III. CASE STUDIES

1. SULFUR HEXAFLUORIDE IN ELECTRIC EQUIPMENT

Sulfur hexafluoride (SF_6) or, as its usually named in electrical engineering, insulating gas is a heavy, inert, nontoxic and incombustible gas. Its molecular weight - 146. Main its using in the world - a gas insulation in electrical transmittance systems and electrical distributing devices and making an inert cover or displacing the gas admixtures in metals smelting.

The industrial production of SF_6 began in 1953 in the United States. It was stimulated by the market introduction of electrical switchgears with gas insulation. In the same years studies on SF_6 application were started in the former USSR. From this period and to date production SF_6 in the World was constantly growing. Rate of this grow increased at the beginning 1970-es, a period of broad introduction of gas-insulated high-voltage swithgears and other electrical equipment. Correspondingly was increasing the rate of SF_6 emission, with the result that to 1995 in atmosphere has enter about 85 700 t. of this gas.

Atmospheric monitoring data clearly and distinctly indicate the increase of the SF_6 concentration in the surface layer from 0,6 ppt* in 1978, when monitoring was started, to 4.0 in 1997. Thereby, annual rate of increase SF_6 atmospheric content is near 7% . Studies of vertical and horizontal gradients of atmospheric concentrations confirms more or less obvious conclusion, that the main sources of sulfur hexafluoride emissions are located in the northern mid-latitudes, i.e. in industrial countries.

The interest to the greenhouse properties of sulfur hexafluoride and its inclusion to the list of GHGs under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (in which SF_6 is included into the "basket" of 6 GHGs for reduction) was caused mainly by the fact that it relatively strongly absorbs infrared radiation in the spectral "windows", where the Earth's heat flux deflects from surface through atmosphere to space. Besides this, the atmospheric lifetime of SF_6 is extremely large (estimated value is about 3 200 years). This value is determined solely by the rate of atmospheric destruction processes, that take place at high altitude, above 60 km. No other processes of removal SF_6 from the atmosphere are known at present. Hence, sulfur hexafluoride is a very effective GHG and anthropogenic sources of its emission outweighting sinks by orders of magnitude. No natural sources are known. The Intergovernmental Panel on Climate Change (IPCC) has adopted the value of Global Warming Potential (GWP) of SF_6 for 100-year time horizon** 23 900. It is by far the highest known GWP_{100} for greenhouse gases.

At present, the contribution of all atmospheric SF_6 to the total global warming is about only 0.1% of the total man-made warming by atmospheric CO_2. At the same time, the radiate forcing of the present SF_6 emission (emission is estimated at 5 900 - 6 500 t/yr) is near 0.7% of forcing related to the annual CO_2 emission*** *(Geller et al., 1997; Maiss and Brenninkmeijer, 1998; Olivier and Bakker, 1999).*

The described above properties of SF_6 caused its current presence in the list of gases being the subject of inventory and regulation. However, the reliable estimates of SF_6 emissions in Russia

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* 1 ppt corresponds to 10^{-12} moles SF_6/1 mole air.

** GWP_{100} is a parameter expressing relative grenenhouse effectiveness of individual GHGs. GWP_{100} of CO_2 by definition is equal 1.

*** annual anthropogenic emission of CO_2 is about 22 Gt/yr.

were lacking, inspite of attempts of some western authors *(Maiss and Brenninkmeijer, 1998, Olivier and Bakker, 1999).* Our study can be considered is a first attempt to estimate emission of SF_6 from the energy sector (electroenergetics) of Russia and first step in the process of accounting for the total SF_6 emission from all sectors of Russian economy. Some preliminary results of this study were included into our publication *(Kokorin et al., 2000).*

The following worldwide applications of produced SF_6 can be listed based on *Olivier and Bakker (1999)* publication*:*

- Production of electrical equipment (Gas Insulated Switchgears (GIS), circuit breakers, gas-insulated high-voltage lines and mini-stations),
- Utilities (use of electrical equipment - refilling, leakages compensation, accidents etc; use in accelerators for scientific and/or military purposes),
- Magnesium production (primary production and die castling), with application as cover gas in foundries to prevent oxidation,
- Adiabatic properties applications, notably in tennis balls, shoe soles and in truck tires,
- Electronic industry - semiconductor manufacturing (plasma etching and as an etchant before chemical vapor deposition),
- Other applications: soundproof windows, degassing of aluminum specialties, gas tracers, application in medical purposes etc.

It is noted that soundproof windows (double glazing) and truck tires filled with SF_6 are used mainly in Germany and, somewhat, in some surrounding countries. Use in primary aluminum production to degas aluminum specialties was not introduced widely and occurred only during several years in the 1990-es *(Maiss and Brenninkmeijer, 1998).*

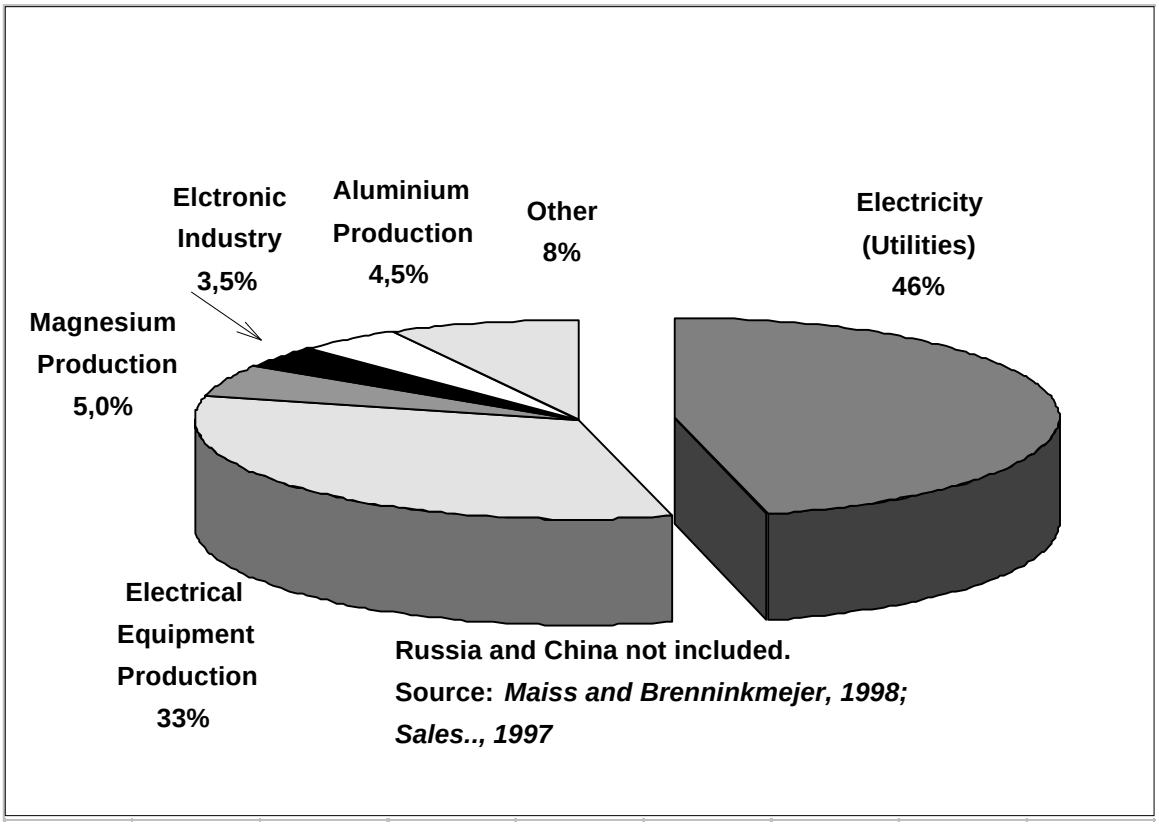
Figure 1 shows distribution of the world SF_6 production by end-use sector (1992 - 1996 averages, not including Russia and China). Total production of sulfur hexafluoride in Russia and China was estimated at 400 t. in 1992 and 880 t. in 1996, or about 12% of the total World production *(Maiss and Brenninkmeijer, 1998*; referred to the information of “Solvay Fluor und Derivate Gmbx”).

Beginning of practical introducing the gas-filled electrotechnical devices in Russia is dated from the end 1980-es. According to the information of RAO EES Russia (operator of the greater part high-voltage power lines and equipment in the country), towards the beginning 1990-es was used only about ten units of such equipment. During current decennial SF_6-filled equipment was introduced enough intensive and at present its share in the gross amount of the equipment stock of the RAO EES Russia is close to 10%.

Thirteen models of gas-filled circuit breakers on voltages 35, 110, 220, 330 and 500 kV are in use in the electroenergetic sector of Russia, including 9 domestic-designed models. Sulfur hexafluoride is also used in a number types of transformers and in the GISes on the voltages 110 and 220 kV. Four Russian plants produce SF_6-filled devices. Circuit breakers and transformers are installed at electricity supply networks in many regions of the country. GISes are used mainly in Moscow region, Urals and West Siberia. At the networks of the Novgorod region SF_6-filled devices are not installed.

Figure 3.1.1

Distribution of global SF_6 production by end-use (1992-1996 averages)



The generalized information on the number of SF_6-filled equipment, sulfur hexafluoride contents and its emission to the atmosphere due to leakages (1999 data) is included in the Table 3.1.1. It is necessary to note that all equipment, installed at the 110 kV and higher-voltage networks belongs to the RAO EES Russia power networks, whereas substantial part of 35-kV equipment is operated by independent local networks.

Estimates of emissions, included in Table 3.1.1, are based on the exploitation leakage normative prescribed by technical conditions on various types of devices. According to the normative, equipment produced in 1980-es characterized by annual leakages of 2-3%, to the middle 1990-es normative values decreased to 1%. At present there is no data on actual (measured) emissions from the equipment, being in use. According to our estimates, the 1999 weighted averages of leakages are 1.13% per year for operated in the country GISes, and 2.83% per year for circuit breakers stock. Emission from transformers was estimated, based on average annual leakage of 1.5%.

Thereby, taking into consideration the SF_6 contents in the equipment, the generalized emission factor is estimated at 1.16 kg/unit of equipment per annum. In future this factor will apparently tend to decrease as a result of expected removal or modernization of elder types of equipment and introduction new ones with lower leakage rates.

At present, the greater part of the SF_6-filled equipment is in the beginning or middle of its life cycle. By this reason, emissions related to the equipment withdraw and utilization are considered negligible and do not accounted for in our study. More important is to estimate SF_6

emissions from the production of electrical equipment. Unfortunately, information on emissions from Russian manufacturers is lacking. The analysis of data from different sources *(e.g. NEMA, 1997; 1998; SF6-switchgear.., 1998)*, carried out by *Maiss and Brenninkmeijer (1998)*, shows that in the USA, European region and Japan emissions in the process of manufacturing are about 40-42% of the total SF_6 contents in the equipment. (Emissions from development, testing and installation are included to this amount for Japan). In China emissions expected to be about 100% of the SF_6 contents.

Table 3.1.1

Number of SF_6-filled equipment and estimated emissions from leakage

Equipment	Number of Units	Total SF_6 Contents, t	Annual Emission, kg
GISes	39	44.5	503
Transformers	168	0.76	11.3
Circuit Breakers			
RAO EES	502	4.88	138
Local companies	≈70	≈0.28	≈4.2
Totals	**≈570**	**≈50**	**≈660**

Olivier and Bakker (1999) assume the slightly lower emissions: 30% of the total contents for years prior to 1990 and 12% since 1995 for the European manufacturers and 35% of content for Japanese ones. For manufacturers of circuit breakers in the USA the amount of emission is estimated 55% for years up to 1970, decreasing to 29% in 1995. Manufacturing in other countries is expected to cause 50% emission.

By using the data from Table 1 and assuming 40% emission for Russian manufacturers, we can estimate the total sulfur hexaftoride emission to the atmosphere from this source at 20 000 kg for the whole 1985 - 1999 period.

Other sources of SF_6 emissions in Russia, obviously, play well smaller role. Sulfur dioxide, not SF_6, is used as a cover inert gas in magnesium production. Information on SF_6 use in electronic industry is lacking, however it is known that falling-off of production in this branch in 1990-es was one of the most greater in Russia and, consequently, emissions can not be significant at present. SF_6-filled tires and footwear are not produced in the country. Soundproof windows also are not manufactured (but possibly in small quantities can be imported ready to installation. For getting quantitative information on this applications it is necessary undertaking the additional studies.

To estimate contribution of estimated sulfur hexaftoride emission to the total GHG emission in the country, can be used the results of the 1996 CO_2 Russian emission inventory (to be presented to the UNFCC). National totals of the CO_2 emission was 1496 Mt in that year. According to the Table 1 data, the 1996 utility emission in the electroenergetics equals 0.66 t/yr. (the 1996 emission of SF_6 considered roughly the same as the 1999 emission presented in Table 1). It can be assumed that not more 15% of the total 1985 - 1999 emission of sulfur hexafluoride from the equipment manufacturing (3 tons) was released to the atmosphere in 1996. By multiplying the sum of these two emissions by the GWP_{100} of sulfur hexafluoride (GWP_{100}=23 900, see above), the equivalent emission of approximately 87.5 kt CO_2 can be

obtained. It makes 0.006% of the total CO_2 emission in Russia. Share of the SF_6 in the total GHG emission can be easily estimated based on the fact, that contribution of the CO_2 to the total Russian emission is slightly more 70%.

As for the electroenergetic sector (big power stations generating marketable electricity and heat), its CO_2 emission was 517 Mt in 1996. The CO_2-equivalent of the SF_6 emission from utilities (emission from equipment manufacturing not considered because, according to the IPCC/UNFCCC classification, it is allocated to the industrial, rather then energy, sector) is 0.016 Mt, i.e. 0.003% of the CO_2 emission related to electroenergetics. Thereby, contribution of the SF_6-filled equipment to the total GHG emission in the electroenergetics of Russia is practically unimportant.

It can be also mentioned, that the SF_6 emission of 0.016 Mt CO_2-equivalent is by four orders of magnitude less than the total decrease of the CO_2 emission from electroenergetics in the 1990 - 1996 period (it decreased by about 200 Mt, according to the RAO EES statistics). So, possible in the nearest years increase of emission from SF_6 (due to introduction of new equipment) is expected to be substantially less (in the CO_2-equivalent), then the emission trend occurring from changes in the amount of fossil fuels burning.

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2. METHANE EMISSIONS AT COAL MINES

Underground coal mining is entailed by methane emissions from coal bearing formations, constituting certain technological hazard. To secure safety conditions, degasification of coal strata and gob areas is employed alongside with ventilation of mining entries, when methane diluted with air is delivered to the surface. In the process of surface coal mining coalbed methane liberates into atmosphere in a normal way.

About 55 percents of Russia's underground coal output is related to Kuznets coal basin (Kuzbass), the major part of which is located within boundaries of Kemerovo region. Worth to note, that nearly 70 percents of entire cocking coal production comes from the region. Kuznetsk coal basin's area amounts to – 26.7 thousand km^2, the maximum length - 335 km, width - 110 km. Total geological coal reserves of Kuzbass to 1,800 meters depth are estimated to 637 billion tonnes. By some estimates, methane resources incorporated within Kuzbass coal seams quantifies 13.1 trillion m^3 [1-4].

Herein IPCC methods application aimed for Kuzbass coalbed methane emissions estimate will be considered. In conformity with methods to define total methane emissions their amounts, produced during following operations are taken into consideration:

- coal underground mining;
- coal surface mining;
- successive coal handling.

Extracted and utilized methane volumes are subtracted from aggregated methane emissions amount.

Estimation of methane emissions liberated in the process of underground coal mining becomes the most significant, as the mining process is performed at big depths, where coal seams are specific with high gas content. To secure coal mining safe operation, engineering services of coal mines undertake steady control of methane emissions, therefore averting their penetration into mining entries and making them gassy ones. Control data can be obtained at regional office of Mines' Health and Safety Department (Gasgortechnadzor) with high accuracy, corresponding to Tier 3 of IPCC methods. Table 3.2.1 exhibits a data fragment of a coal yield and absolute methane emissions at Kuzbass coal mines for 1998 year period, employed for the estimate of methane emissions, produced during underground coal mining.

Table 3.2.1.

Part of data, employed for the estimate of methane emissions at Kuzbass coal mines in 1998

Mine	Coal output (10^3 x tonnes)	Absolute methane emissions (m^3/min)	Total methane emissions (m^3)	Total methane emissions (10^3 tonnes)
Fizkulturnik	380	0.86	452,016	0.30
Sibirskoye	550	1.94	1,019,664	0.68
Pervomaiskaya	750	15.85	8,330,760	5.58
Berezovskaya	495	18.41	9,676,296	6.48
Volkova	270	7.03	3,694,968	2.48
Kirova	2,119	60.4	31,746,240	21.27
Koltchuginskoye	815	6.5	3,416,400	2.29
7th November	1,048	32.6	17,134,560	11.48
Jaroslavskogo	480	17.1	8,987,760	6.02
Komsomolets	830	85.8	45,096,480	30.21

Changes of coal output mined by underground method and methane emissions reduction in the period between 1990 –1998 years are exhibited on Fig. 3.2. 1.

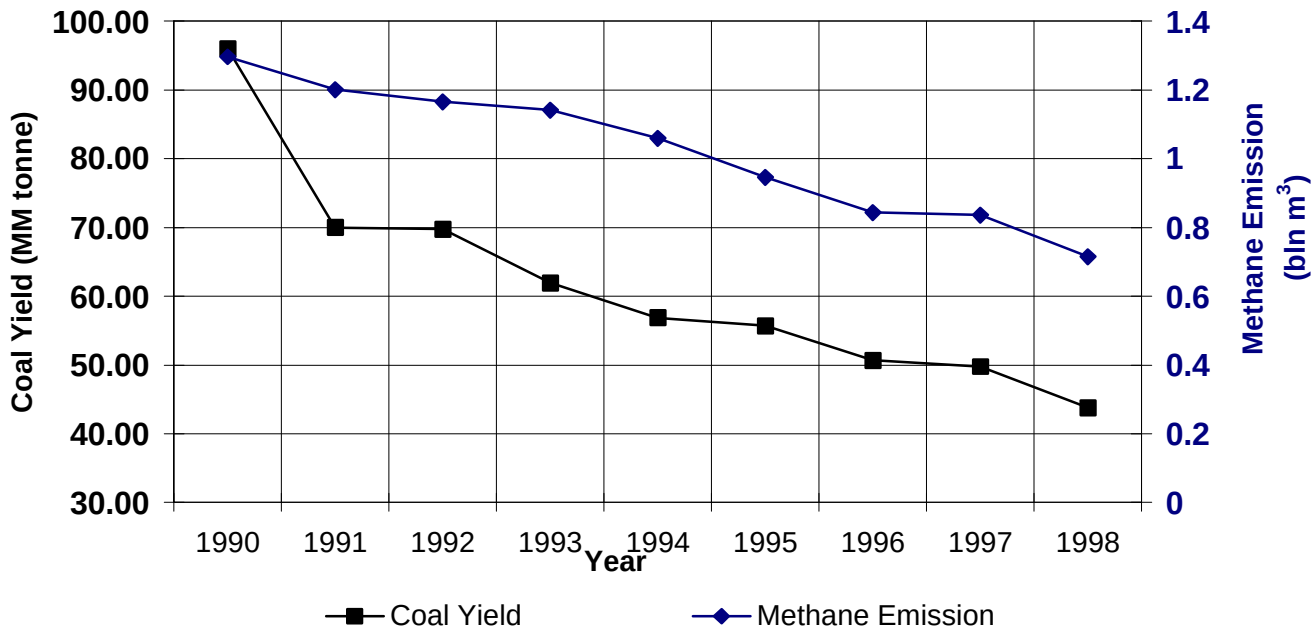

Figure. 3.2.1. Methane emissions and coal output mined by underground method in kuzbass from 1990-1998

Methane emission induced by surface coal mining was estimated by the following equation:

Emission (Gg Ñ´$_4$)* = [Methane content *(m^3 Ñ´$_4$/tonne)
+ Tentative Coefficient of Emission for Surrounding Strata
(m^3 Ñ´$_4$/tonne)*] ´ *Coal Output Produced by Surface Mining (tonne)´
***Converting Coefficient (0.67 Gg/10^6 m^3)*].**

Conducted analysis of geophysical data, available at the region's biggest coal company Kuzbassrazrezugol, that comprises a major portion of Kuzbass open pits, has revealed insufficient study of desorption properties of coal seams mined by surface method. Therefore, methane content was defined indirectly, on the premises of coal rank information, pertaining type of coal mined at certain open pit and known compliance of gas content with a coal rank. In case of data deficiency a gas content was assumed equal to a mean value, established for Kuzbass open coal pits – 8.50 m^3/t.

Table 3.2.2. Estimate of methane emissions induced by surface mining

Surface Mine	Coal output (10^3 x tones)	Coal rank	Gas content , (m^3/tonne)	Methane emissions (10^3 tonne)
Kedrovsky	5,501.7	Baking	8.50	31.33
Mokhovsky	1,538.5	Long-Flame	6.00	6.18
Sartaki	1,579.1	Long-Flame	6.00	6.35
Karakannsky	1,775.0	Long-Flame	6.00	7.14
Batchatsky	6,503.9	Baking	8.50	37.04
Krasny Brod	3,235.0	Lean	9.50	20.59
Kiselevsky	1,071.2	Baking	8.50	6.10
Vakhrushevrazreugol	1,612.5	Fat, Long-Flame	8.50	9.18
Taldinsky	2,943.2	Fat, Long-Flame	8.50	16.76
Erunakovsky	2,311.7	Fat	8.50	13.17
Listvaynsky	1,140.0	Lean	9.50	7.26
Kaltansky	786.3	Lean	9.50	5.00
Osinnikovsky	1,448.8	Lean	9.50	9.22
Krasnogorsky	3,008.0	Lean	9.50	19.15
Tomoosinsky	3,223.0	Baking	8.50	18.35
Sibirginsky	2,469.0	Lean	9.50	15.72
Olzersky	1,303.0	Fat, Baking, Lean	8.50	7.42
Barzasky	219.0	Data n/a	8.50	1.25
Shestaki	185.0	Baking	8.50	1.05
Prokopjevsky	530.0	Data n/a	8.50	3.02
Taldinsky-Severny	487.0	Data n/a	8.50	2.77
Berezovsky	141.0	Data n/a	8.50	0.80
Mezdurechensky	4,003.2	Lean, Baking, Coking	10.00	26.82
Chernigovsky	3,429.3	Baking	8.50	19.53
Zadubrovsky	500.0	Data n/a	8.50	2.85

Table 3.2.2 presents information, employed for the estimation of methane emissions, produced during surface mining in Kuzbass in 1998.

Changes of coal output mined by surface method and related fluctuation of methane emissions are exhibited on Fig. 3.2.2

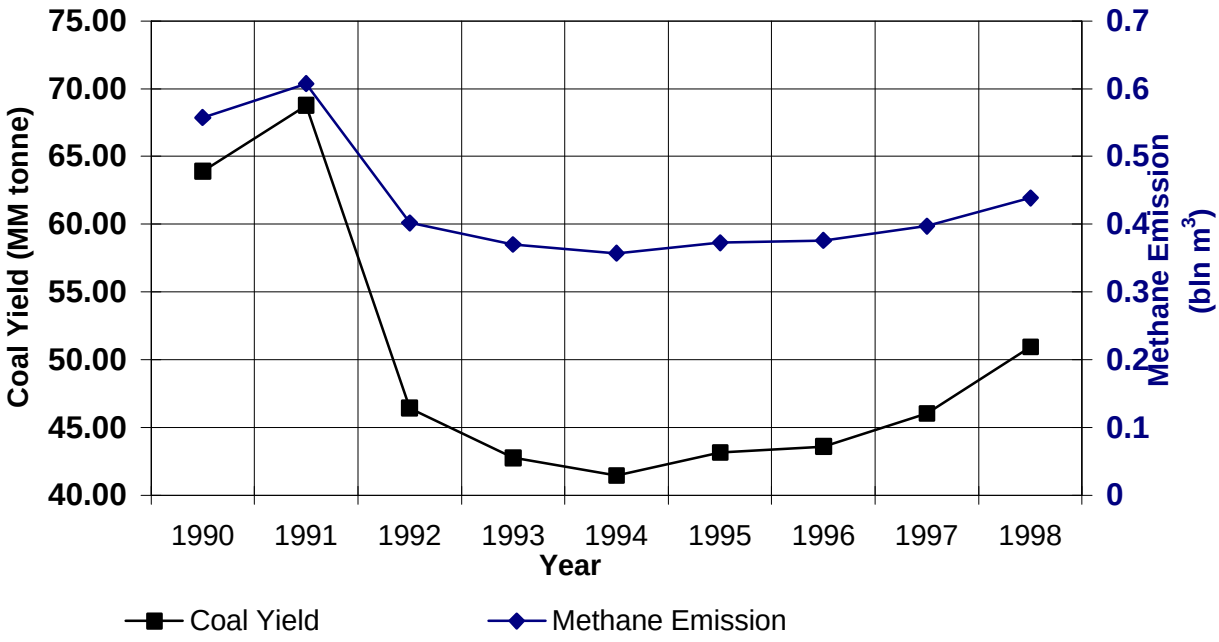

Fig. 3.2.2. coal output and methane emissions during surface coal mining at Kuzbass mines in 1990-1998

Emission, stipulated by successive coal handling was estimated with the formula:

Emission (Gg Ñ˝$_4$) = Methane content (m^3 Ñ˝$_4$/t)
´ Amount of Coal Produced by Underground Method (tonne) ´ Portion of Methane Released During Successive Coal Handling (%)
***´ Converting Coefficient (Gg/10^6 m^3)*]**.

Calculation was performed with assumption that methane from coal, mined by underground or surface method emitted into atmosphere during a coal extraction stage. Methane portion released during successive coal handling was assumed as equal to 31%. Table 3 displays primary data fragment and estimate of methane emissions released during successive coal handling. Fig. 3 presents the estimate of methane missions induced by successive handling of coal, mined by underground method

Table 3.2.3. Estimate of methane emissions during successive coal handling (transportation, processing)

Mine	Methane content (m^3/tonne)	Coal output (10^3 x tonnes)	Methane emissions (m^3)	Methane emissions (10^3 tonnes)
Fizkulturnik	14.5	380	179,075	0.12
Sibirskoye	12	550	214,500	0.14
Pervomaiskaya	25	750	609,375	0.41
Berezovskaya	26	495	418,275	0.28
Volkova	13	270	114,075	0.08
Kirova	21	2,119	1,446,218	0.97
Koltchuginskoye	17	815	450,288	0.30
7th of November	16	1,048	544,960	0.37
Jaroslavskogo	15	480	234,000	0.16
Komsomolets	20	830	539,500	0.36

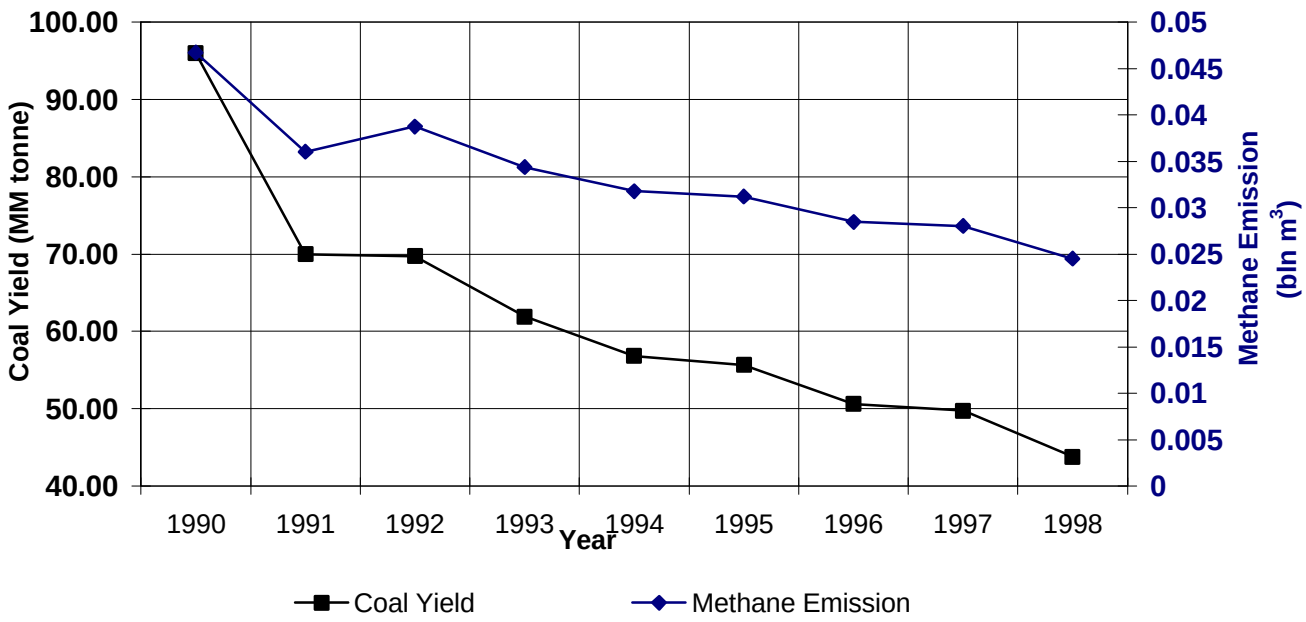

Fig. 3.2.3. Reduction of coal output mined by underground method and methane emissions during successive coal handling in 1990-1998

Degasification of coal seams is undertaken in Kuznetsk coal basin. Methane captured by degasification facilities is of high concentration (40-90%) within a methane\air mixture and may be effectively used for heat and electricity generation. Fluctuation of methane captured volumes in Kuznetsk coal basin is exhibited on Fig. 4. Utilization of methane on commercial basis is not currently undertaken in the region. Therefore, amount of utilized methane was not included into overall estimate of methane emissions.

Overall methane emissions estimate obtained with regard of methane emission induced by underground and surface mining, incorporating as well those, produced during coal transportation and processing is shown on Fig. 3.2.4

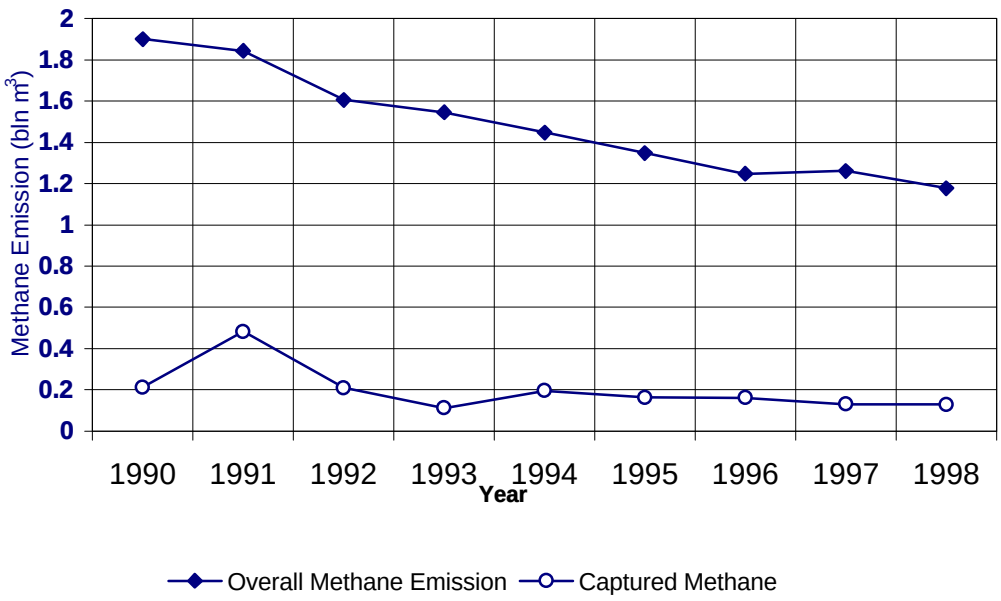

Fig. 3.2.4. Total methane emissions and methane captured amount in Kuzbass in 1990 – 1998

Methane emission analysis, conducted on the bases of IPCC method's recommendations has revealed a sharp methane liberation decline into atmosphere in Kuznetsk coal basin from 1,265 tones to 786 tones per annum. However planning coal yield increase for 2000 year may cause some changes in the existing tendency

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3. PROBLEMS OF EMISSION ESTIMATION IN FORESTS

According to United Nations Framework Convention on Climate Change (UN FCCC), the Parties of the Convention are obliged to make regular inventories of greenhouse gas (GHG) emissions (Climate Change, 1995). Within the frames of UN FCCC Kyoto Protocol, Russian Federation faces the task of precise control on GHG emissions in various sectors of national economy including land use change and forestry. A special attention should be drawn to development of forests on lands that formerly have been under different land use. The aim of this case study is to consider practical application of Articles 3.3 and 3.4 of Kyoto Protocol and make a preliminary assessment of carbon dioxide sinks defined in accordance to Article 3.3 for the territory of Novgorod region that is taken as an example.

Objects and methods

As follows from the Articles 3.3 and 3.4 of Kyoto Protocol, the increase of netto sinks of greenhouse gases (GHG) can be achieved as a result of direct human-induced activities on aforestation and reforestation, i.e. by development of artificial forests on lands that have been previously under different use. Besides, it is important that these types of activities should be performed after the year 1990. Practically speaking carbon dioxide (CO_2) sinks are defined as artificial forest stands developed as a result of anthropogenic changes in land use. Table 3.3.1 illustrates development artificial forests (forest plantations) on lands that have been accepted by Novgorod Regional Department for Forestry form other types of land use.

Table 3.3.1.

Forest plantations developed in 1990-1998 on lands that have formerly been under other land use, but were accepted by Novgorod Regional Department for Forestry.

Year	The area of forest plantations (ha) developed on lands that previously were		
	peat mines	sand-pits	agricultural lands
1990	35	-	-
1991	-	-	-
1992	50	-	-
1993	30	-	5
1994	47	16	48
1995	63	7	157
1996	154	16	83
1997	20	27	23
1998	86	41	106

It may seem that all types of human activities in Table 1 fit in the definitions of Articles 3.3 and 3.4 of Kyoto Protocol. However, the IPCC definition sets time frames for the changes in land use. Based on this time frames, only forest plantations on former agricultural lands are fully consistent to definition of “aforestation” of the Kyoto Protocol. Therefore, the objects of investigation were forest stands developed since 1990 on former agricultural lands in Novgorod region.

Formation of highly productive forest stands is a priority task of artificial forestry. Therefore, in young plantations forest management activities are aimed at development of quality stands. Besides, the majority of activities start, as soon as the plantations have been transferred into forested land category (The Instruction on Management Cuttings, 1996). As a rule, the transfer into forested land is performed, when the plantations are 6 years old. Meanwhile, the earliest assessments of forest stock are made for 20-year-old stands (Tretyakov et al., 1952). It must be noticed that present methods enable evaluating biomass of dominant forest component that

is the tree layer, whereas ground vegetation cover and undergrowth lack of sufficient assessment. Consequently, it is a rather difficult to estimate biomass of forest plantations that are less than 10 years old.

Several assumptions have been made to make the appropriate assessments. These are based on the information on typical forest management practices and forest planting technologies applied over the territory of Novgorod region. So far as in 90% of cases regional artificial forests are formed with spruce, it was assumed that pure spruce plantations are developed on former agricultural lands. The 3-year-old spruce seedlings were considered as the material that is normally used for planting. According to regional forestry experts, from 4000 to 4500 seedlings are planted per 1 ha of lands. Their vitality varies from 90 to 93%. Therefore, the value of 4250 seedlings per 1 ha was taken for our calculations. The vitality of newly planted trees as assumed 92%. Thus, in 1998 the age of artificial spruce stands on former agricultural lands of Novgorod region was determined as the sum of number of years passed since the time of planting and the value of 3 years that the seedlings grew in nursery. Table 3.3.2 presents age of spruce forest plantations developed on former agricultural lands of Novgorod region as they were for the year 1998.

Table 3.3.2.

The age of spruce forest plantations on former agricultural lands of Novgorod region as they were for the year 1998.

The year of planting	The age of plantations in 1998, yeras
1993	8
1994	7
1995	6
1996	5
1997	4
1998	3

Based on reference data and expert judgment, the following methods of forest stock assessment were identified for young artificial stands:

1. In case forest plantations are 6 years old or less, their stock per 1 hectare is determined according to “The Stock of Young Stands in Cubic Meters per Hectare” Reference Manual that was compiled in 1981 by South-Eastern Forest Inventory Enterprise under *Lesproekt* All-Union Association.
2. The stock of plantations elder than 6 years is estimated based on the scale of one tree in bark according to Zagreev et al. (1992) and subsequent recalculation into stock per 1 hectare with regard to stand density and tree vitality.

Both methods of assessments were applied to estimate the stock of forest plantations on former agricultural lands of Novgorod region. Therefore, the biomass of forest plantations developed in 1993-1994 and 1995-1997 was calculated independently. The biomass of artificial forest stands developed in 1998 was not estimated, because no methods are currently available for biomass assessment of 3-year old forest stands.

The average diameter at breath height (1.3 m) of 7- to 8-year-old spruce stands (planted in 1993 and 1994) was assumed 1.0 cm, whereas their height was taken about 2.0 m. Then the volume of 1 tree in bark was 0.0002 m^3 (Zagreev et al., 1992). The stock per hectare was obtained from multiplication the number of trees per hectare by the volume of one tree. The number of trees per hectare was calculated based on average number of seedlings planted (4250 per ha) and their mean vitality (92%).

According to regional experts, the average height of 3- to 6-year-old spruce stands is about 0.6

m. Average density of young stands is about 0.4 (Zagreev et al., 1992). As follows from "The Stock of Young Stands in Cubic Meters per Hectare" Reference Manual, the stock of spruce plantation density 1.0 is 4.0 m^3/ha. Consequently, it is 1.6 m^3/ha for the density 0.4

Values of stand stock were recalculated in tones of dry matter with the use of conversion factors for young stands 1.190 t/m^3 (Isaev et al., 1993) and 0.5 for dry matter (*Revised 1996 IPCC Guidelines*, 1997). Results of calculations were used for determination total biomass reserves. The calculation was made according to percentage ratio for pine stand components taken from Lozovoy et al. (1990). The 10-year-age pine and spruce stands are assumed to be almost similar. The obtained results were transformed in CO_2 and expressed in Gg.

Results and discussion

Table 3.3.3 presents the stock of spruce stands of various age per hectare and for total area.

Table 3.3.3.

The stock of spruce plantations per 1 hectare and for total area.

The age of plantation, years	Stock, m^3/ha	Total area of plantations	Resulting stock for total area of plantations, m^3
3-6	1.60	263	420.80
7-8	0.78	53	41.45

As follows from Table 3, the stock per hectare of spruce plantations of various age differs almost 2 times. Obviously it is because the accuracy of assessment methods applied. No doubt that the assessments for 7- to 8-year old spruce stands are more precise than rough estimates for the younger ones. But there is no information available on the volume of 3- to 6-year-old trees in bark. Hence, both methods have limited possibilities of application and therefore, they need to be used together.

Table 3.3.4 presents the percentage ratio between components of pine stands in dry matter that were calculated based on the data by Lozovoy et al., (1990). This ratio was used to estimate total biomass of spruce stands on former agricultural lands of Novgorod region after 1990.

Table 3.3.4.

The percentage ratio between pine stand components in dry matter (calculated according to the data of Lozovoy et al., 1990).

Parameter	Percent of total stand biomass, %
Stem with bark	66
Live shoots	9
Needle	9
Roots	16
Total	100

The stems with bark are about 66% of total stand biomass (Table 3.3.4). Consequently, it is possible to calculate total stand biomass accumulated by the year 1998. Table 3.3.5 presents results of calculations of total carbon in stems with bark and summary biomass accumulated by spruce plantations of various age developed on former agricultural lands of Novgorod region.

Table 3.3.5.

The total carbon in stems with bark and summary biomass of spruce plantations on former agricultural lands of Novgorod region recalculated for t of dry matter.

Age of plantations, years	Carbon in stems with bark, t of dry matter	Summary biomass for plantations, t of dry matter
3-6	250.4	379.4
7-8	24.7	37.4

Total	416.8

In 1998, summary biomass of 3- to 6-year-old spruce plantations (planted in 1995-1997) was 379.4 t. Consequently, carbon dioxide (CO_2) absorbed by the stand was 1.39 Gg. Total biomass of 7- to 8-year-old plantations (planted in 1993-1994) was 37.4 t. They are the sinks of 0.14 Gg of CO_2. Therefore, in Novgorod region artificial forests on former agricultural lands became the sinks of 1.53 Gg of carbon dioxide.

Within the period form 1990 to 1998 the area of agricultural lands in Novgorod region changed by 1500 hectares. Forest plantations were developed on 28% of the above territory. From 1990 to 1997 the area of agricultural lands of Russian Federation changed by 7.6 million hectares (The Agriculture in Russia, 1998). If assume that forest plantations were developed on 28% of this territory, their total area will be about 2.1 million hectares. Rough estimates show that 1 ha of forest plantations on former agricultural lands is a sink of 0.005 Gg of CO_2. Consequently, 2.1 million hectares accumulate approximately 10 500 Gg of carbon dioxide. Thus, experience of Novgorod region shows that artificial forest plantations on former agricultural lands play an important role in absorption CO_2 from the atmosphere.

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Conclusion

1. Only artificial forest plantations on former agricultural lands can be directly referred to the term of “afforestation” according Article 3.3 of the Kyoto Protocol.
2. Artificial forests on former agricultural lands play an important role as sinks of atmospheric carbon dioxide (CO_2). The calculations made for the territory of Novgorod region show that in 1998, 316 hectares of forest plantations absorbed 1.53 Gg of CO_2.
3. It seems desirable to improve accuracy of estimations of CO_2 absorption by artificial forests.

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4. IN-DEPTH STUDY OF LEADING ENTERPRISES OF THE NOVGOROD REGION, WHICH ARE POTENTIAL PARTICIPANTS OF INTERNATIONAL COOPERATION ON EMISSION REDUCTION

This study is aimed at providing additional and more detailed information on the greenhouse gases emissions in the largest enterprises of Novgorod region, which could be considered as the potential partners in the JI-projects and emissions trading. First of all, after the detailed discussion with the regional experts, the following list of the perspective enterprises and organizations was prepared:

1. OAO AKRON
2. TES-20 (Novgorod)
3. Underground gas storage Nevskoye
4. UGLOVSKY Lime Production Factory
5. BOROVICHI Fireproof Materials Factory
6. OAO “Okulovsky Bumazhnik” (paper and cellulose production)
7. Russian-Finnish enterprise “RAUTAMA” (wood processing)
8. Flider Chudovo Company (thermo-isolation materials production)
9. Plywood factory (in Parphino)
10. Chekizovsky meat processing factory
11. Meat processing factory “Myasnoy Dvor”
12. Pestovsky wood processing factory
13. UPITER enterprise (optics production)
14. Municipal heat distribution “Levoberezhnaya”
15. Novgorod waste polygon
16. Malovishera glass factory
17. Water treatment station in Novgorod
18. Aircraft repairing enterprise
19. Automobile repairing enterprise
20. Silicate bricks factory in Borovichi
21. Galvanic factory in Novgorod
22. Swine Farm Factory NOVGORODSKY

For preparing a short list of enterprises the following criteria were used:

- Sustainable economic state of the enterprise
- Well expressed willingness of the management to participate in the project
- Clear and concrete possibilities of GHG emission reduction at the enterprise
- Substantial share of enterprise in total GHG emissions in the region

After more detailed assessment and obtaining on-site data and additional information about the activity of enterprises in GHG emissions and possibilities of emission reduction, six enterprises were selected:

- Joint Stock Company AKRON
- Power Plant TES-20 in Novgorod

- Underground Gas Storage NEVSKAYA
- UGLOVSKY Lime Production Factory
- BOROVICHI Fireproof Materials Factory
- Swine Farm Factory NOVGORODSKY

Special visits were organised for on-site collect of detail information relevant to GHG emissions, activity data, and JI possibilities. During the on-site visits situations in districts ("Raions") of the region are discussed with local authorities in detail, including information on wide range of enterprises relevant to assessment of main GHG sources. Totally six main industrial Raions were visited (Novgorod, Borovichi, Okulovka, Valdai, Demyansk and Krestsy).

UNDERGROUND GAS STORAGE STATION NEVSKAYA

Location: Krestsy Raion. Director Alexey Alexeevich Bondarenko and Head of local Raion Committee for Environment Protection Igor Alexeevich Vetkin.

In the Novgorod region there are the following trunk pipelines: Serpukhov - S. Petersburg and Gryazovets - Leningrad and supplementary chains: Valdai - Chudovo and Valdai - Pskov. Compressor stations gas transportation are located near Valdai and Novgorod (NEVSKAYA storage has one more - "Krestsy" compressor station, which works one-half of the year). "Valdai" station use electric compressor units only and moreover it usually is out of operation and serve as reserve station. So, only very low methane emissions. "Novgorod" station has 5 gas-fuel units GPAC-6.3 but it is also reserve station, usually it works 2-3 weeks in winter, when maximum gas use and transportation, and gas density increases. The main "drive" of gas is "Torzhok" compressor station in Tver Region.

The NEVSKAYA is the largest storage in Europe, it works from 1975. Gas deposition for store in underground layers is in summer, while consumption in winter, when maximum gas use by utilities and population. The storage consists of:

- Gas field area 100 km^2 (33km * 3km) with 85 wells for put in and out (29 is acting now, rest is the reserve);
- Compressor station for gas pumping in the underground storage (gas is going from due to pressure in the storage);
- Pipelines, valve and control equipment, meters, etc.;
- Supplementary infrastructure.

The main parameters of station's work are presented in Table 3.4.1.

Table 3.4.1. Operation of Underground Gas Storage NEVSKAYA

Parameter	1990	1994	1996	1997	1998
Volume of gas pumped down for storage, billion m^3	0.376	0.460	0.632	0.592	0.750
Permitted gas emissions, t.	2812	3441	4727	3220	4080

Compressor station has 13 pump units 10GKNa-40/150 (40 input pressure, 150 output), which use gas as a fuel. They are very old: design of 1956; produced in 1975. Simultaneously 9-10 units are in operation, while others in service or repair. Start and switch off unit is associated

with service fugitive emissions, usually there are 1-2 such events daily (totally for all units, which work). This number is considered as a big achievements of the station because several years ago the number was up to 15 stops per day. It was achieved be better care for units.

Specific use of gas as a fuel for compressors was 1.63% of total gas amount compressed (data of summer 1999). It is planned to buy and install new units "Caterpillar", there is already the contract of 16.7 million USD, but no funds are available yet. Potentially energy efficiency can be increased by about 2 times by new equipment. The N_2O emissions also could be associated with work of these compressors as well as NO_x, however no N_2O estimates are available now.

Question on electric units has been considered, but this idea was rejected because it is cheaper to use gas. Prices of electricity is rather high in the Region, sometimes 2 times higher than in other region. Such situation is caused by the fact that Novgorod region is mainly import electricity from other.

There is computer system for measuring of gas transportation, which is duplicated by usual-type manual devices. Use of gas as fuel at the station is accounted for in detail by the same computer system.

There are no measuring of service and non-controlled emissions. Permitted amount of gas loss ("norm" leakage) is 0.8% of gas processed in the NEVSKAYA station. There are three type of gas loss: 1) start and take-off of compressors (pumping in to the storage, summer half year only), 2) blowing of separators (preparation of gas from the storage to transportation by pipelines, winter half year only), 3) non-controlled leakage in valves and at linkage of different equipment. Emission in to the atmosphere caused by start and take off of compressors is less than 0.8%. According to opinion of station's administration, other emissions: blow up of separators and non-controlled leakage are very small, they are significantly smaller than technological emissions in service of compressor units.

Controlled fugitive gas releases are in winter service, when blow up of separators. The special two-step system is used to minimize gas loss: there are two reservoirs of blowing, gas is pumped back from the first, therefore, gas is emitted to the atmosphere from the second only, when methane is already dissolved by air.

Auto transport plays a minor role from GHG emission point of view.

Table 3.4.2. Estimates of GHG emissions from Nevskaya station.

	1990	1994	1996	1997	1998
Fugitive CH4 Emissions, Gg CH4	0,308	0,377	0,518	0,486	0,615
CO2 Emissions from Gas Combustion, Gg CO2	11,220	13,795	18,945	15,818	22,439
CH4 Emissions from Gas Combustion, Gg CH4	0,0002	0,0003	0,0003	0,0003	0,0004
N2O Emissions from Gas Combustion, Gg N2O	0,000	0,000	0,000	0,000	0,000
Total Emissions, Gg CO2 equivalent.	17,692	21,718	29,829	26,030	35,362

Potential -projects:

- installation of new compressor units (reduction of gas consumption by 2 times or reduction of CO2 emissions by 10 Gg)
- fuel saving in process of gas heating after withdraw from underground
- improvement of operation regime

SWINE FARM FACTORY JSC ZAO NOVGORODSKY SWINOCOMBINAT

Location: Novgorod Raion. Principal Energy Engineer Vladimir Fedorov, Principal Breeding Engineer Galina Bruzgalova and Head of local Raion Committee for Environment Protection Vasili Shvalev.

The farm produces mainly pork and also beef and milk for Novgorod Region and it's capital city. In 1998 production was 1300 t (7500t in 1990). Total number of employees is 540 in 1999, 850 in 1990. Number of swine in 1998-1999 is 14.5 - 15 th. (1990 -50 th., 1988 maximum - 53 th.), while maximum "installed capacity" of the farm is 58 th. There are centralized system of manure transportation and utilisation, waste treatment systems, which were built stage by stage from 1974. Swine of two breeds (Large White and Black) plus boars of Landras and Duroc breeds. Average life weight of swine in the end of production cycle is 65-68 kg., average daily increase in weight 150g/day. In 1990 this parameter was 600g/day. The reason of decrease is bad feeding due to high price of nutriment feed-staff, replacement by roughage is not equivalent.

Structure of swine bunch (that is important for calculation of methane emission) is the following:

- Dams (average weight 130 kg) - 2 th.;
- Baby pigs (8 kg) - 5-5.5 th.;
- 2-4 month pigs (20 kg) - 3.5 th.;
- Swine (average weight 50 kg) - 3.5 th.

There are no seasonal variation of the structure.

Cattle are in stables in winter and on pasture from May 20 to October 1 (except some part of calves). Total number of animals 850-950 (season variations), structure of the bunch is:

- Dairy cows (450 kg) - 300-400;
- Young cows (370 kg) - 80;
- Calves of previous year (200 kg) - 200;
- Calves of current year (100 kg) - 200;
- Baby calves - not sufficient for GHG emission.

Liquid (water dissolved) waste of swine production are weekly disposed to waste treatment system, where there are mechanical refinement, settler basins and then transportation on fields (mainly with multiyear forage grasses). There was also biological treatment in aerotanks (aerotanks were have been installed on 1986 and put out of operation in early 90s).

Volume of manure is about 20t/day (humidity 78-90%), volume of liquid waste at output of waste treatment system is 390 m^3/day. BOD_5 at input is 1850 mg/l, at output 612 mg/l, after fields where treated wastewater is finally discharged - 12.6 mg/l. Waste treatment system is not used for cattle manure and municipal waste. Cattle waste is transported from farm by tractors directly to fields or compost paddock. There is only aerobic compost processing.

There is gas boiler house with three small units DKVR-6.5/13 installed in 1974 and two rather modern units DE16. The later large unit can produce 16 t of vapour per hour. Installed capacity is used only partially, last winter one small and one large. For 1999 3.877 million m^3 of gas was ordered but less amount will be really used. In 1998 4.950 million m^3 was used that is more than 2 times less than in 1990 when 10-11 million m^3 was used for farm itself and living houses, which formerly were under ownership of the farm (currently it is private property of people and other sources of heat are used).

Administration of the farm would like to organise methane collection/production from waste with subsequent fuel-use of gas, however there are no available funds now.

Methane from manure and waste is the main GHG source here. Emission decreased in about 5 times, especially emission from waste. Boiler is the main CO_2 source, additionally some small amount of petrol and diezel fuel is used by cars and tractors. Methane extraction and utilisation could be considered as the main possibility to reduce GHG emission.

Table 3.4.3. Estimate of CH4 emissions from Swine farm factory

	1990	1994	1996	1997	1998
from manure, tons of CH4	196	180	116	98	60
from waste, tons of CH4	73,5	67,5	43,5	36,8	22,5
Total, tons of CH4	269,5	247,5	159,5	134,8	82,5
Total, Gg CO2 equivalent	5,660	5,198	3,350	2,831	1,733

Potential projects:

- collection of methane from manure and waste and its utilization for fuel combustion (e.g. for heating of the swine factory)

POWER PLANT TES-20 IN NOVGOROD

Location: Novgorod City. Director Anatoly Fedorovich Golub, Principal Engineer Sergei Miroshnichenko and Head of local Raion Committee for Environment Protection Vasili Shvalev were key persons here.

The Station works on 30 years. Main equipment were not replaced from the beginning (three Vapour-Gas Turbo Units with gas/coal jets). Coal is Kuznetsk energy coal, brand “TP”, ash 8-12%, mainly from “Mezhdurechensky” surface mine. Change of coal supplier to reduce transportation cost is impossible because burning equipment requires only certain coal (after combustion slag has to flow from unit, instead of transformation to cake). Main fuel is gas, gas is burn 97% of total time of the year and only 3% coal. Last year high pressure pipeline was built (27 atmosphere) to provide possibility to use new gas turbines and avoid use of coal at all. It requires large means, which are not available now (order of magnitude dozen million USD). However, the main reason for new units is that deadline of old units (“norm of use”) is very close, it was extended to 2002 and there are only small chance to get more extension. If new best units, efficiency can be increased by 20-30%.

Table 3.4.4.Fuel use on Novgorod TES-20

Fuel	1990	1994	1996	1997	1998
Natural gas, M m^3	420.865	385.560	354.418	347.108	379.732
Coal, t	149,876	114,566	85,181	24,131	14,867
Petrol, t.	No data	73	71	129	118
Diesel oil, t.	No data	73	80	67	81

Monthly heat production in 1998 was 70-75 th. Gcal, electricity production – 60 million kWh. All heat is used by AKRON Chemical Plant as vapour of 10 (sometimes), 27 and 40 atmosphere and hot water (from October 1st to April 15th). Electricity goes to United Grid of Russia. Specific parameters of fuel-use for electricity and heat were 370-380 g/kW and 150 g/kW in 1990 and 400 g/kW and 170 g/kW in 1998. The growth is explained by lower (less effective) use of installed capacity. Currently one of three units is not used.

Evidently that CO_2 from fuel combustion is the main GHG source, non-CO_2 emissions will be calculated but it will be minor. Use of auto and other transport on the Power Plant may contribute very small amount, however it is reflected in data table above. Problem of 1990 data is caused by wide use of car fuel for non-production purposes (e.g. for operation of social objects).

Table 3.4.5. Emissions of greenhouse gases from fuel combustion in Novgorod TES-20

	1990	1991	1992	1993	1994	1995	1996	1997	1998*
CO2 Emissions, Gg	1119	1068	1073	1044	958	833	844	698	698
CH4 Emissions, Gg	0,018	0,017	0,017	0,017	0,016	0,014	0,014	0,012	0,012
N2O Emissions, Gg	0,006	0,006	0,006	0,005	0,005	0,004	0,004	0,002	0,002
Total, Gg CO2 equivalent	1121,2	1070,2	1075,2	1045,9	959,9	834,5	845,5	698,9	698,9

* Estimate.

Potential projects

- Installation of new gas turbine energy units (energy saving 20-30%)
- Optimization of the heat distribution systems

JOINT STOCK COMPANY AKRON

Location: Novgorod City. Member of the Board Sergei Nikolaevich Kuzin, Director on Technical Development Vladimir Borisovich Ovchinnikov.

AKRON joint-stock company is one of the leading Russian companies in fertilizers and other chemical products production. Except of plant in Novgorod, company has the Dorogobuzh fertilizers plant in the Smolensk region of Russia and a number of small service companies. All activities data listed below covering Novgorod plant only.

About 89% volume of sales company accounts for mineral fertilizers and ammonia, 10% for products of organic and inorganic chemistry, 1% - for consumer goods. Share of AKRON in the nitric fertilizer production in Russia was 19% (1997).

In 1998 economic efficiency of AKRON was the same as in 1997 despite hard market situation, lower demand, increase in prices of raw materials and dramatic inflation. In 1988 AKRON was claimed the winner in the contest "Best enterprises of Russia - 98" in nomination "For best efficiency of using all types of resources".

Amount of methanol produced was about 70 kt in 1998. (The more detailed data for the 1990 - 1998 period will be obtained later.) The grater part of methanol produced is used for technological processes of AKRON. After reconstruction of methanol production line in 1998 total amount of sale of organic chemistry products increased in 7% in comparison with 1997.

The AKRON supplies mineral fertilizers to agricultural enterprises of North and North-West regions of Russia and exports it abroad. Exported is more 80% of the total amount fertilizers produced (see Table 3.4.7) because of low payable demand of domestic consumers. Cost of natural gas used for fertilizer production contributes upto70% to the total cost of production.

Plant is equipped with modern enough technological appointments with relatively high energy efficiency. Methanol production facilities were used on 100% of installed capacity in 1998, mineral fertilizers facilities on 83%, ammonia - on 99%. Measures aimed on energy efficiency increase, reduction of losses, reduction raw materials per ton of production use and improvement of management are implemented. Managers care for sanitary protection zone around the plant and would like to determine the zone on solid scientific basis (possibly reduce area of the zone).

One ton of ammonia require about 1200 m^3 gas as raw material. Energy use accounts for 9.5 Gcal per ton of ammonia, while rather good technology is used (principal reconstruction was made in 1975 and 1979, but the technology is not bad even after 20 years). Currently the best equipment (e.g. from Germany) could reduce energy use to 7 Gcal per ton and additionally improve reliability of production process. Main part of ammonia is used for fertilizer production inside AKRON, the excess (about 220 kt) was sold to consumers, mainly abroad. Nitric acid is produced from ammonia using high-pressure process.

Carbon dioxide from ammonia production is used in urea production, some amount is sold to end-consumers (in solid, liquid and gaseous form).

Selective catalytic reduction technology (SCR) is used in nitric acid production process for atmospheric emission cleaning (non-GHG). In 1998 a water treatment facilities were reconstructed within the framework of Russian - Danish co-operation that has allowed to improve quality of sewages, discharged to the rivers, to meet acting norms.

The main GHG emission is CO_2, however N_2O in nitric acid production is also very essential source. Accounting of gas use for non-fuel purposes has a key importance. It is also important to take into account amount of CO_2 produced as end product (liquid, solid and gas forms). Additional data on production will be collected and presented by AKRON specialists in next months.

Table 3.4.6. GHG emission related activities at AO AKRON in 1990 - 1998

Volume of production	Year				
	1990	1994	1996	1997	1998
Ammonia, t	926,302	850,098	924,956	875,978	887,756
Nitric acid, t	877,904	646,368	822,750	805,168	752,857
Natural gas, used for ammonia production (burning not included), m^3	1,141,232	1,083,378	1,141,556	1,078,894	1,086,097
Mineral fertilizers, t	1,989,649	1,555,990	2,008,956	1,936,239	1,958,975
including urea, t	351,745	350,346	371,534	260,280	347,450

Table 3.4.7. Structure of sales of AO AKRON by region in 1998

Region	Sales, %
Russia	11
CIS countries	2
Europe	17
America	12
Asia	57
Others	1

Table 3.4.8. Emissions of greenhouse from AO AKRON

	1990	1994	1996	1997	1998
Emissions of N2O from nitric acid, Gg N2O	6,2	4,6	5,8	5,6	5,2
Emissions of CO2from ammonia production, Gg CO2	2091	1986	2093	1980	1991
Emissions CH4from methanol production, Gg CH4	0,2	0,15	0,13	0,11	0,14
Emissions of CO2 from gas combustion, Gg CO2	258,9	203,4	295,9	277,4	277,4
Emissions of CH4 from gas combustion, Gg CH4	0,005	0,004	0,005	0,005	0,005
Emissions of N2O from gas combustion, Gg N2O	0,000	0,000	0,001	0,001	0,001
Total emissions, Gg CO2 equivalent	4276,2	3618,6	4190,0	3996,1	3883,8

Potential projects

- improvement of energy use in ammonia production

UGLOVSKY LIME PRODUCTION FACTORY

Location: Uglovka, Okulovka Raion. Deputy General Director on Labor Protection and Environment Vladimir Ivanovich Lapin, Acting Principal Engineer Alexander Antonovich Sosynkov and Head of local Raion Committee for Environment Protection Mikhail Yakovlevich Schetinkin.

The factory works from 1879. It has about 700 employees now and it is almost the same as in 1990. The Factory is the main enterprise of the settlement Uglovka, thus catastrophic unemployment if destroy of the factory. Several brands of lime are produced:

- "Cloggy" lime (contents of CaO+MgO 65-70%; MgO ≤5%);
- Lime powder with additives (contents of CaO+MgO 60-70%; MgO ≤5%);
- Metallurgy lime (contents of CaO ≥65%, MgO ≤ 1%).
- Mineral admixture for road paving materials; (contents of $CaCO_3$ 88.7 - 99.3% and $MgCO_3$ 0.3 - 1.7%);
- Powder for liming of agricultural soils; contents of $CaCO_3$ and $MgCO_3$ are the same as in the previous case);
- Component for animal and poultry feeds; contents of $CaCO_3$ and $MgCO_3$ are the same as in the previous case).

Decrease is caused mostly by sharp decrease in payable demand, especially in agriculture and in 1992 - 1994 (level of 1991 was about 90% of 1990).

Table 3.4.9. Lime and limestone production

	1990	1994	1996	1997	1998
Lime - all types (th. t)	360.98	235.05	293.24	163.51	158.08
Limestone (th. t)	254.89	8.69	1.44	0.53	0.83

The raw material - limestone is excavated in career on 2-3 km from the factory. Heavy-weight tracks BelAZ and KrAZ are used for transportation. Simultaneously (round clock, 3 pairs) 3-4 BelAZ tracks work and also 5-7 smaller tracks. Unfortunately all tracks are about 20 years old and they are in rather bad condition. Excavators (diezel as well as electric) have the same problem. Use of diezel fuel is 20 - 25 th. t per week. Replacement of tracks and bulldozers is considered as mail possibility to reduce GHG emissions. Use of second hand but good foreign tracks and bulldozers (e.g. “Caterpillar”) could save up to 30% of Diesel fuel.

The limestone is processed by electric breaking units, then it is baked. Only gas is used for furnaces. Specific use is about 50 m^3 per ton of lime. Limestone powder and mineral powder is processed without baking. The main equipment used its resource by 80%. For example, breaking machine “Krupp” was received from Germany after Second World War as reparation. Shortage in funds does not allow to buy new equipment, but rather good second hand units were bought from other factories, which had dramatic economic problems. New shop for lime powder production was open in 1997-1998, where old production lines were completely replaced.

Construction material enterprises (bricks, glass, etc.), chemical enterprises (use for neutralization of chemical waste), asphalt factories and agriculture are consumers of factory’s production. Production of lime powder is increased because it is more profitable now to produce end-product than sub-product.

The factory is owner of living houses and infrastructure of Uglovka town, including boiler house with two gas units DKVR 4/13.

The factory is outstanding source of non-GHG gases (emission of CO, solid particles, and also NO_x is accounted as 16% of the total emission of these pollutants in the Region). It indicates importance of relevant measures, where GHG could be a “sub-product”.

The main emission is CO_2 of baking processes and ÑÎ$_2$ of gas-fuel combustion. Tracks also contribute significant amount, which can be effectively reduced if replacement of fleet (even if imported second hand tracks and bulldozers).

Table 3.4.10. Emissions of greenhouse gases from fuel combustion in Uglovsky lime production factory

	1990	1994	1996	1997	1998
Emissions of CO2 from lime production, Gg CO2	190	125	155	80	75
Emissions CO2 from gas combustion, Gg CO2	90,3	64,1	57,7	43,1	33,9
Emissions CH4 from gas combustion, Gg CH4	0,002	0,001	0,001	0,001	0,001
Emissions N2O from gas combustion, Gg N2O	0,000	0,000	0,000	0,000	0,000
Total emissions, Gg CO2 equivalent	280,3	189,1	212,7	123,1	108,9

Potential projects

- Substitution of old tracks and bulldozers by the new ones (up to 30% fuel saving)
- Substitution of old breaking units
- Optimization of furnace functioning (fuel use reduction)

BOROVICHI FIREPROOF MATERIALS FACTORY

Location: Borovichi City (Borovichi Raion). Deputy Principal Engineer Gennadii Alexandrovich Abramov, Head of local Raion Committee for Environment Protection Valerii Kapitonov and Inspector of the Committee responsible for the enterprise Konstantin Victorovich Mikhailov.

The Factory works from 1828. It has about 4800 employees now and it had 7000 in 1990. Production is all brands of fireproof materials for metallurgy, special materials for oil extraction from wells (propant powder), etc. Raw material is fireclay, which excavated in careers. Before 1990 there was mine digging of fireclay (no methane emission). In the past there was also brown coal mine near Lubytino town with associated methane emission, but it was closed before 1990. Other raw material is bauxite transported by railroad from Boxitogorsk or imported.

Careers are on distance of 30 km from the factory. Excavators use electricity, then high-weight diezel tracks; BelAZ inside careers, KamAZ and KrAZ for transportation to the factory. Track fleet is in permanent modernization and it is rather good now. Data on use of petrol and diesel fuel will be collected later.

There are the following technological processes: mechanical breaking; baking in rotation furnaces (use of natural gas as a fuel); pressing; baking of sub-products by tunnel furnaces (also use of gas only). Equipment is in good conditions. Rotation furnaces were installed in 1963 - 1970, but they were permanently modernized. Tunnel furnaces were installed in 1997 - 1998. Especially modern equipment is used for production of materials for oil extraction.

The factory has it's own power plant, which uses gas (mazut is reserved fuel, but it is not used last years). The plant is attached to United Grid of Russia. Currently the plant uses only a part of it's installed capacity due economic reason, electricity from Udomlya Nuclear Power Station (Tver Region) is cheaper. Total use of gas as fuel for production and for power plant is 105 million m^3 (1998).

Factory's products are used by Russian metallurgy plants, the main partner is Cherepovetsky Metallurgy Plant (40%). Some amount is exported to Finland and other countries, including South America. Decrease in production in 1990 - 1999 was about 40%.

The factory has rather modern waste treatment system, including biological refinement of liquid waste.

In previous years, before 1995-1996, the factory was owner of several small coal boiler houses, which produced heat for living houses and infrastructure of some districts of the town. Currently all of them are under ownership of municipalities.

Thus, the main GHG sources are the following: baking furnaces (gas-use), electric power units (use of gas and sometimes negligible amounts of mazut); high-weight tracks for fireclay transportation. All of them could be considered as potential activities for emission reduction. Additionally CO_2 emission in baking process could be investigated. Some additional activity data for emission estimation , will be additionally requested from the administration of the Factory.

Table 3.4.11. Emissions of greenhouse gases from fuel combustion Borovichi fireproof materials factory

	1990	1994	1996	1997	1998
CO2 Emissions, Gg CO2	254,4	230,2	198,1	223,5	196,1
CH4 Emissions, Gg CH4	0,005	0,004	0,004	0,004	0,004
N2O Emissions, Gg N2O	0,001	0,000	0,000	0,000	0,000
Total, Gg CO2 equivalent	254,7	230,4	198,3	223,7	196,3

Potential projects

- Furnace improvement
- Modernization of energy equipment
- Reduction of emissions from transport

SUMMARY DATA

Aggregate data on the selected six enterprises which are considered as the potential participants of the greenhouse gas emissions reduction projects (1998) are presented in Table 3.4.12.

Table 3.4.12. Aggregate data on GHG emissions by enterprise, 1998.

	CO_2	CH_4	N_2O	CO_2 equivalent	approximate emission reduction estimate
NEVSKAYA gas station	22,4	0,615	0	35,362	~10
Novgorod swine farm factory	-	0,083	-	1,733	~1
Novgorod TES-20	698	0,012	0,002	698,9	100 - 140
Borovichi fireproof materials factory	196	0,004	0	196,3	~20
Uglovsky lime production factory	109	0,001	0	108,9	~3
AKRON	2271	0,145	5,201	3883,8	~100
TOTAL	**3296,4**	**0,86**	**5,203**	**4925**	**~250**

In sum, these 6 enterprises emit more than a half of total regional GHG emissions (the largest share belongs to AKRON). In most of the enterprises GHG emissions can be reduced by 15 – 25% and the potential aggregate emission reduction amounts to approximately 250 thousand tons of CO_2 -equivalent annually.