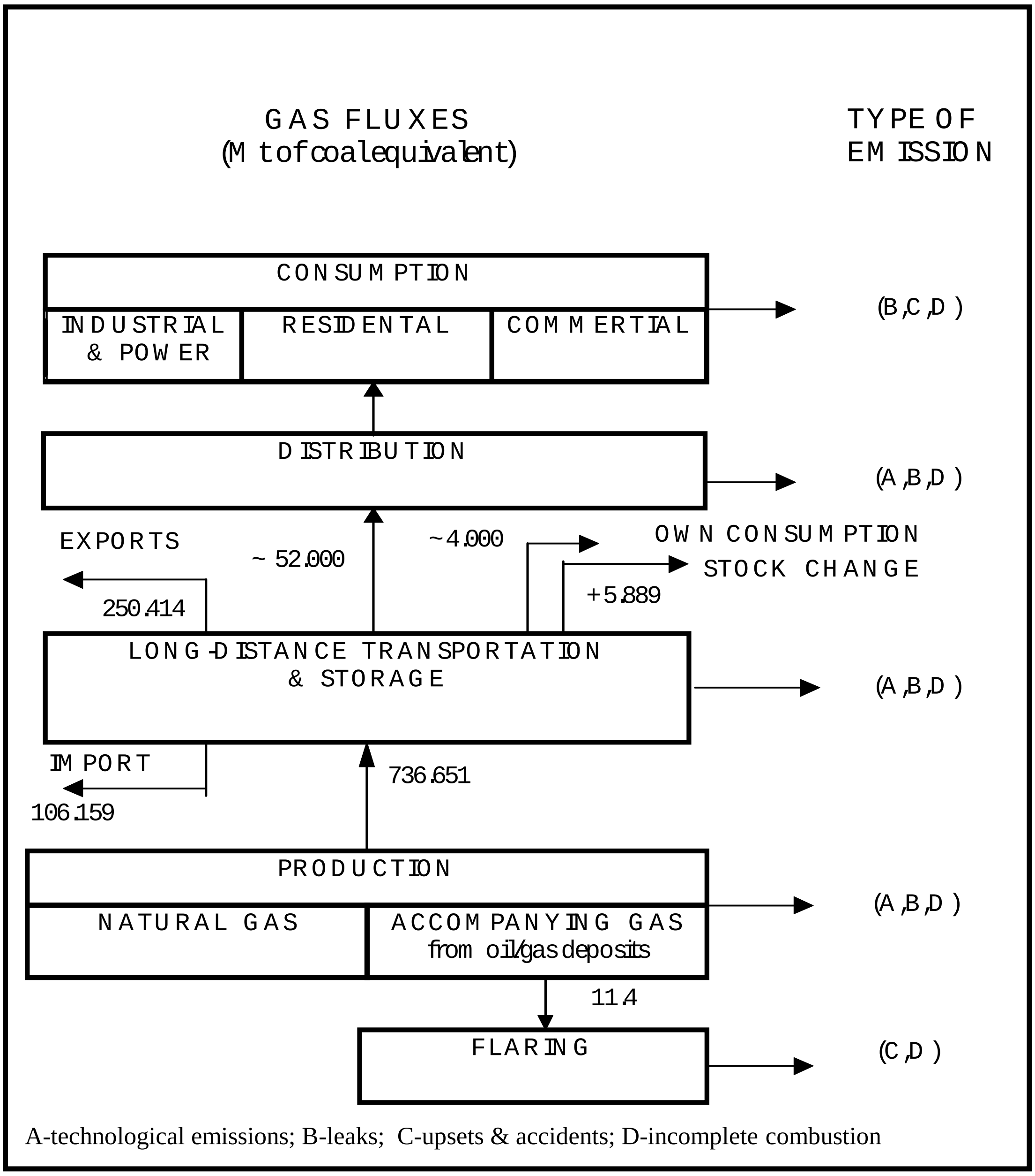
The conservative estimation of emission at 16.0 Mt CH_4/yr in 1990 can be considered as probable one.

Alternative method of estimating emission from the transportation and storage of natural gas is the following. On the base of data from concern "Gasprom", 9.3 per cent of extracted in 1991 gas was used for technological purposes of the pipelines. Converted to CH_4, it equals to 46.1 Mt CH_4. At the same time, estimation of gas consumption by equipment of gas storage and transportation system, taking into account its capacity factor, results in estimation of factual gas consumption for technological purposes at 15.5 Mt CH_4.

The rest part of declared consumption is emission to the atmosphere and illegal (not accounted for) consumption of gas. So far as there are no any reliable estimations of illegal gas consumption in Russia, we can consider the value 30.6 Mt CH_4 as the upper theoretically possible limit of methane emission on the stage of gas transportation and storage. This value was obtained (see Fig. 2.3) as a difference between accounted technological usage (46.1 Mt) and the real usage (15.5 Mt).

Figure 2.2

Fluxes of Natural Gas and CH_4 Emissions in the Russian Economy (1990)



Estimates of fugitive emissions of CH_4 from oil-related activities carried out using Tier 1 IPCC and emission factors recommended for the former USSR and Eastern Europe countries are listed in Table 2.21.

Uncertainties of the estimation reflect the uncertainties of emission factors. Emission from the transportation is expected to be underestimated, because amount of oil transported by tankering is relatively small in Russia, as compared with another ways of transportation. Emissions from the oil prospecting and exploration were not estimated because of lack emission coefficients appliable to these processes.

Figure 2.3.

Estimation of the Upper Limit of CH_4 Emission from Gas Transportation and Storage

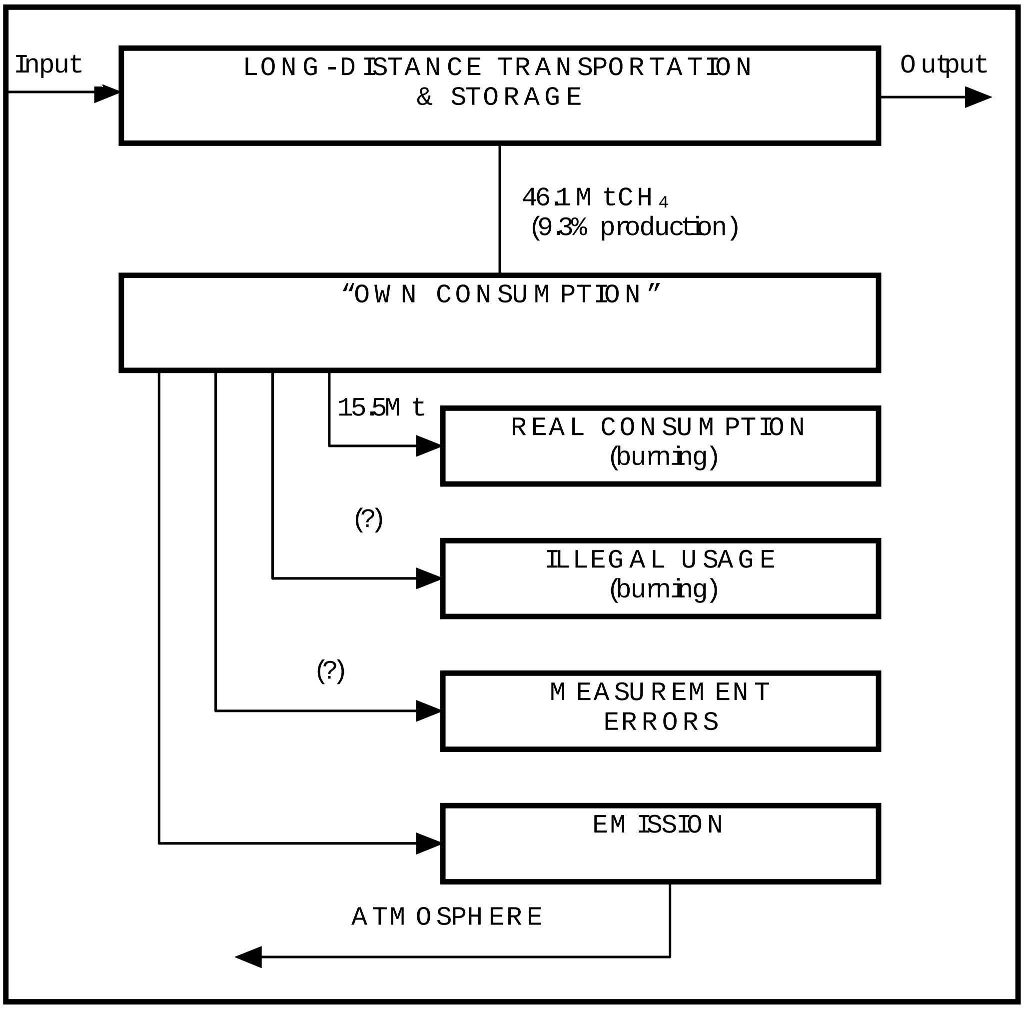


Table 2.21

Methane Emissions from Oil Activities

Category	Activity	Emission Factor	CH_4 Emissions (Mt CH_4)
Exploration	number of wells drilled NA	kg CH_4/well drilled NA	NA
Production	PJ oil produced 21633	300-5000	0,006-0,11
Transport	PJ oil loaded in tankers 1260	745	0,001
Refining	PJ oil refined 12602	90-1400	0,001-0,020
Storage	PJ oil refined 12602	20-250	0,0002-0,003
Total			0,008-0,13

2.2.4. N_2O Emissions From Energy

All the processes connected with organic fuel combustion result in some measure in N_2O emissions connected with oxidizing of atmospheric nitrogen by burning. Emission factor values are higher by low-temperature burning while NO and NO_2 production increases by high-temperature processes.

There are two main ways of approach to estimate emissions from sources of such a type:

- the approach based on using N_2O emission factors per kilometer of distance traveled for different categories of vehicles;
- the approach based on using N_2O emission factors per mass unit of used fuel for different categories of vehicles.

The first way of approach requires detailed statistical data on vehicle park and mean distances traveled per year. Because of data unsufficiency discussed in section 2.1.2 using such a way of approach under the RF conditions, we can result in significant error in the emission estimate.

Let us conduct the estimate using the second way of approach. The IPCC data on emission factors per mass unit of used fuel are shown in Table 2.22. There are no data on emission factors from motor vehicles using compressed and liquefied gas and from jet and turboprop aircraft.

Table 2.22

N_2O emission factors for mobile sources

Source	Emission factor (g/ÌJ)
Motor vehicles:	
gasoline	0.0005-0.001
diesel	0.002-0.004
Motorcycles	0.0009-0.002
Ocean-going ships and boats	0.002
Locomotives	0.002
Farm equipment	0.002
Construction and industrial	0.002
Pistol-driven aircraft	0.0009

The total amount of fuel consumed by motor vehicles registered by the State Automobile Inspection (excluding motorcycles) was 46594 kt in 1990. Basing on the data of this source, one can calculate the share of diesel oil and gasoline in the total consumption. They are correspondingly 39 and 61 per cent (in further calculations these shares will be accepted as 40 and 60 per cent correspondingly). Using emission factors from Table 2.22, gasoline calorific value of 44.80 TJ/kt and diesel oil calorific value of 44.33 TJ/kt (IPCC data) we obtain emission from diesel vehicles equal to 1.62-3.24 kt and emission from gasoline vehicles equal to 0.62-1.26 kt N_2O.

Fuel consumption by marine and river transport (diesel oil, black oil and, in negligible measure, jet kerosene) was 998 kt and 1907 kt correspondingly. Not taking into account jet kerosene consumption and using diesel and black oil calorific value of 43.33 TJ/kt, we obtain N_2O emission equal to 0.25 kt.

Diesel oil consumption by locomotives of all types (excluding industrial railway transport) was 5844 kt. Analogous to the above mentioned calculation, we obtain N_2O emission equal to 0.51 kt.

Pistol-driven aircraft consumed 295 kt of aviation benzene in 1990. Using calorific value of 44.80 TJ/kt and the data from Table 2.22, we obtain emission of 0.011 kt.

Let us estimate N_2O emission from the rest of the mobile sources not included in the above mentioned calculations. First of all, we will estimate emission from gasoline. Gasoline production was 61 425 kt of coal equivalent (coal equivalent) in the RF in 1990, imports were 1839 kt, exports 13 956 kt, stock change was -2116 kt. So, internal consumption of gasoline was 51 424 t.c.e. Non-fuel use of gasoline (as solvent, etc.) is probably negligible, and we will not consider it. Hence, the whole internal consumption of gasoline in the RF can be considered as N_2O emission source. The total calorific value of this amount of gasoline is 51424 x 29.3 TJ/k t.c.e. = 1.51×10^6 TJ. Basing on the above mentioned data, the total calorific value of gasoline used by motor vehicles registered by the State Automobile Inspection (excluding motorcycles) is 1.25×10^6 TJ. Correspondingly, emission from the rest of motor vehicles consuming gasoline is equal to $(1.51 - 1.25) \times 10^6$ TJ x 10^6 MJ/TJ x (0.0005....0.001) g/MJ = $(0.00013 - 0.00026) \times 10^{12}$ g N_2O, i.e. 0.13 - 0.26 kt N_2O.

The total calorific value of diesel oil considered in the above mentioned calculations is equal to 1.19×10^6 TJ. The total internal consumption and consumption by international marine transport of diesel oil and naval oil was 90 875 kt, or 2.66×10^6 TJ in the RF in 1990.

The following values should be subtracted from this value:

- bunker fuel; emissions from bunker fuel are not considered in national Inventories of GHG emissions and sinks (according to the UNFCCC). Let us note that for emissions from mobile sources with gasoline engines, emissions from international transport are included in National Inventories, i.e. gasoline is excluded from “bunker fuel”;
- oil products that were not used as fuel, or combusted by any other way, but used for different purposes. (Actually, this fuel does not contribute to N_2O emissions from mobile combustion).

In 1990 in Russia marine bunker fuel consumption of all types by Russian and foreign ships refueled in Russian sea-ports was equal to 4290 kt. Taking the mean calorific values of black and diesel oil to be 42.0 TJ/kt, we obtain the total calorific value of used bunker fuel is equal to 1.8×10^5 TJ. Corresponding N_2O emission is 0.36 kt.

To estimate non-combusted diesel oil we use data on carbon stored. According to these data, in 190460 t.c.e. of diesel oil were not combusted, taking into account the share of carbon stored for diesel oil, the factor being of 0.5 (IPCC, 1995). Calorific value of this fuel is equal to 460 kt. e.f. x 29.3 TJ/kt.c.e x 0.5 = 6.7×10^4 TJ.

Using these results, we can calculate the total calorific value of diesel and black oil, consumption of which was not taken into account in previously carried-out calculations:

$$Q_d = Q - Q_b - Q_s - \sum Q_i \qquad (2.1)$$

where q is the total calorific value of diesel and black oil consumed at home,

Q_b is the total calorific value of bunker fuel,

Q_s is the total calorific value of non-combusted fuel,

Q_i are the total calorific values of fuel considered in previously conducted calculations.

Calculation carried-out according to this equation provides a value of 1.40 x 10^6 TJ.

To estimate emission from this part of fuel, one can use emission factors for diesel vehicles, because such part of fuel is used by motor vehicles and off-road, construction, farm and forestry equipment (close to diesel vehicles as to emission factors) as well as by industrial railway transport. As a result, we obtain emission value equal to 2.8 - 5.6 kt N_2O. Summarizing this result with previously calculated emission from diesel oil consumption, we obtain the total N_2O emission equal to 5.2 - 9.6 kt in 1990.

In spite of the fact that the lack of data on N_2O emission factors from transport using compressed and liquefied gas, does not enable to estimate emission from these sources accurately, we are sure that the share of the transport of this kind in the total emission from mobile sources does not exceed 1 per cent. (The share of motor vehicles using gas fuel is 0.6 per cent of the whole vehicle park; transport of other types does not use gas fuel excluding experimental models.

Fuelwood is not used in the RF as fuel for mobile emission sources. Solid fuel is used for locomotives in negligible amount.

The results of N_2O emission estimates from mobile sources are summarized in Table 2.23 We should note that these estimates probably overestimate actual emission in some measure, because some part (not very large) of diesel oil and, may be, of naval oil is used as fuel for stationary diesel electric power plants. They are widespread especially in distant northern and eastern regions of Russia. From the other hand, this overestimation will not influence in a large measure on the accuracy of the estimation of the total emission from mobile and stationary sources, because it is actually based on formal redistribution of consumed fuel between the mobile and stationary sources.

Emission factors for stationary sources using fossil fuel (the IPCC, data) are shown in Table 2.24.

The so called “fluidized bed combustion” characterized by higher emission factors, is not used in Russia on an industrial scale.

Table 2.23

N_2O emission to the atmosphere from mobile sources from the RF territory in 1990 ã.

Emission sources			Emission estimated, kt			
			Min	Probable	Mean	Max
Mobile sources			6.0	8.6	8.6	11.1
	Including: liquid fuel		6.0	8.6	8.6	11.1
		Including: gasoline	0.8	1.2	1.2	1.5
		diesel	5.2	7.4	7.4	9.6
	solid fuel		0[1]	0[1]	0[1]	0[1]
	gas fuel		0[1]	0[1]	0[1]	0[1]
	wood fuel		0	0	0	0
Marine bunker fuel[2)]			0.26	0.26	0.26	0.26

1) Emission is negligible
2) is not included in the RF national emission

Domestic consumption of coal was 222498 kt.c.e. in Russia in 1990. We should subtract 947 kt.c.e. of coal processing products from this amount used for non-combustion processes. Taking into account coal equivalent value of 29.3 TJ/kt.c.e., we can obtain the total calorific value of the fuel used - $6.49 * 10^6$ ÒJ. Since solid fuel is not practically used in mobile sources (see above), the calculation of emission (see Table 2.25) can be obtained by multiplying this result by emission factors from Table 2.24.

Table 2.24

N_2O emission factors for stationary sources

Source	Emission factor (kg/ÒJ)	
	Range	Most probable
Coal	0-10	1.4
Oil	0-2.8	0.6
Gas	0-1.1	0.1

The analogous calculation for gas fuel based on interior gas consumption of 587344 kt.c.e., its non-fuel used (processing) of 86444 kt.c.e. and IPCC-recommended carbon storage factor by gas processing of 0.33 results in 1.7 kt N_2O (the limits of uncertainty being of 0 - 18.3 kt).

The interior consumption of liquid fuel was 470075 kt in 1990. The subtraction of oil products not used as fuel taking into account corresponding carbon storage factors enables to obtain the value of liquid fuel consumption resulting in to N_2O emission of 434054 kt.c.e. Further, we should subtract from this value liquid fuel consumption by mobile sources (estimated above) and consumption of marine and aircraft bunker fuel (1400 kt.c.e. from the RF Goscomstat estimates. The results of final calculation of the emission are shown in Table 2.25.

We should note that using our way of approach, we do not subtract from the interior consumption of all three types of fossil fuel its losses by processing, transport and consumption. Thus, N_2O emission is overestimated in some measure. However, this overestimation is not significant, because it is essentially lower than the error connected with uncertainty of emission factors.

From the Goscomstat data (see Section 2.1.1), the interior consumption of wood fuel was equal to 19.349 Mt.c.e.

It is possible to calculate the amount of N_2O emitted using the equation:

$$Å_N = C_W * Ê_q * K_m * K_o * K_{NC} * K_{N2O}, \qquad (2.2)$$

where C_W is the interior consumption of wood fuel;

$Ê_q$ = 7000/4750 is a ratio of coal equivalent value to the low calorific value of wood fuel;

Table 2.25

N_2O emission to the atmosphere from stationary sources using fossil fuels in 1990 ã.

Emission sources	Emission estimated, kt			
	Min	Probable	Mean	Max
Stationary sources of emission	0	15.9	53	107
Including: liquid fuel	0	5.1	12	24
solid fuel	0	9.1	32	65
gas fuel	0	1.7	9	18

K_m = 0.45-0.50 is a carbon mass share in wood;

K_o = 0.87 is mean carbon oxidation factor by fuel wood combustion;

K_{NC} = 0.01 is a ration between nitrogen and carbon content in wood burning products;

K_{N2O} = 0.005-0.009 - is a ration between N-N_2O and the total nitrogen in burning products (IPCC, 1995).

Applying this equation, we obtain (assuming K_m = 0.48) emission equal to 0.83 kt N-N_2O in 1990 ã. Recalculation of N-N_2O emission to this one expressed in N_2O mass, can be carried out as following:

$$Å = E_N * (M_{N2O} / M_N), \tag{2.3}$$

By this way, we obtain emission of 1.31 kt N_2O in 1990.

Using the alternative estimates of fuelwood consumption (27.1 - 40.7 Mt.c.f) from the Section 2.1.1., we obtain (from 2.2 and 2.3) N_2O emission of 1.8 - 2.8 kt N_2O per year, or 1.4 - 2.2 times as large as the value obtained when the previous way of calculation was used.

The results of calculations obtained using the both ways are summarized in Table 2.26.

Table 2.26

N_2O emission from fuelwood combustion

Emission sources	Emission estimated (kt N_2O)			
	Min	Probable	Mean	Max
Wood combustion	1.3	1.8	2.1	2.8

Since the state statistics do not completely account for fuelwood laying-in at the local level and self-laying-in by the population, the estimate of 1.3 kt N_2O (from the Goscomstat data) obviously should be considered only as a theoretical low limit of emission. Value of 1.8 kt N_2O per year is considered in this study as the most probable emission in 1990.

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3. Emissions from Industrial Processes

3.1. CO_2 Emissions from Cement Production

Carbon dioxide is emitted during the production of clinker, an intermediate product from which cement is made. In a process of calcination, calcium carbonate is heated, forming lime and carbon dioxide. Lime then undergoes additional treatment to form clinker, and finally cement.

IPCC Guidelines recommends to use clinker production statistics and coefficient of CO_2 emission for clinker while calculating emissions, as preferable variant. Clinker statistics are not available in Russia. Imports and exports of clinker were not reflected by national statistics, that indicates zero or negligible foreign trade. Hence, cement statistics can be used for the estimation of emission without considerable increase of estimation error. Total cement production in 1990 was 83.0 Mt. Data on cement production by brand in 1991 (1990 data are not available) are shown in Table 3.1. Share of Portland cement was 72.2 per cent. Default emission factor of 0.4985 t CO_2/t cement or 0.136 t CO_2 as C/t cement can be used to calculate emission (Table 3.2). Estimated emission is 41.1 Mt CO_2 (11.3 MtC).

Table3.1

Cement production by brand in Russia in 1991

Cement Type	Production, Mt					
	Total	Brand*				
		300	400	500	550	600
Portland Cement	52.9	1.2	33.3	17.3	1.0	0.1
Cement Total	73.3	7.7	46.2	18.2	1.1	0.1

*)Ultimate compression strength of standard cement-sand mixture (1:3) after hardening

Estimates of 1990 emissions of CO_2 from the production of cement in the economic regions are listed in the Table 3.2. These estimates were derived from our previous estimate of total CO_2 emission from cement using data on regional cement production.

3.2. N_2O Emissions

N_2O is produced by chemical industry of the RF (the Cherepovetsk plant) for medical purposes (as anesthetic drug by surgical operations). It is emitted to the atmosphere after its usage and as a result of losses by its production. Usually is assumed that the whole amount of N_2O used for medical purposes is emitted to the atmosphere. Unfortunately, statistic data in N_2O production and consumption are not available in the Goscomstat and the Committee on chemical industry for the period of 1990-1993. We possess the data presented by Scientific and Research Institute of Medical Industry

Table 3.2

Emissions from Cement Production by Economic Region of Russia

Region	Productions	Emissions	Emissions

	(kt)	(Mt C)	(per cent of total)
North	1783	0.24	2.1
North-West	4080	0.56	5.0
Central	10706	1.46	12.9
Volga-Vyatka	3002	0.41	3.6
Central-Chernozem	8737	1.19	10.5
Volga	10651	1.45	12.8
North-Caucasus	8568	1.17	10.3
Ural	16022	2.18	19.3
West-Siberia	7406	1.01	8.9
East-Siberia	7208	0.98	8.7
Far East	4873	0.66	5.9
Total	**83036**	**11.31**	**100.0**

Economy under the Ministry of Public Health and Medical Industry of the RF, concerning the need of medical institutions in N_2O for the period of 1994-1996 (Table 3.3).

Table 3.3

N_2O need in medicine in 1994-1996.

Year	Need (t)
1994	1545.19
1995	2252.07
1996	2097.14

Since we have no information on the influence of any organizational or economical factors upon the N_2O consumption dynamics for the period after 1990, the mean emission for 1994-1996 of 2.0 kt was considered as the estimate of 1990 N_2O emission from medicine usage, and averaged minimum (1.5 kt) and maximum (2.3 kt) values for this period were considered as the limits of uncertainty interval.

There are no data to estimate N_2O emission resulted from technological losses by its production. However, we can suppose this emission is at least not greater than this one from medicine.

Among the industrial processes N_2O emission factors are known only for processes of manufacture of adipic and nitric acids. On a data of Committee RF of Chemical industry all production of adipic acid in former USSR was outside of Russian territory. Amount of production of nitric acid in recalculation on monohydrate, i.e. on pure HNO_3 was 541.5 kt (based on the 1991 data of Goskomstat RF; in 1990 data was not collected).

Application of IPCC-recommended emission factors of 2-9 g N_2O per kg HNO_3 results in average emission of 3.0 thousand ton N_2O at a range of possible emissions 1.1-4.9 kt.

3.3. Other Data

According to IPCC and OECD publications, CO_2 emissions from the following processes have been reported:

- Production: coke, iron, steel, aluminum, ferro-alloys, fertilizers, limestone, lime, dolomite, bricks, glass, paper, pulp and print, soda ash, CO_2;
- Consumption: limestone and soda ash.

Non-combustion emissions have been reported in the following industrial processes:

- primary metals production and associated processes (coke, sinter, pig iron, steel);
- chemical manufacturing processes; production of a variety of chemicals like carbon black, ethylene, dichloroethylene, styrene and methanol including oil refining process.

Data on corresponding emission-related activities are included in Table 3.4 and may be used if reliable emission coefficients will be published.

Table 3.4

Emission-Related Industrial Activities in 1990

Process		Activity
Agricultural Liming		22.593 Mt of crushed dolomite and limestone produced for agricultural liming
Aluminium Production		Not less 2.3 Mt (estimated)
Ferro-alloy Production		Not less 0.5 Mt (estimated)
Calcium Carbide Production		288 kt
Coke Production		39.3 Mt (reduced to 6% humidity)
Nitrogen Fertilizers Production		7.19 Mt or 4.95 Mt if reduced to N_2
Cast Iron Production		59.4 Mt
Steel Production	Total	89.6 Mt
	Electric	28.5 Mt
	Converter-Oxygen	13.3 Mt
Primary Oil Refining		297 Mt
Methanol Production		2.22 Mt
Ammonia Production		12.6 Mt
Sodium Carbonate		2.26 Mt
Carbon Black		Not less 65 kt (estimated)
Vinylchloride Production		490 kt
Polyethylene Low and High Density Production		773 kt
Polyvinylchloride Production		490 kt
Polyethylene Production		773 kt
Polypropylene Production		95.8 kt
Stryrene Butadiene Rubber Production		2.18 Mt
Phtalic Anhydride Production		126 kt
Acrylonitrile Production		
Paper	Total	5.24 Mt
	Newspaper Type	1.72 Mt
Cardboard	Usual	3.06 Mt
	Packing	1.61 Mt

Table 3.4 (continued)

Paper Pulp Production		7.53
Bread Production		18.2 Mt
Wine Production		75.7 M liters
Beer Production		336 M liters
Spirits Production		138 M liters
Bricks Production		24.5 G pieces
Glass	Construction Type	145 M sq. meters
	Window Type	130 M sq. meters

In addition to the data on emission factors included into IPCC Gudelines, national estimation of the share of coke gas emitted to the atmosphere during coke production - 6 per cent can be used for improving calculation quality. Coke gas includes 20-34 per cent CH_4 by volume.

Taking into consideration great amounts of fossil fuels, namely gas and coal, produced, transported and consumed in Russia, industrial non-combustion emissions of methane are considered to be of minor importance in national scale.

Rough estimation of aluminium production - source of carbon tetrafluoride - CF_4 and hexafluorethane - C_2F_6 is also included into Table 3.4. Official data on the production of magnesium is not available, however domestic and internetional expert estimates may be obtained.

4. Emissions from Waste

4.1. CH_4 Emissions from Solid Waste

Wastes to be removed from cities and other settlements can be divided into solid and liquid ones and by their quality and origin - to municipal wastes (from dwelling houses and public buildings, trade, medical, and other institutions), construction wastes, and industrial ones.

In this section municipal solid waste (MSW) are mainly considered. They present a main source of methane emission. About 25 per cent of non-utilized industrial wastes are also landfilled in Russia. The rest of them are transported to toxic industrial waste grounds which practically do not emit gases because conditions required for gas-emitting reactions are absent there.

4.1.1. Quantitative characteristics of solid waste generated in Russia

In 1990 about 26 Mt MSW were annually collected and transported from settlements in Russia. Dynamics of MSW collecting and transport as well as urban population amount for the period of 1960-1990 are shown in Table 4.1.

Table 4.1.

Amount of urban MSW transported to landfills in Russia

Year	Amount of MSW, Mt	Urban population (millions)	Year	Amount of MSW, Mt	Urban population (millions)
1960	3.0	63.7	1975	16.2	89.3
1961	3.4	66.1	1976	18.9	91.1
1962	3.9	NA	1977	20.1	92.5
1963	4.7	69.7	1978	21.1	93.9
1964	5.4	71.6	1979	21.4	95.3
1965	6.8	73.2	1980	22.0	96.6
1966	7.4	74.7	1981	22.4	97.7
1967	8.6	76.4	1982	23.0	99.0
1968	9.9	77.8	1983	23.8	100.4
1969	10.0	79.3	1984	24.5	101.6
1970	10.7	81.0	1985	24.8	102.8
1971	11.8	82.4	1986	25.3	104.1
1972	13.0	84.1	1987	26.1	105.7
1973	14.0	85.8	1988	27.0	107.1
1974	15.0	87.5	1989	26.8	108.4
			1990	26.4	109.2

Fraction urban population embraced with municipal system of MSW collection and transportation (state on 1990) is shown in Table 4.2.

Table 4.2.

Fraction urban population embraced with municipal systems of solid waste collection and transportation

Population (10^3 persons)	Number of towns	Total population (10^6 persons)	Fraction population embraced with municipal systems of solid

			waste collection and transportation (%)
less 100			64
100-250	91	13.829	79
250-750	60	25.049	86
more 750	16	29.767	88

All MSW collected by municipal systems must be treated and utilized. In 1990 about 90 per cent of MSW were rendered by landfilling, the remained 8 per cent were utilized at plants (Table 4.3).

Table 4.3.

Fraction MSW in Russia by methodology of treatment

(1990 data)

MSW amount	Mt	%
Total	26.4	100
Landfilled	24.3	91.9
Incinerated	1.5	5.8
Used for compost production	0.6	2.3

In Table 4.4. data on MSW transportation to landfills and processing plants are shown for the period of 1989-1993 (from the Goskomstat data).

Table 4.4

MSW transportation to landfills and processing plants in Russia (1989-1993)*

MSW amount	Year			
	1989	1990	1991	1993
Transported to landfills (Mt)	23.6	24.3	24.7	23.9
Transported to processing plants (Mt)	0.4	0.7	0.4	1.8

* State Committee of Russian Federation for Statistics data in millions of cubic meters were converted using density 206 kg/cubic meter MSW.

Let us compare the given value with calculation carried out in accordance with the IPCC recommendations (volume 2, Worksheet 6-1 (Supplement)) for Russian Federation (Table 4.5.). Urban population number (early 1990) is presented from the Goskomstat data (Table 5.1.).

From this Table one can see that annual MSW landfilled (from the IPCC calculation techniques) will be equal to 20.3 Mt, i.e., less than landfilled in reality by 4 Mt, or 16 per cent (Table 4.4.).

Table 4.5

Estimating Total Municipal Solid Waste Landfilled

A Urban Population (10^6 person)	B Waste Generation Rate (Gg MSW/10^6 person/year)	C Waste Generated (Gg MSW)	D Fraction Landfilled	E Annual MSW Landfilled (Gg MSW)
		C+(AxB)		E+(CxD)
109.2	219	23914.4	0.85	20327.5

4.1.2. Basic characteristics of MSW landfills and dumps in Russia

Data on the total amount of landfills, their area and capacity are contained in statistical accounts ("form N^o 3") of the former Ministry of Housing and Municipal Economy of Russian Federation. Data from these accounts on 950 towns of Russia are used below. All information concerns the period of 1972-1985, i.e. the landfills which are at a stage of the intensive and stable gas generation in 1990-1995.

The relationship between the amount of MSW landfilled in Russia and annual MSW amount collected in towns is presented in Table 4.6.

The main part of landfilled MSW is transported from towns annually producing from 100 to 600 thousand ton of MSW.

Table 4.6

Relationship between the amount of MSW landfilled and amount of MSW collected in towns of Russia

Amount of MSW collected in the town (10^3 t/year)	<10	10-40	40-100	100-200	200-400	400-600	>600
Total amount of MSW landfilled (Mt/year)	11.2	22.3	22.5	55.6	66.7	44.4	3.7

Above 20 per cent of the total amount landfilled MSW are deposited at a great amount of small landfills of an area of 10-15 ha belonging to small- and medium-size towns (population below 250-300 thousand persons). The total number of such landfills (through the towns of Russian Federation) where MSW collection and transportation are organized was above 1500. Besides, a great number of open dumps and landfills out of control is located in small towns and settlements, gardens, cottage cooperatives, agricultural associations, etc. The number of such landfills is in the range of tens of thousand. Only across the Moscow district it reaches 6 thousands. However, small landfills emit low volume of methane.

As a rule, a town has one acting landfill being in use for 10-15 years. After it is filled up, a new site for the landfill is chosen, and the previous one is closed and must be recultivated.

An averaged morphological MSW composition by climatic zones of the former USSR (from long-term data) is shown in Table 4.7.

Table 4.7

Averaged morphological MSW composition by climatic zones of the former USSR (mass %)

Waste component		Climatic zone		
		middle	southern	northern
Organic components total		63.7	65.5	58.3
Organic components	Paper. cardboard	27.5	24.0	22.5
	Food waste	34	40	32
	Wood	2.2	1.5	3.8

Mixed components total		18.4	22.5	20.7
Mixed components	Textile	5.5	5.5	5.5
	Bones	1.2	1.5	1.2
	Other	1.7	1.5	1.2
	Siftings (below 15 mm)	10	14	11
Inorganic components total		17.9	12.0	21.0
Inorganic components	Steel products	2.7	1.8	3.8
	Glass	6.5	4.5	8
	Rubber	3	2	3
	Stone	2	1.5	3
	Plastics	3.5	2	3

Here part of organic components (paper, food waste, wood) is equal to 58-62 per cent, and taking into account organic components contained in textile, siftings and other mixed components of the wastes, it is 72 per cent

Averaged atomic composition of MSW components for landfills of Russia is shown in Table 4.8.

4.1.3. Methane emission factors for emissions from solid waste disposal

Emission coefficients of biogas were estimated as a result of joint long-term investigations conducted in late 1980s by a number of scientific and research institutes and scientific and industrial organizations from the countries participated in the Council for Mutual Economic Aid. The aim of this investigation was to study gas generation processes across MSW landfills in certain regions of the USSR, German Democratic Republic, Poland, Bulgaria and Czechoslovakia. It was calculated that biogas emission from 1 ton of landfilled MSW is equal in average to 200 cubic meters for the whole period of active emission (10-20 years). It was discovered that the biogas emitted from the landfill surface consists of about 55 per cent of methane and about 45 per cent of carbon dioxide (other components forming about 2 per cent of the biogas emitted) No landfill methane was recovered in 1990.

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Table 4.8.

Ñomposition of MSW components

Component	Atomic composition (mass %)						
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ashes	Humidity
Paper	27.7	3.7	28.3	0.16	0.14	15	25
Food waste	12.6	1.8	8.0	0.95	0.15	4.5	72
Textile	40.4	4.9	23.2	3.4	0.1	8.0	20
Wood	40.5	4.8	33.8	0.1	-	0.8	20
Plastics	55.1	7.6	17.5	0.9	0.3	10.6	8
Rubber	65.0	5.0	12.6	0.2	0.6	11.6	5
Glass, stone, metals	-	-	-	-	-	100	-
Ashes, slag	25.2	0.45	0.7	-	0.45	63.2	10
Other	47.0	5.3	27.7	0.1	0.2	11.7	8
Siftings	13.9	1.9	14.1	-	0.1	50	20

4.1.4. Estimate of Emission

Emission of CH_4 from MSW is observed for about 20 years from the moment of its landfilling. Maximum of emission is reported near the 10^{th} year and the curve of temporal distribution of emission intensity is practically symmetric about that maximum. From the other hand, according to the data by Academy of Municipal Economy amount of landfilled waste was linearly increasing in the 1970-1990 period (see Table 4.1). Correlating this data one can come to the conclusion that 1990 methane emission from MSW is equal to the 1980 emission calculated on the assumption that landfilling was constant in time in previous 20 years, e.g., in 1960-1980. Such an approach was used when calculating emission for the First National Communication of Russian Federation, resulting in 2.4 Mt CH_4 of estimated emission.

Present estimate of the Russian Country Study is based on the same approach but uses the statistical data on the amount of transported to the landfilling sites MSW instead of previously used sanitary normatives of MSW generation in towns. CH_4 emission is estimated as 1.8 Mt. However this estimation does not take into account MSW transported to the illegal sites (though these sites more often whole are open, e.g. MSW being deposited in aerobic conditions hindering methane generation).

4.2. CH_4 Emissions from Liquid Waste

Wastewater and sewerage sludge containing organic material (volatile solids) are a potential source of methane generation. Methane emission can occur by their treatment in corresponding wastewater treatment systems, as well as a result of natural processes of organic material decomposition when wastewater and sewerage sludge penetrate into the environment without needed processing . Depending on its origin, type, and qualitative characteristics of its admixtures, wastewater can be subdivided into domestic (house and black), and industrial one. As a rule, wastewater of all noted types penetrates in a municipal sewerage system in Russia. Their mixture forms the so called municipal wastewater.

In accordance with classification adopted in Russia, municipal wastewater includes domestic wastewater from residential houses (from sanitary equipment of kitchens, toilets), water from bath-houses, laundries, dining-rooms, hospitals; water from washing premises and apartments, and others both from residential houses and public buildings, and non-technological premises of industrial plants.

Industrial wastewater from municipal enterprises belongs to liquid industrial wastes of the towns. Its discharge into the municipal sewerage system is carried-out after the local treatment when it reaches parameters meeting the existing requirements of industrial wastewater dumped into the municipal sewerage system. For most of the towns of Russia with developed industry the total volume of industrial wastewater makes about 40 per cent of the flow of treated wastes.

As a rule, the rest of industrial wastewater is processed separately and then either is dumped into rivers, lakes, reservoirs, etc., or recirculated at the industrial enterprises.

All municipal wastes are transported to the municipal wastewater treatment systems (aeration stations) included in the municipal sewerage system. Wastes from buildings deprived of sewerage also belong to domestic wastewater. They are collected in cesspools and then transported by special municipal or departmental transport.

The amount and the composition of wastewater transported to the municipal wastewater treatment systems vary by region of Russia (see Table 4.9) and the season of the year depending on the degree of improvement of residential houses and the availability of industrial enterprises.

Table 4.9

Municipal wastewater outflow and treatment in 1990

Region	Wastewater Outflow (m^3)		
	Total	Of which Wastewater Treated in Wastewater Treatment Systems	Of which Wastewater Undergone the Complete Biological Treatment
St. Petersburg City	1097	920	917
Moscow City	2145	2145	2145
North	700	532	515
North-West (not including St. Petersburg)	422	340	332
Central (not including Moscow)	3625	2550	2420
Volga-Vyatka	1271	901	868
Central-Chernozem	787	691	588
Volga	2142	1647	1545
North-Caucasus	1805	1420	1335
Ural	2552	1741	1651
West-Siberia	1924	1389	1332
East-Siberia	1145	939	839
Far East	788	435	354
Kaliningrad Region	85	73	0
Total	**20488**	**15723**	**14841**

As a rule, in Russia the industrial wastewater can not be considered as the methane generating one, because the main methods of its treatment are the classic ways of mechanical and biological processing in settling tanks, aeration tanks, biological filters, oxidative channels, etc. By normal operating of these constructions, the wastewater is processed under aerobic conditions preventing methane generation.

Anaerobic methods of treatment of the industrial wastewater containing a large amount of organic pollutants (in UASB-reactors, digesters with immobilised biomass, etc.) used in the other countries are under development in Russia. Because of a number of reasons including more severe climatological conditions than in most countries of the world, such structures as anaerobic ponds and similar to them volumetric structures with the depth of more than 1.5-2 m where methane can be generated in theory are not almost used in Russia.

According to the standards adopted in Russia, the content of pollutants in domestic wastewater calculated per capita of urban population per day can be assumed (for the estimates) equal to 65 g of mixed material and 75 g of BOD_{total} of non-settled wastewater that corresponds to 50 g of BOD_5.

In the municipal sewerage systems the objects potentially emitting methane to the atmosphere are the structures for the sludge processing incorporated in the municipal sewerage treatment system.

As a rule, multi-stage wastewater treatment is provided:

- - mechanical treatment (screens, sand-traps, primary settling tanks);
- - biological treatment (aeration tanks, secondary settling tanks);
- - chlorination of the treated wastewater (chlorination chambers and contact reservoirs).

The treated water is discharged into a reservoir by gravity.

The sludge generated during the municipal wastewater treatment as concentrated liquid waste containing volatile solids is processed to remove moisture, to render harmless, and to disinfect it. When it is possible and expediently, the aim is to produce biogas by methane fermentation and to utilize biogas.

After the processing the sludge is stored on special spots for long-term storage, or used as fertilizer.

Except methane (60-65 per cent) the end products of methane fermentation presented in biogas are carbon dioxide (up to 35-40 per cent), and, in negligible amounts, sulphurreted hydrogen and ammonia. The amount of emitted gas is in average 8-10 m^3/m^3 of the fermented sludge. By fermentation temperature of 33^{o}C (the so called, mesophilic regime), the process of fermentation takes 10-14 days, and by 53^{o}C (thermophilic regime) it takes 5-10 days. Under natural conditions (by temperature of 10-18^{o}C) the fermentation requires 3-4 months and longer.

The main units emitting methane to the atmosphere by the sludge processing are the following:

- digesters for anaerobic fermentation of the liquid sludge of municipal wastewater containing volatile solids; the result is production and utilization of biogas as fuel.
- sludge beds for drying the sludge.

Methane emission to the atmosphere from the digesters can occur by accidental emission of biogas, e.g. when a gas burner for non-utilized biogas does not operate.

Calculating methane emission can be carried-out by the following way:

1. According to the requirements adopted in Russia we should calculate the maximum permissible fermentation of dry ash-free material of the sludge R_{lim} (in per cent) in dependence on its chemical composition:

$$R_{lim} = (0.92J + 0.62Y = 0.34B) * 100 \qquad (4.1)$$

where J, Y, B are the contents of proteins, fats and carbohydrates in 1 g of dry ash-free sludge.

When data on the chemical composition of the sludge are not available, it can be allowed to assume R_{lim} value on the base of expert estimates. E.g., for fermentation of municipal sewerage sludge from the primary settling tanks R_{lim} = 53 per cent, for activated sludge R_{lim} = 44 per cent. Accordingly, for raw sludge/activated sludge mixture

$$R_{lim} = (0.53*O + 0.44*I)/K \qquad (4.2)$$

where O, I, K are the mass values of dry ash-free raw sludge, activated sludge and their mixture.

In evaluating the amount of dry ash-free material as a first approximation, the ash contain in raw sludge and activated sludge assumed to be equal to 35 per cent of dry material mass.

According to the expert estimates, taking into account an effect of wastewater clarifying in the primary settling tanks, dry ash-free material mass is assessed as 45 per cent - 29.25 g per capita per day.

The mass of dry excess activated sludge can be calculated on the base of well-known equation for the activated sludge growth P_i (*)

$$P_i = 0.8C + KL, \quad g/m^3 \qquad (4.3)$$

where C is concentration of suspended solids in the wastewater transported to an aeration tank; it is nearly equal to 35.75 g per capita per day;

L is BOD_{total} of wastewater transported to the aeration tank; it is nearly equal to 41.25 g per capita per day; k is the sludge growth factor; it is assumed K = 0.3.

2) Decomposition of the ash-free material by its fermentation is calculated according to equation 4 in dependence on a load dose of a digester (D_{mt})

$$R_r = R_{lim} - K_r*D_{mt} \qquad (4.4)$$

where K_r is proportionality factor depending on the fermentation regime and characteristics of the sludge.

Tables 4.10 and 4.11 show K_r values under the most typical operating conditions of the digesters at the municipal aeration stations.

Table 4.10

Load dose and K_r factor value by mesophilic fermentation (fermentation temperature of 33°C)

Moisture of loaded sediment, %	93	94	95	96	97
Daily load dose, %	7	8	8	9	10
K_r factor	1.05	0.89	0.72	0.56	0.4

Table 4.11

Load dose and K_r factor value by thermophilic fermentation (fermentation temperature of 53°C)

Moisture of loaded sediment, %	93	94	95	96	97
Daily load dose, %	14	16	17	18	19
K_r factor	0.455	0.385	0.31	0.24	0.17

3) It is assumed that biogas yield from the digesters is equal to 1 g per 1 g of decomposed ash-free material, methane emission to the atmosphere can be calculated on the base of the following equation:

$$E = K_1 * K_2 * R_r / 100, \quad tCH_4/t \text{ ash-free sludge} \qquad (4.5)$$

where K_1 is a share of methane in biogas, K_1 = 0.6-0.65; it is assumed that K_1 = 0.63;

K_2 is a time share of the digester's operation when biogas is not flared and emitted to the atmosphere; K_2 = 0.01-1.

Comparing the above mentioned techniques with the IPCC recommendations we can safely assume that the principal difference is in the quantitative estimation of methane production from volatile solids of anaerobically fermented substances.

According to the techniques adopted in Russia, this value is calculated on the base of dry ash-free material decomposition. According to the IPCC techniques, it is calculated on the base of methane yield from a unit of fermented mass, calculated for BOD_5 with the use of conversion factor of 0.22 g CH_4/g BOD_5 in wastewater.

On the base of the expert estimate the mean value of ash-free sludge decomposition in the digesters is equal to 43 per cent. According to the techniques adopted in Russia, methane production calculated for 1000 m^3 (1000 tones) of treated wastewater, or correspondingly for 1000*0.8%*(100-96)%*(100-35)% = 0.208 t of ash-free sludge is

208*43%*63% = 56.3 kg CH_4.

As is known, in the case when fermented sludge is transported from the digesters to the sludge beds, fermentation continues.

As this takes place, according to the expert estimates, the total methane yield can be calculated taking into account the increase in decomposition of sludge volatile solids up to 45 per cent.

Consequently, under the described conditions the methane production can be considered equal to 56.3*45/43 = 58.9 kg CH_4 for 1000 m^3 of treated wastewater.

According to the IPCC techniques, the calculation is conducted as applied to the given population number. In this case, i.e. calculating for 1000 m^3 /day of treated wastewater, the population number can be estimated on the base of specific water-withdrawal quota - q.

In one's turn, "q"- value can be calculated on the base of data on the amount of wastewater treated in the municipal systems (see Table 4.9), and data on the urban population number.

Specific water-withdrawal quota (from 1992 data) for the municipal sewerage system can be considered as equal to:

$q = 10866*10^6/(109672*10^3*365) = 0.271$ m^3 per capita per day in Russia. (The amount of wastes passed through complete biological treatment systems was taken into account, but not the total wastewater withdraw because methane production from the rest of wastewater is absent, or negligible in Russia).

So, carrying-out the calculations according to the IPCC techniques, we obtain the value of methane production (under the above mentioned conditions) from 100 m^3/day of wastewater equal to

(1000/0.271)*50*0.22 = 40.6 kg CH_4 .

It makes about 70 per cent of the value obtained on the base of the techniques adopted in Russia for calculating methane emission from the municipal sewerage treatment system with the complete biological treatment and equipped with the digesters and the sludge beds to dry fermented sludge.

Therefore, if we consider the both techniques are correct, the value of ash-free material decomposition is (from the IPCC techniques)

45% * 0.7 = 31%.

As to the wastewater treatment systems in developed western countries, lower methane emission factor seems to be well substantiated because in these countries, in parallel with anaerobic fermentation of sludge, less productive (concerning biogas emission factor) processes participate in methane generation (the anaerobic treatment of a number of wastes containing volatile solids, e.g. in food industry).

Some additional differences in the results of the calculations are connected with a simplified approach to methane emission factor from 1 g BOD_5. On the base of the IPCC techniques, this factor assumed to be constant and equal to 0.22 g CH_4 per 1g BOD_5.

In reality, this value largely depends on the wastewater characteristics. In particular, the content of organic carbon (a source of methane generation) and the value of Chemical Oxygen Demand (COD) in wastewater varies by the wastewater type, and that correlation between these factors and BOD_5 is not linear. Therefore, the value of considered factor is not constant.

Taking into account the above mentioned peculiarities, we should accept that the results of the expected methane yield calculation obtained on the base of the both techniques do not fundamentally contradict one another.

However, taking into consideration the observed difference in the obtained values, and calculating methane emission from the sewerage systems on the base of the IPCC techniques under Russian conditions, we should use higher methane emission factor from 1 g BOD_5 - 0.3g CH_4 per 1 g BOD_5. A share of anaerobic processes in the total wastewater outflow and the amount of utilized methane (in biogas) should also be taken into account.

As one can see from Table 4.12, in Russia the climatological conditions are unfavourable for methane production from non-fermented sludge transported to the sludge beds for drying. In particular, even in Moscow (Central Region) there are only four months (from May to September) when the monthly mean temperature is above 15^{o}C that at the minimum meets the conditions, under which anaerobic fermentation of sludge can take place.

Table 4.12

Climatological data on the Russian Federation

Region	Duration of the period with the mean monthly temperature below $8^{o}C$, days
North	>250
North-West (St. Petersburg)	219
Central (Moscow) (Kostroma)	205 224
Volga-Vyatka (Nizhni Novgorod)	218
Northern Caucasia	<200
Ural	211
Western Siberia	>250

Most of this relatively warm period corresponds to the stages of biochemical process preceding methane emission itself.

The above mentioned characteristic features coincide with the results of the investigations devoted to anaerobic fermentation of the municipal solid wastes in landfills and grounds.

So, over most of Russian territory (excluding some regions, mainly the southern ones - Stavropol and Krasnodar Territories, Rostov-on-Don oblast, Daghestan, and other republics of the Northern Caucasia) methane emission to the atmosphere from the sludge located on the sludge beds is not expected. Taking into account the above mentioned factors and physicochemical characteristics of non-fermented sludge, we can consider that the calculated limit of decomposition of volatile solids in the sludge beds accompanied by methane generation is equal to 15-20 per cent by the duration of effective methane generation period of 4-6 months. Data on methane emission to the atmosphere are shown in Table 4.13 (methane yield from the beds when biogas is not utilized).

According to the calculations, the total amount of biogas obtained from municipal sewerage sludge and utilized as fuel in 1990-1992 was in average 120 Mm^3 (thousand tones), and in 1993-1995 it was 100 Mm^3 (thousand tones). The highest degree of biogas utilization (practically complete) is a characteristic feature of two largest treatment stations of Russia and Europe (Moscow). Unfortunately, in a number of middle- and small-size towns in Russia the degree of biogas utilization is lower, or it is not conducted at all.

Table 4.13

Methane emission to the atmosphere from the municipal wastewater treatment systems in 1990-1995

Region	Emission (t)		
	From the Digesters and the Sludge Beds for Fermented Sludge	From the Sludge Beds for Non-Fermented Sludge	Total
Moscow City	600	0	600
North	4430	0	4430
North-West	3700	0	3700
Central (not including Moscow)	22080	0	22080

Volga-Vyatka	4160	0	4160
Central-Chernozem	2270	0	2270
Volga	21090	0	21090
North-Caucasus	16470	5850	22320
Ural	28230	0	28230
West-Siberia	17500	0	17500
East-Siberia	4420	0	4420
Total	125450	5850	131300
Unaccounted Systems (10%)	12545	585	13130
In All	**137955**	**6435**	**144430**

4.3. N_2O Emissions from Solid Waste Incineration

Emission of such a type are the result of incineration of municipal solid wastes (MSW) and sludge produced by wastewater treatment (IPCC, 1995).

The amount of MSW transported to incineration plants was 1,5 Mt in 1990 (or 5.8 per cent of the total amount of MSW stored). The use of emission factors of 26-293 g N_2O /t recommended by the IPCC results to emission estimates equal to 0.039-0.45 kt (the uncertainty reflects this one of the emission factors). So, the mean value of emission is 0.24 kt per year.

Actual emission can some exceed the calculated one for two reasons:

- incineration of MSW not transported by municipal services and therefore not taken into account by statistics; for example Moscow municipal committee for environmental protection estimates illegal waste deposition as 20 per cent of the total industrial and municipal solid waste.
- rather widespread partial burning of MSW transported to the landfills before their final landfilling.

In this connection, one can expect that the probable value of N_2O emission from MSW incineration will by closer to the upper limit of the uncertainty interval, than to its middle; we estimate is as 0.35 kt.

Incineration of sludge produced by wastewater processing, is not done in Russia. Sludge is either landfilled, or used as agricultural fertilizer.

Let us estimate the distribution of emissions from MSW incineration by the RF economic region. Table 4.13 shows capacities of operating MSW incineration plants and N_2O emissions calculated supposing that real emissions are distributed by the plants in proportion to their capacity. Emissions by the economic region were calculated on the base of these data (Table 4.14).

Table 4.13

N_2O Emission from MSW Incineration Plants in the RF

City	Capacity (kt MSW/year)	Emission (t/year)
Moscow (2 plants)	275	109
Vladimir	52	21
Vladivostok	105	42
Sochi	110	44
Murmansk	100	40
Pyatigorsk	240	95
Total	**882**	**351**[1)]

1) difference from 0.35 kt per year is a result of rounding.

Table 4.14

Distribution of Emission from MSW Incineration Among the Economic Regions of Russia

Region	Cities	Emissions	
		t/year	%
North-West	Murmansk	40	11.4
Central	Moscow, Vladimir	130	37.0
North-Caucasian	Pyatigorsk, Sochi	139	39.6
the Far East	Vladivostok	42	12.0
Total		**351**	**100.0**

5. Anthropogenic Atmospheric Formation of N_2O

Except for direct emission, there is one else way of N_2O emission to the atmosphere. It is N_2O production in the troposphere from atmospheric NH_3. Correspondingly, N_2O resulted from oxidation of anthropogenic NH_3 should be considered as a constitutional part of N_2O anthropogenic emission. According to the published estimates, 1.3 per cent of the total NH_3 amount emitted to the atmosphere is oxidized to N_2O. In the temporal latitudes this process is less intensive because of lower OH concentration in troposphere. In particular, it was proposed to use oxidation factor of 0.01 (0 - 0.05) per cent for emissions from the territory of the Netherlands.

On the base of data obtained by many investigators, emissions from animal wastes and fertilizers are in total about 90 per cent of NH_3 anthropogenic emission. Delivery of nitric fertilizers to agriculture (recalculated to 100 per cent N_2) was 4217 kt in 1990. Emission factors (N emission to the atmosphere as NH_3) for nitric fertilizers of different kinds vary within the range of 1-15 per cent. In average, emission factor is considered to be equal to 5-8 per cent. Using emission factor of 8 per cent, we obtain emission of 337 kt N, i.e., 410 kt NH_3.

NH_3 emission factors for animal wastes, animal population in 1990 and emissions are shown in Table 5.1. It is necessary to note that under Russian conditions with its less intensive technologies of live-stock-raising than in Western Europe, the emission factors can be some lower than shown in Table 5.1. However, we not posses any quantitative information on this problem.

Table 5.1

NH_3 Emission from animal wastes

Animal type	Animal population (mln)	Emission factor (kt NH_3/mln head $*$ yr)	Emission (kt NH_3)
Cattle	57.0	18.0	1026.0
Swine	38.3	2.8	107.0
Sheep and goats	58.2	3.1	180.0
Horses	2.6	9.4	24.4
Poultry	659.8	0.26	171.6
Reindeers	2.3	5.0[1)]	11.5
Total			**1520.5**

1) Autohor's' estimate

Emission from body wastes should by added to emission from animal wastes, emission factor in this case is estimated as 1.3 kg NH_3-N/year per capita. In 1990 population number in Russia was 109.239 mln people, and emission of this kind was 193 kt NH_3-N or 303 kt NH_3.

From the RF Goscomstat data, NH_3 emission from industry (stationary sources) was 59.5 kt in 1992 (including fertilizers' production). Emissions from mobile sources should be added to this value (according to our estimate, about 12 kt).

And, finally, NH_3 emission from arable soils can be estimated on the base of the area of agricultural lands (it was 222.1 M Ha in 1988 and emission factor about 3 kg/Ha per year. Emission of such a type is about 670 kt per year in the RF.

So, the total NH_3 emission from Russian territory is estimated as 2.9 Mt in 1990. Using above mentioned oxidation factor on nitrogen basis equal to 0,01 per cent, we obtain the amount of N_2O produced in the atmosphere: 0,83 kt per year.

6. Emissions of Indirect Greenhouse Gases

Data on the amount of three types of indirect greenhouse gases, namely CO, N_2O and NMHC emitted by stationary sources in all sectors of national economy is available from the State statistics (Table 6.1).

Table 6.1

Emissions of Indirect GHGs From Stationary Sources in the USSR and Russia in 1990

GHG	USSR (includ. Russia)		Russia	
	Emission[1] (Mt)	Degree of trapping (%)	Emission[1] (Mt)	Degree of trapping (%)
CO	15.7	18.9	8.1	38.0
NO_x	4.6	9.6	3.0	9.4
Hydrocarbons (without VOC[2])	6.8	18.2	4.1	20.1

1) Not includes trapped gases
2) VOC - volative organic compounds

Data on emissions from mobile sources is not collected by the State statistics. By this reason, emissions from mobile sources included in the section 2.1.2 were estimated (according to the adopted in Russia methodologies, see reference list) using the emission coefficients for road vehicles, locomotives and aircraft listed in Table 6.2, and emission coefficients for marine and river transport included in Table 6.3.

Table 6.2

Emission Coefficients of Indirect Greenhouse Gases Emissions

Pollutants	Emission coefficient (t/t fuel consumed)						
	Gaso-line AI-93	Gaso-line A-76	Diesel Oil	LPG	Natural Gas (comp-ressed)	Engine Oil	Kero-sene
Carbon monoxide	0.25	0.36	0.03	0.36	0.15	0.03	0.05
Hydrocarbons	0.031	0.039	0.015	0.039	0.021	0.012	0.03
Nitrogen oxides[1]	0.03	0.03	0.06	0.03	0.026	0.054	0.034

1) - 100% conversion to NO_2 assumed

Table 6.3

Experimental data on pollutant emission from combustion of one ton of different fuel types in the engines of sea ships and river boats

Pollutants	Emission coefficient (t/t fuel consumed)	
	Diesel oil	Engine oil
Carbon monoxide	0.03	0.03
Hydrocarbons	0.015	0.012
Nitrogen oxides[1]	0.06	0.054

Results of estimation are shown in Table 6.4.

Table 6.4

Emissions of Indirect GHG's from Road, Railroad, Marine, River and Air Transport (1990)

Type	Emissions (Gg)		
	CO	NO_x [1)]	NMHC
Passenger Cars	1345	197	261
Urban and Road Buses	2902	232	225
Light Trucks	2023	265	247
Heavy-Duty Vehicles	3950	1320	616
Road Transport Totals	10220	2014	1349
Passenger Locomotives	30	68	7
Cargo Locomotives	196	666	58
"Industrial" Cargo Locomotives	38	125	11
Railway Transport Totals	264	859	76
Internal River Transport	46	122	32
Marine Transport	30	74	21
Aviation	177	66	112
Transport Totals	**10737**	**3135**	**1590**

1) - 100% conversion to NO_2 assumed

As it was mentioned in section 2.1.2 some part of mobile sources of emission is not accounted for by the transport sector statistics. Corresponding to this sources emissions were not calculated and are not reflected in Table 6.4.

To include this emissions to inventory one can use data on fuel consumption from Table 6.5, showing share of accounted mobile sources in the total consumption of secondary liquid fuels in Russia. Correction coefficients for emissions were calculated using this data. The improved estimation of emissions (see Table 6.6) was made by multiplying emissions listed in Table 6.4 by this coefficients. (For emissions from diesel oil coefficient 2.5 was used instead of calculated 3.33 to reflect usage of diesel oil by stationary combustion for local electricity production in the northern and other distant regions of the country).

Table 6.5

Fuel consumption by transport sector of RF

Fuel type	Volume of consumption in RTC (% of total consumption)	Correction Coefficient
Motor gasoline	93	1.08
Aviation gasoline	95	1.05
Diesel oil	30	3.33
Engine oil	95	1.05
Naval black oil	95	1.05
Jet kerosene	55	1.82
Gas-turbine oil	95	1.05

1) - 100% conversion to NO_2 assumed

Bunker fuels were not extracted from the total amount of fuels in this calculations, resulting in overestimation of total GHGs emissions by first per cent (for the estimation share of bunker fuels in the total consumption of fossil fuels see section 2.1.1). Emissions of NMHC are expected to be even more overestimated due to the fact that some adopted in Russia methodologies used for described above estimations do not provide subtraction of CH_4 from emissions calculated. Total uncertainty of this estimates seems to be relatively high.

Table 6.6

Indirect GHG's Emissions from Mobile Sources (1990)

Type	Correction Coefficient	Emissions (Gg)		
		CO	NO_x[1)]	NMHC
Passenger Cars	1.08	1453	213	282
Urban and Road Buses	1.08	3134	251	243
Light Trucks	1.08	2185	286	267
Heavy-Duty Vehicles	2.5	9875	3300	1540
Road Transport Totals		16647	4050	2332
Passenger Locomotives	1.00	30	68	7
Cargo Locomotives	1.00	196	666	58
"Industrial" Cargo Locomotives	1.00	38	125	11
Railway Transport Totals		264	859	76
Internal River Transport	1.05	48	128	34
Marine Transport	1.05	32	78	22
Aviation	1.82	322	120	204
Transport Totals		**17313**	**5235**	**2668**

1) - 100% conversion to NO_2 assumed

Combining results of this calculation with data on emissions from stationary sources (Table 1.1) results in estimates presented in Table 6.7.

Table 6.7

Indirect Greenhouse Gases Emissions in Russia (1990)

GHG	Emissions (Gg)		
	CO	NO_x[2)]	NMHC
From Stationary Sources	8100	3000	4100
From Mobile Sources[10]	17300	5200	2700
Totals	**25400**	**8200**	**6800**

1) - Rounded

2) - 100% convertion to NO_2 assumed

7. Conclusions

The emission-related activities in the Russian Federation were analyzed and technogenic GHG's emissions calculations for the three key greenhouse gases: CO_2, CH_4 and N_2O were carried out, resulting in the following estimates of the 1990 emissions:

CO_2:

* CO_2 emission from energy sources - 625 MtC, including 228 MtC from liquid fuels, 156 MtC from solid fuels and 241 MtC from natural gas;
* CO_2 emission from cement production - 11.3 MtC;
    - Total CO_2 emission (not including emission from bunker fuels) - 636 MtC;
    - Emission from maritime and aviation bunker fuels - 3.5 MtC

CH_4:

* CH_4 emission in the gas sector - 16.0 (11.8-26.5) Mt CH_4;
* CH_4 emission from solid fuel - 2.9 Mt CH_4, including 2.3 Mt CH_4 from underground mining, 0.17 Mt CH_4 from surface mining, and 0.4 Mt CH_4 on the post-mining stage;
* CH_4 emission from liquid fuel - 0.07 (0.009-0.13), not including emissions from oil prospecting and exploration;
* CH_4 emission from municipal solid waste - 1.8 Mt CH_4;
* CH_4 emission from municipal and industrial wastewater treatment - 0.14 Mt CH_4;
    - Total CH_4 emission - 20.9 Mt CH_4

N_2O

* N_2O emissions from energy: mobile combustion - 8.6 kt N_2O, stationary combustion - 15.9 kt N_2O, combustion of traditional fuel (fuelwood) - 1.8 kt N_2O;
* N_2O emission from industrial sources: 2.0 kt N_2O from medical use, and 3.0 kt N_2O from the production of nitric acid;
* N_2O emission from solid waste incineration - 0.35 kt N_2O.
* N_2O emission by oxidation of technogenic NH_3 emitted from Russian territory is preliminary estimated at 0.83 kt N_2O.
    - Total N_2O emission - 32.5 kt N_2O.

Emission of CO_2 prevails in the total technogenic emission, the grater part of it being from energy sector (fossil fuels). CH_4 emission is on the second place with gas sector playing the leading role.

Estimates of 1990 emissions of in economic regions of the Russian Federation were carried out to investigate distribution of emissions on the territory of Russia.

Emissions of indirect GHG's (CO, NO_x, and NMHC) for 1990 were estimated using data of national statistics on stationary emissions and scientific estimates of mobile emissions.

The results included in this Report were partially used for the preparation of the First National Communication of the Russian Federation on the activity under the UN Framework Convention on Climate Change and will be used in the future work on fulfillment of RF's obligations under the Convention.

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