Greenhouse gas inventory in region Yugra of Russia

Valery P. Anufriev, Anatoliy P. Kuligin, Alexander N. Medvedev, Marina A. Medvedeva, and Alexander P. Sergeev

***Abstract*—**Some results of greenhouse gas (GHG) inventory are presented for Yugra - the largest oil-and-gas producing region of Russia. The inventory was carried out on the basis of methodology, recommended by the Intergovernmental Panel on Climate Change (IPCC) for national inventories. The majority of emission sources in Yugra refer to the sector "Energy". The default emission factors of IPCC were used for all the sector categories except Fugitive emissions from Oil and Natural Gas activities. The regional emission factors were calculated for this category on the actual data of oil-and-gas companies. The regional statistics was the main data source. The special attention was paid to the results consistency, so as the inventory covered the long period of 20 years (1990-2010). The emission trends were analyzed to avoid the mistakes. Emissions were also matched with the rates of production. The estimation of feasible GHG emissions reduction due to savings of fuel and energy resources, as well as increasing the degree of associated petroleum gas utilization was done. The regional carbon footprint structure was determined.

***Keywords*—**carbon footprint, emissions reduction, greenhouse gas inventory.

I. Introduction

THE international greenhouse gas (GHG) management system has been working in the world about 20 years, in accordance with the United Nations Framework Convention on Climate Change (United Nations 1992).

The system was created for assessing of climatic changes due to anthropogenic activity [1], [2], as well as for developing and realizing of adequate mitigation measures.

At present, GHG emissions and removals assessment is conducted not only on national level (for example [3], [4], [5]), as the Convention requires, but on regional and local levels too. GHG inventory enables local governments to create an emissions baseline, monitor progress, assess the relative contributions of emission sources, and develop a mitigation strategy based on this information [6].

The GHG management is an important task for Yugra (or Khanty-Mansiysk Autonomous Okrug - KMAO), because this region is the main oil-and-gas source in Russia and one of the largest oil-producing world regions. Yugra is a leader in some basic economic indexes in Russian Federation: 1-st position - the oil production, the electric power generation, the industrial production volume; 2-nd position - the gas production [7]. Yugra has the developed system of pipelines for transport oil and natural gas from the deposits, including Yamal peninsula.

The first GHG inventory in Yugra was carried out in 2004, and last year a new one was completed, which included all data on emissions and removals over the period of 1990 - 2010.

Specialized Informational - Analytical System was created for providing the automation, formalization and standardization of GHG inventory process. The system is described in [8], and it is not considered here.

II. Materials and Methods

The GHG inventory was carried out according to 2006 IPCC Guidelines for National Greenhouse Gas Inventories [9], adapted to Yugra conditions. The emissions for each category were calculated according to (1):

$$\text{Emission} = \text{Activity Data} * \text{Emission Factor} \quad (1)$$

The authors have followed to five GHG inventory principles: transparency, completeness, consistency, comparability, and accuracy.

All the initial data and emission factors used are compiled into separate volume of the inventory report.

The special attention was paid to the results consistency, so as the inventory covers the long period of 20 years. The emission trends were analyzed to avoid the mistakes and to achieve consistency. Emissions were also matched with the rates of production.

The regional statistics was the main data source. It was permanently subjected to different changes in its structure during the inventory period. In addition, the data were presented in different statistical reports. So, the special guidelines were developed by authors (as a separate document), to assign the activity data to certain IPCC category. These guidelines identified the code of annual

V.P. Anufriev is with the Ural Federal University, Ekaterinburg, Russia (e-mail: mail@ucee.ru).
A.P. Kuligin is with the Ural Federal University, Ekaterinburg, Russia (e-mail: mail@ucee.ru).
A.N. Medvedev is with the Ural Federal University and the Institute of Industrial Ecology UB RAS, Ekaterinburg, Russia (e-mail: medvedev@ecko.uran.ru).
M.A. Medvedeva is with the Ural Federal University, Ekaterinburg, Russia (e-mail: marmed55@yandex.ru).
A.P. Sergeev is with the Ural Federal University and the Institute of Industrial Ecology UB RAS, Ekaterinburg, Russia (phone: +73433623290; fax: +73433743771; e-mail: alexanderpsergeev@gmail.com).

statistical report, sheets, tables, and calculation algorithms to consolidate the data.

During the period of inventory the new activity data appeared in statistics (such as gas transportation volumes). So, the activity data were reconstructed down to 1990. The actual calorific values of the fuel were used to convert the activity data from mass or volume units to energy units (TJ).

What about the emission factors for sector 1 - Energy. The default emission factors for all the categories, except 1B2 - Fugitive emissions from Oil and Natural Gas activities, were used (the methodical approach of tier 1). As this category input into gross emissions was assessed within 15% - 25%, the methodical approaches of tier 2 or 3 were necessary to use, involving some specific regional coefficients and parameters.

The emission factors for this category depend upon a number of conditions, such as the output gas-oil ratio (GOR), composition of associated petroleum gas (APG), level of its utilization, leakage, flaring, and so on. So the additional efforts were done to identify the regional actual emission factors.

The special request was forwarded to all the vertically integrated oil companies, which produce oil in the region. The companies' data covered more than 70% of oil production since 2000. So they might be considered as representative data.

Two emission factors were calculated in the work: the first one for APG leakage (all the emissions without flaring and utilization), and for APG flaring. Emission factor for APG leakage was calculated according to (2) and (3):

$$EF^{l}_{CO_2} = \frac{\sum_j \sum_i \left[\overline{C^{ij}_{CO_2}} * GOR^{ij} * V^{ij} * LR^{ij} \right]}{\sum_i \sum_j \left[V^{ij} * LR^{ij} \right]} \quad (2)$$

$$EF^{l}_{CH_4} = \frac{\sum_j \sum_i \left[\overline{C^{ij}_{CH_4}} * GOR^{ij} * V^{ij} * LR^{ij} \right]}{\sum_i \sum_j \left[V^{ij} * LR^{ij} \right]} \quad (3)$$

where:
i - year,
j - oilfield.

C^{ij}_{CO2} and C^{ij}_{CH4} are the average concentrations of CO_2 and CH_4 at j oilfield in the year i,

GOR^{ij} is output gas-oil ratio at j oilfield in the year i,

V^{ij} is oil production rate at j oilfield in the year i,

LR^{ij} is APG leakage to APG production ratio at j oilfield in the year i.

The calculation of CO_2 emission factor for flaring was a little bit more complicated. The mean APG composition was assessed for each from j oilfields in the year 1. Then the CO_2 emissions (M^{ij}_{CO2}) were calculated on the assumption of 100% efficiency of APG oxidation. Calculations were done for each j oilfield and year i. Next, the emission factor was calculated according to (4):

$$EF^{f}_{CO_2} = \frac{\sum_j \sum_i \left[\overline{M^{ij}_{CO_2}} * GOR^{ij} * V^{ij} * FR^{ij} \right]}{\sum_i \sum_j \left[V^{ij} * FR^{ij} \right]} \quad (4)$$

where FR_{ij} is the APG flaring to APG production ratio.

The default and the calculated local emission factors are given in Table I.

Table. I. Default IPCC and calculated emission factors ($Gg/(10^3\ m^3$ of oil produced)).

IPCC category	Gas	Emission Factor		
		IPCC default	Local	
		Aver.	Value	standard deviation
1B2ai	Gas removal			
1B2ai	CO_2	9,50E-05/ 1,30E-04	2,78E-05	10,41%
1B2ai	CH_4	7,20E-04/ 9,90E-04	8,54E-04	10,41%
1B2aii	Flaring			
1B2aii	CO_2	4,10E-02/ 5,60E-02	5,64E-02	10,26%

The comparison shows, that calculated values are within the range, indicated by IPCC, but they have much less uncertainty interval.

III. Main Outcomes of GHG Inventory

During the work, the GHG cadastres were prepared for each year of inventory. Emissions from various greenhouse gases were reduced to Carbon Dioxide Equivalent (CO_2-e), using global warming potentials: methane - 23; nitrous oxide - 296; sulfur hexafluoride - 22,200 [10].

The dynamics of emissions, removals and net emissions (emissions minus removals) of all GHGs is shown on Fig. 1.

GHG emissions in 2008 and 2010 almost reached the level of 1990 (Fig. 1), adopted in the Kyoto Protocol as a base, relatively to which the obligations of countries were set out.

However, the GHG emissions growth, which took place from 2000, was more than compensated by the GHG absorption (104.2 Kt CO2-e in 2010).

Since the Kyoto Protocol commitments are set relatively net emissions, Yugra meets these obligations with a reserve, which is estimated as 60000 Kt CO_2-e on 2010 (Table II).

An average contribution of individual GHGs and economy sectors into total emissions is presented in Table III (contributions of HFCs, PFCs and SF_6 are less than 0.01% and they are not shown in the table).

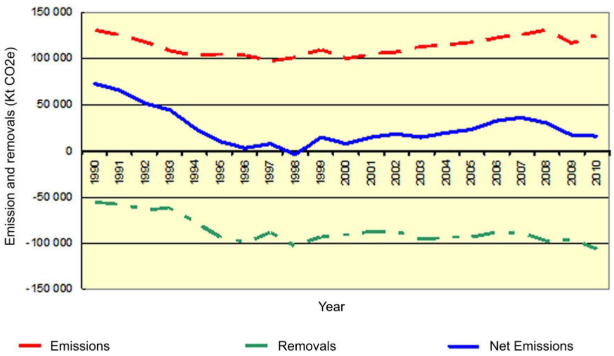

Fig. 1. The dynamics of emission and removals of GHGs in Yugra in 1990 - 2010.

Table. II. The volumes of GHG emissions and removals in 2010 in comparison with base of 1990 (Kt CO_2-e).

	1990	2010	2010/ 1990, %
Emissions:	**130439**	**123370**	**94,6**
Energy	129697	122432	94.4
Industrial Processes and Product Use	13	20	153.8
Agriculture, Forestry and Other Land Use	250	104	41.6
Waste	479	814	169.9
Removals:	**-50480**	**-104229**	**206,5**
Agriculture, Forestry and Other Land Use	-50480	-104229	206,5
Net emissions:	**69908**	**9832**	**14,1%**

Table. III. An average contribution of individual GHGs and economy sectors into total emissions.

Sector	CO_2	CH_4	N_2O
Energy	92,4%	6,8%	0,06%
Industrial Processes and Product Use	0,02%	0,00%	0,00%
Agriculture, Forestry and Other Land Use	0,01%	0,06%	0,03%
Waste	0,01%	0,62%	0,03%
Total emissions	92,5%	7,4%	0,12%

The data show that the sector "Energy" provides 99.26% of the total emissions, including 92.4% of the carbon dioxide emissions.

Dynamics of emissions in 1990 - 2010 tracks the overall economic situation in Russia.

In particular, during the reorganization of the economy (1990 - 2000) the volume of oil and natural gas extraction, as well as theirs transportation and use gradually decreased. Accordingly, the resources of associated petroleum gas decreased, as well as the volumes of its leaks and flaring. It all leaded to essential reduction of GHG emissions.

Overall growth in GHG emissions between 2000 and 2010 was also due to the positive dynamics of the production of energy-intensive products and volumes of works and services. As it is seen (Fig. 2), growth of the main energy-intensive products and services (supply of electricity, oil, condensate and natural gas, transportation of gas) varies from 25% to 55%.

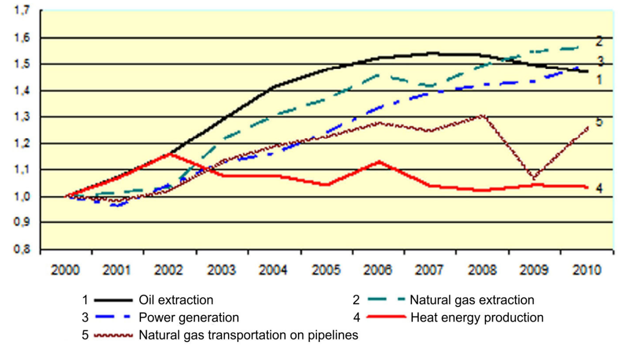

Fig. 2. The dynamics of growth of the main energy-intensive products and services in Yugra in 2000 - 2010.

The structure of emissions in sector "Energy" in 2010 is shown on Fig. 3.

The main emission sources are: the transportation of natural gas on pipelines, the production of electricity and heat, the burning of APG in flares, as well as the extraction of crude oil and natural gas. Together, they produce 94.6% of all greenhouse gas emissions in the sector "Energy".

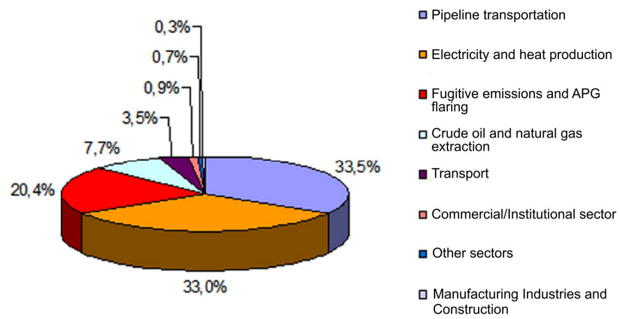

Fig. 3. The emissions structure in the sector "Energy" in 2010.

IV. Emissions Reduction Potential

About 77% of GHG emissions take place during fuel burning for energy purposes, and about 20% - fugitive emissions from the activities with oil and natural gas, primarily from the burning of APG in flares. Accordingly, the following directions of action to reduce greenhouse gas emissions may be considered:

- Improving the energy efficiency of the economy, including power generation, industry (excluding APG), transport, municipal and public sector;

- Reducing the burning of APG in flares.

Projected savings of fuel and energy resources on years in accordance with Energy saving Program of Yugra [11], as well as the corresponding values of emissions reductions are presented in Table. IV.

Table. IV. The potential of carbon dioxide emission reduction due to fuel and energy resources savings in the period 2011-2020 (% of emissions in 2010).

	2011	2012	2013	2014	2015	2016-2020
Electric energy	0,36	0,37	0,37	0,35	0,33	1,57
Heat energy	0,10	0,11	0,10	0,10	0,09	0,44
Natural gas	0,20	0,19	0,19	0,16	0,16	0,75
Sum in a year	0,66	0,68	0,66	0,60	0,58	2,76
Sum from 2011*	0,66	1,34	2,00	2,60	3,18	5,95

* Sum with accumulation

The reduction of carbon dioxide emission was calculated in the program with the accumulation, since the activities undertaken in one year continue to bring savings of fuel and energy resources in the following years too.

The data of the Department of subsoil using of Yugra about the APG production and flaring were used for assessing the potential for reducing of CO_2 emissions due to increasing the degree of APG utilization from the current 86.4% (in 2010) till the standard 95%.

The potential was estimated for the current volume of oil production, the average gas-oil ratio and the weighted average of emission factor for the period of inventory , and it amounted 8720 Kt CO2, or 7.07% of emissions volume.

Thus, the total planned reduction of greenhouse gas emissions in Yugra is about 13% by 2020.

V. Role of Joint Implementation Projects in GHG Emissions Reduction

According to information of the operator of carbon units in Russia, 5 projects of joint implementation (JI) were approved in Yugra, and now 5 more similar projects are on consideration. Also, there is a potential for registration as JI project for at least another 11 projects.

In 2010 the average annual reduction of greenhouse gas emissions on completed projects amounted to about 8500 Kt CO_2-e, or 6.9% of total emissions.

That is, in the absence of energy-saving projects in Yugra, total GHG emissions volume might exceed the base level of 1990 already in 2007.

VI. Carbon Intensity of Different Sectors

Some annual local statistical reports include an information on the fuel, power and heat consumption for the production of specific energy intensive products (such as power, heat, oil and gas-condensate) and activities (such as natural gas transportation, natural gas boosting, etc.).

This information allows assessing the carbon intensity of the products and works. Such assessment was done with the use of the equation (5):

$$CI_i = f_i{*}EFf + p_i{*}\ EFp + h_i{*}\ EFh \quad (1)$$

where CI_i is the carbon intensity of *i* product or activity,

f_i, p_i, and h_i are the specific fuel, power and heat consumption per unit of product or activity,

EFf, EFp, EFh are the emission factors for the fuel used, power production (grid factor) and heat production.

The relative changes in carbon intensity for different kind of activities are shown on the Fig. 4. The year 2003 is taken as a basis.

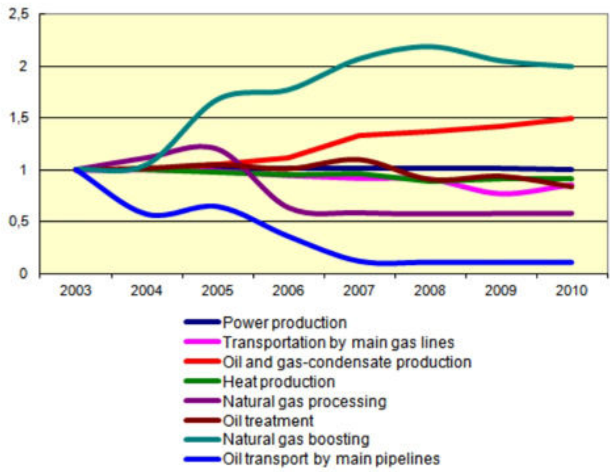

Fig. 4. The carbon intensity for different activities in Yugra in 2003 – 2010.

The raise of carbon intensity of the oil and gas-condensate production and natural gas boosting might be explained by deposits depletion. Reduction of the gas transportation carbon intensity takes place due to the substitution of the out-of-date equipment by efficient modern models.

Basing on the results obtained authors have identified at a first approximation the structure of the total carbon footprint of Yugra.

The carbon footprint is defined in [12] as "a measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary".

To avoid the carbon double counting and the distortion of the whole picture the carbon emissions due to power and heat production (except district heating and power production for export to other regions) are assigned to the end users. The production of the odd power which is exported to the neighbor regions and district heating are considered as free-standing kinds of activities. The usage of power and heat for own needs of generating companies is charged to their footprint.

The structure of the overall Yugra carbon footprint is shown on the Fig. 5.

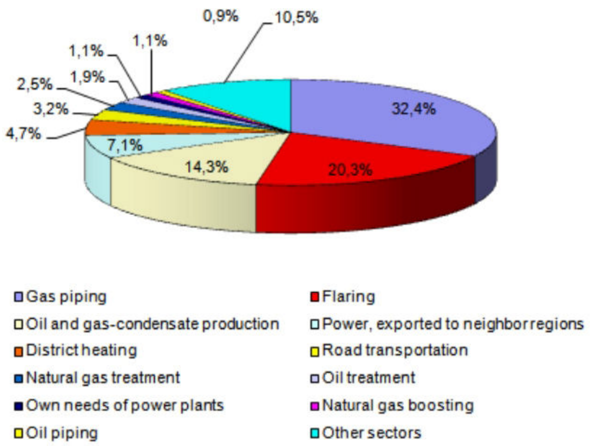

Fig. 5. The Yugra carbon footprint structure in 2010.

First of all one can see, that this kind of statistical report provides more detailed information about the structure of the fuel and energy resources use.

Secondly, the structure of carbon footprint differs from that of the carbon emissions. Most of the carbon emissions from power production are assigned now to other sectors, such as oil production, power export to other regions, etc.

The data on carbon intensity and carbon footprint structure give good informational basis for development of the Regional Low-Carbon Strategy.

VII. Conclusions

1. KMAO - Yugra is one of the main regions of Russia on greenhouse gases emissions.

A growth in GHG emissions was observed in Yugra from 2000 to 2010 due to the positive dynamics of the production of energy-intensive products and volumes of works and services.

In 2010 GHG emissions almost reached the level of 1990, adopted in the Kyoto Protocol as a base. However, this growth was more than compensated by the absorption of GHG. As a result, net GHG emissions decreased in 2010 compared to 1990. Since the Kyoto Protocol commitments are set relatively net emissions, Yugra meets these obligations with a reserve, which is estimated as 60000 Kt CO_2-e on 2010.

2. The joint implementation projects brought an important contribution to the GHGs reduction in Yugra. In 2010 the average annual reduction of greenhouse gas emissions on completed projects amounted to about 8500 Kt CO_2-e, or 6.9% of total emissions. Now 5 similar projects are on consideration and at least another 11 projects have a potential for registration.

3. Yugra has good prospects for further reduction of GHG emissions. In accordance with regional energy saving program, the total reduction of greenhouse gas emissions is planned about 13% by 2020.

4. The data on carbon intensity and carbon footprint structure of Yugra, obtained during the GHG inventory, may be used as an informational basis for development of the Regional Low-Carbon Strategy.

References

[1] Oana Saramet, Anamaria Toma-Bianov, “GHG Emission Reduction - The International Response to Climate Change”, *Advances in Environmental and Geological Science and Engineering, Proceedings of the 2nd International Conference on Environmental and Geological Science and Engineering (EG '09)*, Transilvania University of Brasov, Romania, September 24-26, 2009, pp. 203-207.

[2] Igor Khmelinskii, Peter Stallinga, “Climate Change in the XXIst Century: Mechanisms and Predictions*”, Recent Researches in Energy & Environment, 6th IASME / WSEAS International Conference on Energy & Environment (EE '11)*, Cambridge, UK, February 23-25, 2011, pp. 6-31.

[3] Akram Avami, Bahare Farahmandpour, “Analysis of Environmental Emissions and Greenhouse Gases in Islamic Republic of Iran”, *Wseas Transactions on Environment and Development*, Issue 4, Volume 4, pp. 303-312, April 2008.

[4] Chatchawan Vongmahadlek, Pham Thi Bich Thao, Boonsong Satayopas, Narisara Thongboonchu, “An Inventory of Primary Gaseous Emissions from Thailand with Spatial and Temporal Allocation Profile”, *3rd IASME / WSEAS International Conference on Energy & Environment*, University of Cambridge, UK, February 23-25, 2008, pp. 313-318.

[5] Gabriela Teodorescu, “Climate change impact on urban ecosystems and sustainable development of cities in Romania”, *WSEAS Transactions on Environment and Development*, Issue 2, Volume 6, pp. 103-112, February 2010.

[6] EPA. (2012, July 30). *Developing a Greenhouse Gas Inventory*. USA Environmental Protection Agency. Available: http://epa.gov/statelocalclimate/state/activities/ghg-inventory.html

[7] KhMAO. (2012, July 31). *General information about the Okrug*. Khanty-Mansiysk Autonomous Okrug. Available: http://www2.admhmao.ru/english/obsvedE/frame5.htm

[8] Alexander N. Medvedev, Marina A. Medvedeva, Leonid G. Gorbich, Alexander L. Gorbich, “Informational - Analytical System for Greenhouse Gas Inventory”, *Journal of International Scientific Publications: Ecology & Safety*, Vol. 6, part 1, 2012, pp. 37-44.

[9] Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds), *Guidelines for National Greenhouse Gas Inventories*, IPCC National Greenhouse Gas Inventories Programme, IGES, Japan, 2006.

[10] *Information on Global Warming Potentials*, Technical Paper, FCCC/TP/2004/3, United Nations, 2004.

[11] KhMAO. (2012, July 31). *Targeted program of Khanty-Mansiysk Autonomous Okrug - Yugra “Energy conservation and energy efficiency in the Khanty-Mansiysk Autonomous Okrug - Yugra for 2010-2015 and up to 2020”*. Khanty-Mansiysk Autonomous Okrug. Available: http://www2.admhmao.ru/economic

[12] Wright L., Kemp S., Williams I., ““Carbon footprinting”: towards a universally accepted definition”, *Carbon Management*, 2 (1), p. 61–72, 2011.