# Studies of Greenhouse Gas Emissions at Gazprom: Accounting, Control and the Best Available Technologies for Emissions Reduction

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## Background

A trend towards the use of natural gas and renewable energy sources and improvement of energy performance is a milestone in tackling the climate change problem.
Natural gas is the most attractive fossil fuel, as its combustion gives minimum carbon dioxide emissions, as compared to other types of fossil energy carriers. Nevertheless along the whole process chain, from natural gas production to its supplies to the end users, existing technologies produce significant volume of greenhouse gases.
Production, processing, transmission and storage of oil and natural gas are global industry sources of greenhouse gases (GHG), including methane. Annually up to 88 BCM or around 1200 million tons of methane in CO2 equivalent (MMTCO2E) are emitted into the atmosphere (http://www.globalmethane.org/documents/oil-gas_fs_rus.pdf).
This is exactly why in many countries companies make significant efforts to improve applied technologies, including development of projects aimed at reduction of GHG emissions. However without knowledge of unbiased estimates, trends and anticipated greenhouse gas emissions volume, it is impossible to evaluate projects with respect to carbon-bearing components and expenses for emissions reduction. Availability of reliable and precise system for registration of greenhouse gas emissions is a key to company's managerial decisions to take necessary measures in order to stabilize and reduce greenhouse gas emissions.
The Russian gas industry tries to use systematic approach aimed at reduction of carbon intensity of production, participates in GHG-related investigations. The company follows international practice and corporate standards that ensure fulfillment of requirements of the Climate Change Convention (UN FCCC) and Kyoto Protocol.
Methane and carbon dioxide are the main greenhouse gases (GHG) that are emitted into the atmosphere during operation of process equipment at Gazprom's facilities involved in natural gas production, processing, transmission, storage and distribution.
The present paper is focused on the issues related to GHG emissions and technologies of their reduction in all branches of gas industry. One of the main tasks that the company faces is development of an inventory, accounting and control of GHG emissions, including immediate detection and measurement of methane leaks. Altogether, the largest volume of GHG is emitted during gas transmission.
Estimation and reduction of GHG emissions ensures significant resource saving within the Russian gas industry, helps to increase benefits by feedstock saving an improving of energy performance.

Thus, measures aimed at reduction of GHG emissions may be even profit-making. For example, costs for the use of units with high efficiency factor and for conversion of gas pneumatic regulators to air of the metering equipment may pay off during several months depending on the natural gas price. In case of hydrocarbon financing there is an extra economic benefit, because methane is one of the main greenhouse gases, and value of each ton of preserved methane may be very high. Moreover, the Russian legislation specifies environmental payments and penalties for methane emissions that can be reduced by taking GHG mitigation measures. Also in the emission trading system of the European Union there is a provision for methane to be included in the system in the future.
The paper contains results of large-scale comprehensive studies aimed at estimation, accounting and control of GHG emissions in the Russian gas industry and indicates possibilities of implementation of investment projects in Russia and the best available technologies for reduction of GHG emissions in all branches of the Russian gas industry. This will ensure cost-effectiveness and considerable environmental effect of projects.
The authors provide an example of the implemented technology on the development of greenhouse gas emissions inventory and technical solutions on emissions reduction.

## Aims and methods

JSC Gazprom together with Gazprom VNIIGAZ LLC and foreign companies cooperates on the problems related to greenhouse gases, implements advanced approaches and applies practical experience to assess carbon dioxide and methane emissions from operated process facilities and the infrastructure of production, transmission, storage and distribution.
The aim of the work is to carry out comprehensive investigations targeted at estimation of GHG emissions, develop inventory of GHG emissions, provide accounting and control of GHG emissions and elaborate the system of cost-effective measures to control GHG emissions within the company.
Assessment of GHG emissions was done with the help of process data, calculation, statistical, analytical and software methods. All related international and Russian requirements were fulfilled during development of GHG emissions management system, including transparency, consistency, completeness and accuracy requirements.
The paper describes trends in GHG emissions sector, and evaluates GHG emissions reduction projects in terms of cost effectiveness and commercial benefits.

## Subject of research

The paper provides an example of the implemented technology on development of GHG inventory for the largest Gazprom's gas producing company Gazprom dobycha Yamburg. It operates in the Arctic zone of the West Siberia, where the nature is very susceptible to industrial impact. The Company realizes that the scope of its activities is very large, and that is why it pays much attention to environmental problems, including GHG emissions and climate change.
The paper also provides examples of implementation of innovative technologies aimed at improvement of energy performance and reduction of GHG emissions in the gas transmission system of Russia.

## Regulatory and technical base

Regulatory and legal documents of the Russian Federation determine obligatory requirements for organization of systematic monitoring of the environmental conditions, including atmospheric air.

JSC Gazprom has implemented several internal regulatory documents, which ensure fulfillment of requirements of the United Nations Framework Convention on Climate Change (UN FCCC). Over 10 documents are used to handle, measure, regulate and control GHG emissions and to develop energy and environmental projects aimed at reduction of such emissions. Documents imply several implementation stages: information measurement grid and information management subsystem, which function is to collect, process, accumulate and distribute information. In the gas industry of Russia there are two projects with a pilot status: Inventory of GHG emissions for a gas transportation company and a large gas production company. Both inventories have been verified by independent experts from the Institute of the Global Climate and Ecology.

## Results
## Inventory, accounting and control of GHG emissions

Upon the results of comprehensive studies integral and differential estimates of GHG emissions (use of natural gas as a fuel) have been made for different technological processes (CO2) and regulated process operations (CH4). According to calculations, the total GHG emissions potential for Gazprom amounted to about 140 million tons of CO2-eqv in 2010; in absolute volume values 97% of them are carbon dioxide emissions and 3% - methane (Table 1). Gas transmission sector gives the largest volume of GHG emissions – over 80% (Fig.1). In general, the volume of GHG emissions (CO2-equivalent) in Gazprom equals 10% of the total volume of emissions in the Russian Federation (Fig.2).

Table 1 – Results of GHG emissions estimation at Gazprom

| GHG emissions | Years | | | |
|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 |
| Methane, mln t $CO_2$-eqv./year | 103 | 93 | 60 | 52 |
| Carbon dioxide, mln t/year | 90 | 95 | 71 | 85 |
| Methane from fuel combustion, mln t $CO_2$-eqv./year | 0,2 | 0,2 | 0,1 | 0,2 |
| **TOTAL, $CO_{2\text{-eqv}}$, mln t/year** | 193 | 188 | 131 | 137 |

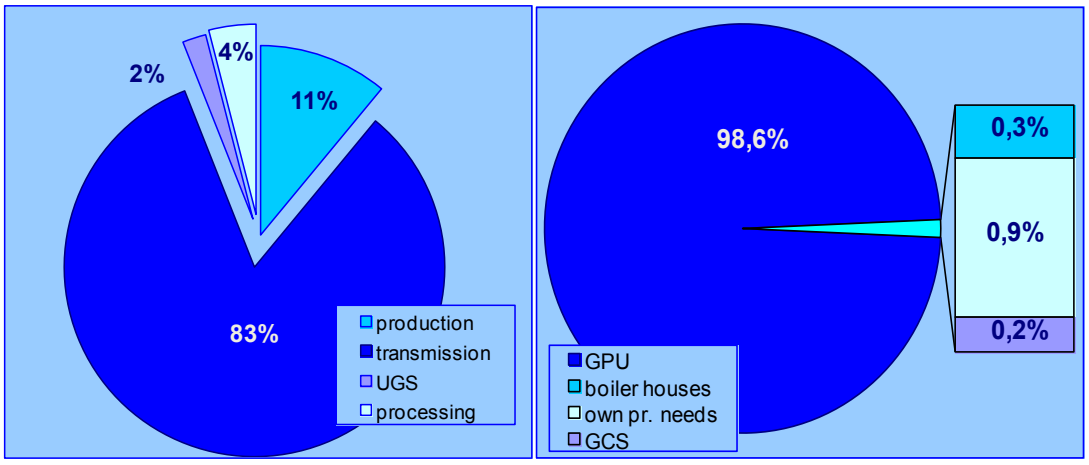


Fig. 1: The structure of GHG emissions by sectors of the gas industry of Russia excluding distribution
(UGS - underground gas storage, GPU - gas pumping unit, GCS - gas cooling station)

Data on the target values of reduction of specific emissions and GHG till 2020 showed that Russia has a real chance to reduce carbon dioxide and methane emissions at gas industry facilities (Fig.3). Dynamics of CO2 emissions corresponds to growth rates of gas production and transmission.

**Experience in development of GHG emission inventory**

Pilot project on GHG emission inventory and software have been developed for Gazprom dobycha Yamburg.
Gazprom dobycha Yamburg produces over 40% of Gazprom's gas and about 10% of the global gas. Main lines of the company's activities include production and processing of gas and gas condensate, geologic exploration, development of new gas, gas condensate and oil gas condensate fields. Gazprom dobycha Yamburg holds licenses for development of five fields: Yamburg, Zapolyarnoye, Tazovskoye, Yuzhno-Parusovoye and Severo-Parusovoye. Since the company creation over 4 trillion $m^3$ of natural gas and about 23 million tons of gas condensate have been produced. The company has about 2 thousand of gas and gas condensate production wells. Gas is treated at 17 comprehensive gas processing units. The length of operated gas pipelines amounts to over 2 thousand km.
The company carries out regular estimations and calculations of methane and carbon dioxide emissions at its process facilities. This helps to obtain data required for management of greenhouse gas emissions.
Comprehensive instrumental examinations aimed at measurement of methane leaks were performed almost for the whole set of the process equipment. This provided consistent estimate of the volume of methane emissions with leaks from each technological block and point. The following distribution of methane leaks from the process equipment has been obtained: 0,5 % - gas sweetening units; up to 6,5 % - gas cooling units of the total number of examined fittings at booster compression stations (BCS). The major volume of methane comes into the atmosphere from vent stacks (74 %). Remaining volume comes from shutoff valves (26 %).
The corporate analytical information system of GHG emission accounting and control was developed to automatically draw up all necessary reports.
GHG emission inventory has been developed with the use of framework technology. Functionally it consists of the following sections: emissions inventory itself, emissions calculation module, and reporting module.
Emissions inventory includes corporate statistical data for the period 2005-2010 for GHG emissions from all types of sources in a gas-producing company. Inventory includes such GHG emission parameters, as disposal of wastes, the use of heat and electric power purchased by Gazprom for own process needs, combustion of the engine fuel by operated vehicles, etc. Overall uncertainty of inventory data does not exceed 6,6 %.
Software complex consists of the following parts: data base, calculation module, user interface, including Windows and Web interfaces.

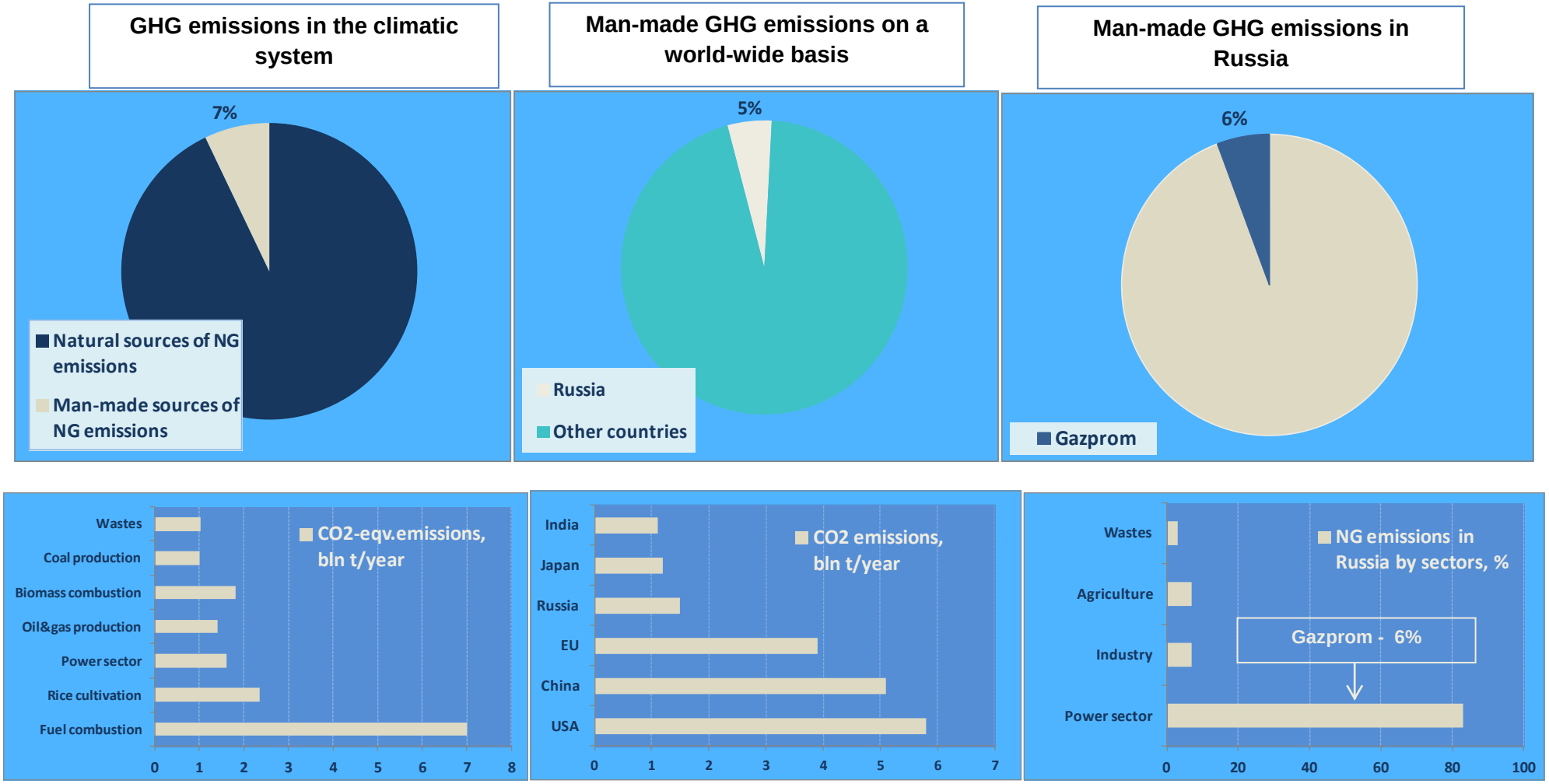
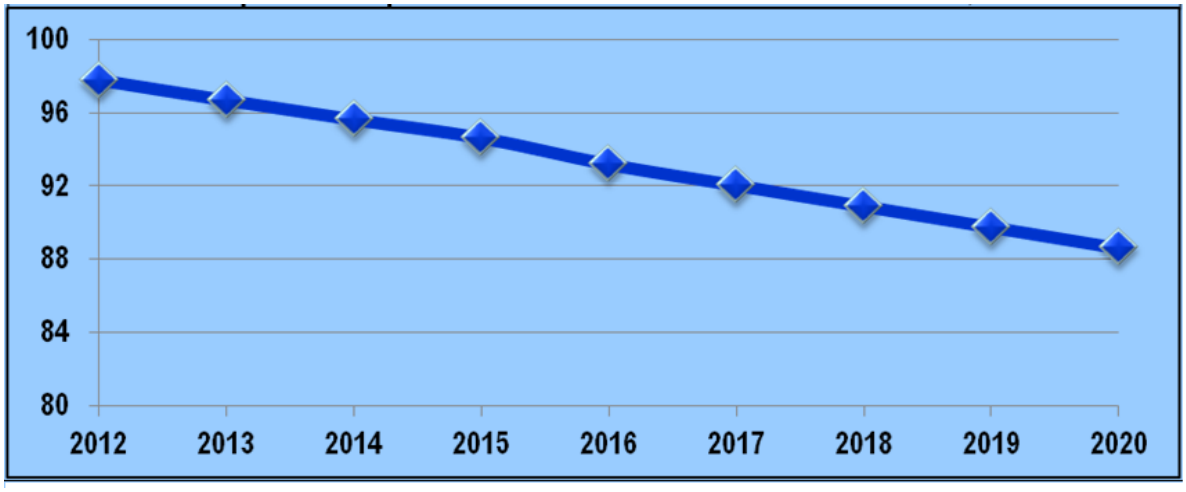



Fig. 2: Global GHG emission parameters




| Energy environmental safety indicators according to the "Power Strategy of Russia till 2030" (ensuring GHG emissions level with reference to 2005) | | |
|---|---|---|
| 1st stage (2009-2015) | 2nd stage (2016-2022) | 3rd stage (2023-2029) |
| at most 83% | at most 90% | at most 105% |

Fig. 3: Target values of Gazprom for reduction of specific GHG emissions in $CO_2$-equivalent, %

Innovative information technologies were used for development of this software, namely:
- independence from applied database management system;
- use of development framework with a possibility of creation of web-interface and desktop interface with one code;
- use of reserved ("sleeping") record technology (Fig.4).

Ability to choose the type of user interface allows to optimize the use of the system in case of remote facilities, when there is no permanent connection. Web-interface allows remote access, accumulation of relevant data in one place, and no need to change work environment on PC.

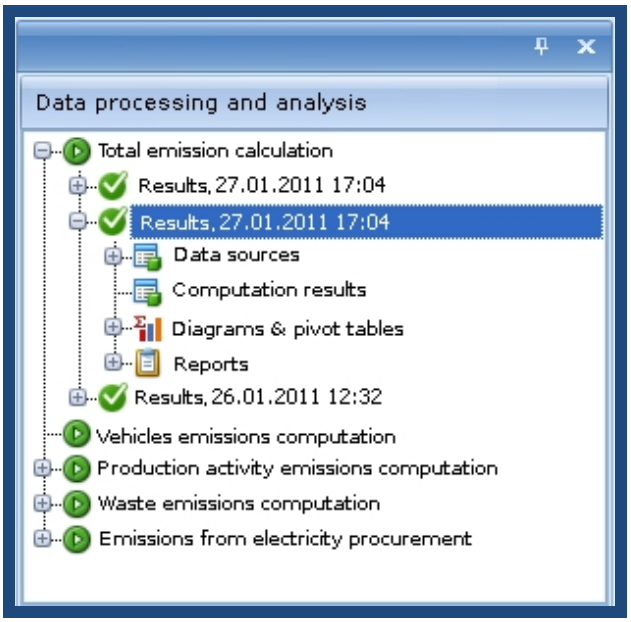



Figure 4: Use of sleeping record technology

Framework technology enables to make user diagram sets with a possibility to choose data source and screen representation of diagrams (Fig. 5). Thus, the system provides the possibility of OnLine Analytical Processing (OLAP). The system also has significantly broadened options for output data reporting according to What You See Is What You Get principle (WYSIWYG).

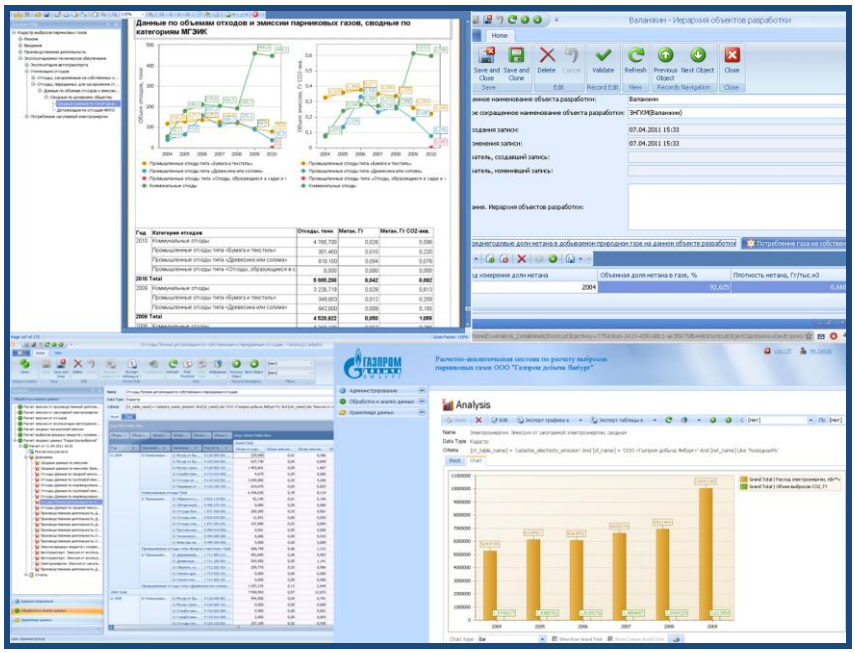


Figure 5: Work with diagrams

Inventory's software widely uses separation of access rights. First of all this is done for convenience of data input by certain departments and for provision only those data that are required for this or that department or for solving a certain problem.

The use of the open code technology in combination with development means allow to provide software without any obligations to pay license fees to third companies enables unlimited distribution of the "On-line Emissions Inventory".

Calculation and analytical module enables reporting in a variety of formats for reviewing, analysis and editing: PDF, Excel, RTF, HTML, CSV, slide show.

GHG emission inventory is the first of its kind developed by Gazprom for a gas-producing company.

Inventory's function is to register and control GHG emissions. On-line emissions inventory allows specialists of Gazprom's companies to input source data to calculate GHG emissions independently from each other. It means that the specialist who has access to on-line inventory is able to input data into the system. Data quality control and minimization of errors during transmission of source data into on-line inventory is ensured.

Data from on-line inventory are available for all specialists, management personnel and Gazprom VNIIGAZ as well.

On-line inventory helps to choose cost-effective options for emissions management, plan and take measures to reduce GHG emissions and improve energy performance of the Company's equipment.

Gazprom actively participates in practical implementation of the corporate system of GHG emissions management.

Gas industry of Russia has GHG emissions management system that ensures information support of managerial decision-making, investment attracting, participation in ranked studies of competitors, implementation of Gazprom's environmental policy in terms of transparency of the corporate environmental data and climate conservation measures, preparation of information materials on Gazprom's activities on GHG emissions, implementation of provisions of the Russian legislation in the field of climate change.

Fig.6 provides management strategy for GHG emissions at Gazprom. The system includes integral and differential estimates of GHG emissions with the use of statistic reporting data, results of large-scale instrumental studies and analytical calculations. The work on development of information and analytical complex for accounting, estimation and control of GHG emissions volume, calculation and analysis of specific emissions and storage of accumulated data is currently underway.

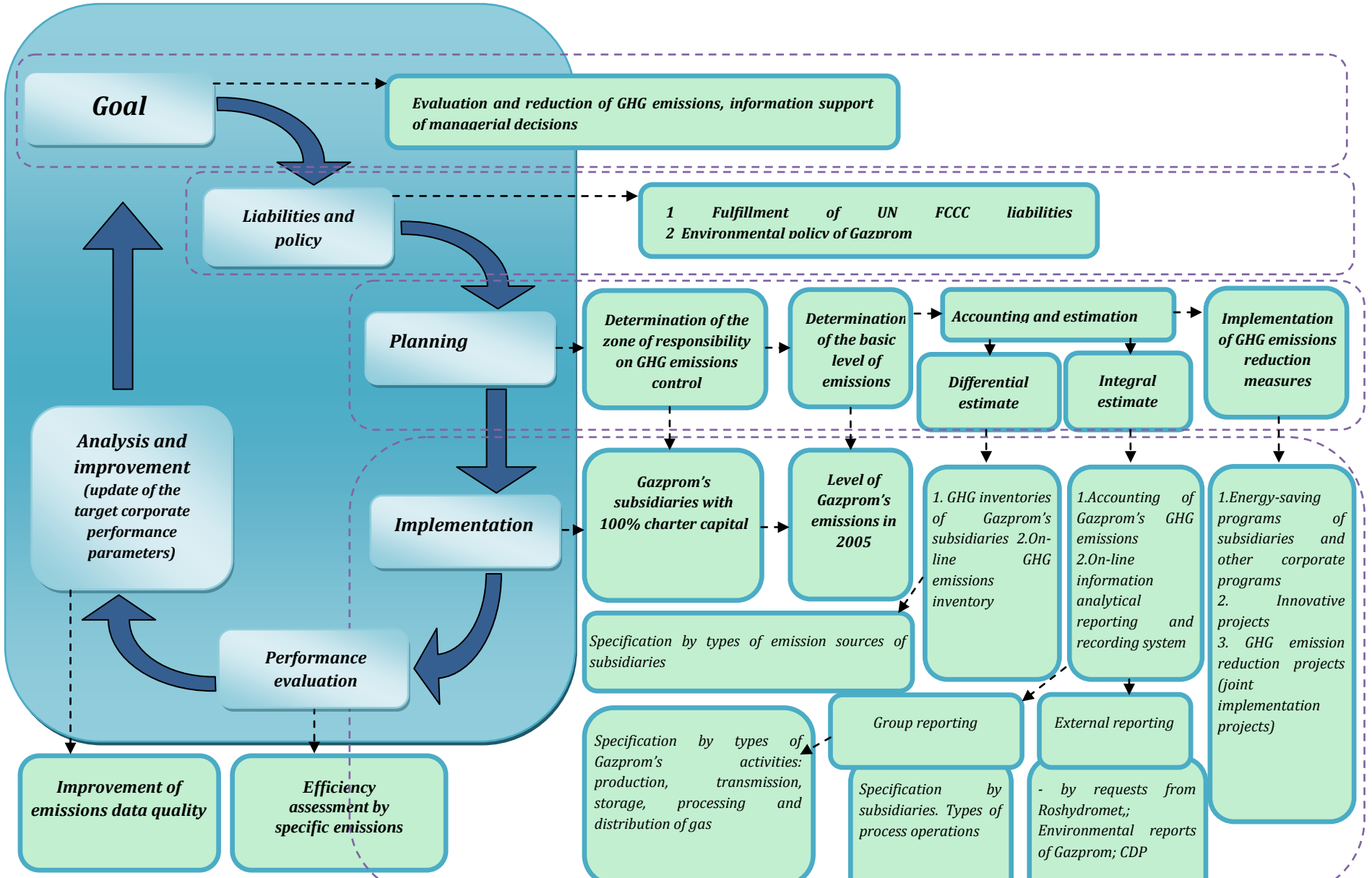



Fig. 6: Management strategy for GHG emissions in the gas industry of Russia

## Implementation of the best available technologies: experience of Gazprom

Gas industry of Russia implements a task-oriented policy, which implies improvement of energy performance and reduction of GHG emissions across all sectors with account of requirements of the “Power Strategy of Russia till 2030”, the Strategy of the Environmental Safety of Russia, Master Plan of the Gas Industry Development till 2030, the Program of Gazprom’s Innovative Development till 2020.
Large-scale comprehensive programs have been developed and are being implemented to save resources, improve power performance and reduce GHG emissions. They include:

- Gazprom’s Energy Saving and Energy Performance Strategy for 2011-2020;
- integrated programs for 2011-2015 on reconstruction and technical equipment modernization during gas production, processing, transmission and storage;
- environmental programs.

There are also targeted programs: The Program of Implementation of the Top-Priority GHG Emission Reduction Projects till 2012 and Energy-Saving Program of Gazprom for 2011-2013.
Technologies and measures for implementation of innovative resource-saving technologies, power performance improvement and GHG emission reduction for all Gazprom’s activities are given below.

*Carrying out steady-state gas dynamic well surveys without gas release into the atmosphere.* This technology is based on the use of telemetry system data to register flow rate and pressure on the wellhead. This in combination with measurement of bottom hole pressure by bottom hole apparatus helps to assess well’s production rate without stopping its operation. Survey modes are set by regulation of gas flow rate by wellhead equipment, for example choke valve. Production wells are equipped with multi-parameter sensors, which register well parameters at the wellhead, namely pressure, temperature and flow rate.

*Application of information management system for remote control and operation regulation of each well.* The system allows automated emergency shut-down of wells and ensures reduction of natural gas losses into the atmosphere during well development and gas dynamic surveys. This technology is most of all effective at wells, which operation is complicated by water entries, but which have high deliverability and high drainage volumes, which ensure their continuous operation till field decommissioning.

*Application of gas utilization technology with a closed well blowing system* (with gas return after well blowing into the inlet reservoir). Gas released by blowing is captured, stored and later used for process purposes.

*Increase of the operation pressure up to 11,8 MPa* in large-diameter pipelines with internal smooth coating.

*Use of gas turbine gas pumping units (GPU)* with power performance indicators corresponding to the global standards, including advanced gas turbine engines with 32-41 % efficiency factor in 2-30 MW power range and up to 42 % in 44-50 MW power range, which leads to higher consumption of fuel gas hence increase of carbon dioxide emissions per gas turbine, but in total to a lower emission.

*Use of pneumatic or electric start of GPU* results in reduction of methane emissions into the atmosphere. During start-up of older GPUs natural gas used for turbine expander operation, injection profile blowing and valves operation comes into the atmosphere. Today modern GPUs use the start-up system with compressed air or electric drive, which helps to reduce emissions of natural gas consumed by start-up turbine expander. Pneumatic start-up system is the main alternative to gas start-up at existing compressor stations (CS). Competitive

strength of electric and hydro start-up systems is justified only at CS under reconstruction, when it is technically impossible to use electric start. Natural gas (methane) emissions reduction potential equals to the volume of gas consumed for GPU start-up. Additional functional possibilities are as follows: use of warm compressed air for GPU heating (back-up, during preparation to start-up and during start-up),fuel gas heating, air supply for pressure charging of dry seals of centrifugal compressor, as a working substance of pneumatic unit, which increases efficiency.

*Equipping remotely-operated tap valves with electric or compressed air drives* will prevent methane emissions into the atmosphere during rearrangement of shutoff valves at CS in case of installment of remotely-operated electrohydraulic drives. In such situation shutoff valves work from the oil pressure power generated by electric pump, i.e. pulse gas emissions are prevented.

Gas consumption during actuation of pneumatic or pneumohydraulic drives of tap valves for 50 – 1420 mm diameter for one closing operation the range amounts to 0,034 – 15500 $m^3$. Rate of pulse gas consumption depends on the valve design of various manufacturers.

**The system of dry gas seals**

Replacement of oil seals by dry gas dynamic seals became a relevant issue for the Russian gas industry today. The main sources of methane emissions from oil seals are as follows: stack of oil deaerator and ventilation stack of bearing housings. Oil may come into the atmosphere also through oil tanks of injectors and oil drains. The system with dry seals is an alternative to traditional system of oil seals. Dry seals work mechanically under the action of counter forces generated during interaction of gas dynamic channels and static pressure. During this operation dynamic and static loads come in balance and ensure constant gap width between rotating and fixed parts of a seal (it means that there is no physical contact between primary rings and rotating associated rings). As these surfaces do not interact, less power is consumed and components wear out much slower, which prolongs service life of seals. Apart from environmental benefits associated with reduction of pollutant emissions into the atmosphere, application of dry seals allows to significantly reduce operation costs and increase compressor efficiency. The company has a vast experience in development, introduction and operation of dry seal systems for compressors with 4 to 25 MW power range. The work in this direction continues and it is planned to significantly increase rates of compressor modernization at Gazprom's GPU. New GPU are already supplied with dry seals.

*Nitrogen units (NU)* are used at gas storages to produce nitrogen for purging of the process equipment. Mobile NU can be operated under different climatic conditions: under high pressure during coiled tubing; during well repair, when nitrogen ensures safety, reduces repair time and the number of required process operations; operations related to well stimulation; pipeline purging and pressure tests; removal of water from some components of the equipment and pipeline sections; purging of process equipment at gas treatment units at UGS.

*Optimization of operation modes of gas transmission facilities* is done with the use of advanced modeling systems: distribution of gas flows by pipelines; modes "compressor station-gas pipeline", distribution of loads between compressor stations of each gas pipeline.

*Carrying out process and repair operations without blowing gas into the atmosphere:* gas pumping from trunk line sections subject to repair; use of gas for own process needs of CS during scheduled preventive repair; hot tapping technologies; repair technologies for defect sections with the help of strengthening couplings.

*Reconstruction and upgrading of the process equipment,* including: replacement, upgrading and reconstruction of GPU; reconstruction (overhaul repair) of line telemechanics systems; replacement of standard GPU laminar regenerators with tubular ones. Reconstruction (overhaul repair) of line sections of gas mains with low design pressure increases throughput capacity of a gas pipeline section and reduces consumption of fuel gas by the same volume of pumped gas. Replacement of standard plate regenerators with tubular ones leads to increase of the available capacity of the unit and its efficiency, which saves fuel gas.

*Experience of using mobile compressor stations for gas pumping*

Authors analyzed effectiveness of the Russian and foreign mobile compressor stations (MCS) on the basis of the results of tests on pumping of natural gas by MCS manufactured by Russian and foreign companies.

Today in Russia and abroad the possibility of using MCS during scheduled preventive repair is of great interest both for manufacturers of compressor equipment and for companies that operate or own gas pipeline networks. MCSs allow saving of significant volumes of natural gas, reduce GHG emissions into the atmosphere, and fulfill obligations of Russia on voluntary reduction of GHG emissions.

MCS tests in Russia were carried out in November 2010 on the 13$^{th}$ km of Central Asia – Centre III gas main.

Germany has been testing MCS since 2010 as well. In September 2010 pilot tests of MCS were carried out on the 13$^{th}$ km of gas pipeline of Werne CS and 114$^{th}$ km of TENP gas pipeline between CS Schwarzach and CS Huegelheim. Parameters of the equipment of the tested MCS are given in Tables 2, 3 and 4, and results of MCS pilot tests in Table 5.

Table 2 – MCS process parameters

| MCS manufacturer | Gazag, Russia | OGE/LMF, Germany |
|---|---|---|
| Capacity control interval, % | from 0 to 100 | from 0 to 100 |
| Operating pressure range, MPa | from 1,0 to 7,5 | from 0,7 to 7,0 |
| Production rate, $m^3/h$ | 2872 (Psuc = 1,5 MPa) | 2200 - 61000 |
| Temperature range of pumped gas, °C | from - 10 to + 30 | from - 9 to + 40 |
| Nominal power consumed by piston compressor, kW | 626 | 740 |
| Power supply voltage of electric equipment | 380 | 380 |
| Sizes of the main module, mm | | |
| - length | 12192,0 | 9922,0 (13479,0 Mercedes Benz 1848 ACTROS 6 based) |
| - width | 2438,4 | 2543,0 (2543,0 Mercedes Benz 1848 ACTROS based) |
| - height | 2900,0 | 2646,0 (4000,0 Mercedes Benz 1848 ACTROS based) |
| Weight of the main module with equipment, kg | 33793 | 25600 |
| Weight of auxiliary equipment with equipment, kg | 4990 | |

Table 3 – Process parameters of compressors

| MCS manufacturer | Gazag | OGE/LMF |
|---|---|---|
| Compressor model | JGA/6 | BS 604-213 S 7.0 |
| Compressor type | Opposite | --- |
| Number of trains | 6 | 4 |
| Piston stroke, mm | 76 | 130 |
| Rpm of intake shaft | 1800 (max) | 1500 (nominal) |
| Number of compression stages, | 2 | 2 |

| | | |
|---|---|---|
| Max suction pressure, MPa | 7,5 | 7,0 |
| Min suction pressure, MPa | 1,0 | 0,7 |
| Volume compressor output under nominal injection pressure, $m^3/h$ | 2870 (Psuc = 1,5 MPa) | 2200 - 61000 |
| | 4364 (Psuc = 2,0 MPa) | |
| | 4900 (Psuc = 2,5 MPa) | |
| | 6648,7 ( Psuc = 3,0 MPa) | |
| Max power consumption, kW | 626 | 740 |

Table 4 – Process parameters of gas engines

| MCS manufacturer | Gazag | OGE/LMF |
|---|---|---|
| Engine model | G3412C LE | TCG 2016V 16C |
| Engine type | Gas, 4 stroke | Gas |
| Number of cylinders | 12 | 16 |
| Nominal rpm | 1800 | 1500 |
| Nominal engine power, kW | 475 | 827 |
| Engine velocity, rpm | 1800 | 1500 |
| Fuel consumption, $m^3/h$ | 147 | 150 |

Table 5 – Results of MCS pilot tests

| **Parameters** | **Packaged mobile gas compressor unit ARIEL JGA/6 based with Caterpillar G3412C-LE drive** | **Gas engine driven – mobile high pressure gas booster unit for pipeline gas evacuation-natural gas LMF Type BS 604 – 213 S 7.0** | **Gas engine driven – mobile high pressure gas booster unit for pipeline gas evacuation-natural gas LMF Type BS 604 – 213 S 7.0** |
|---|---|---|---|
| Test time | November 2010 | September 2010 | September 2010 |
| Test site | Ust-Buzulukskoye LPU MG | Werne CS | Willstätt station (at TENP pipeline) |
| Gas pipeline diameter (DN), mm | 1200 | 900 | 900 |
| Length of the cut off section, m | 13000 | 13000 | 114000 |
| Initial suction pressure, MPa | 4,37 | 3,20 | 2,15 |
| Final suction pressure, MPa | 1,00 | 0,70 | 0,92 |
| Pumped volume of natural gas, thous. $m^3$ | 573,67 | 210,00 | 1080,00 |
| Duration of pumping, days | 5 | 3 | 7 |
| Net working time, h | 93,83 | 15,00 | 106,00 |
| Average capacity for the whole pumping period, $m^3/h$ | 6113,93 | 14000,00 | 10188,68 |
| Fuel gas consumption, $m^3$ | 6604,40 (according to flow meter) | --- | --- |

Figures 7 and 8 show cross-plots of gas pressure in pipe and the volume of pumped (saved) gas from gas pumping time at Ust-Buzulukskoye section operation unit of main gas pipelines (LPU MG), Werne CS and TENP pipeline at station Willstätt respectively.

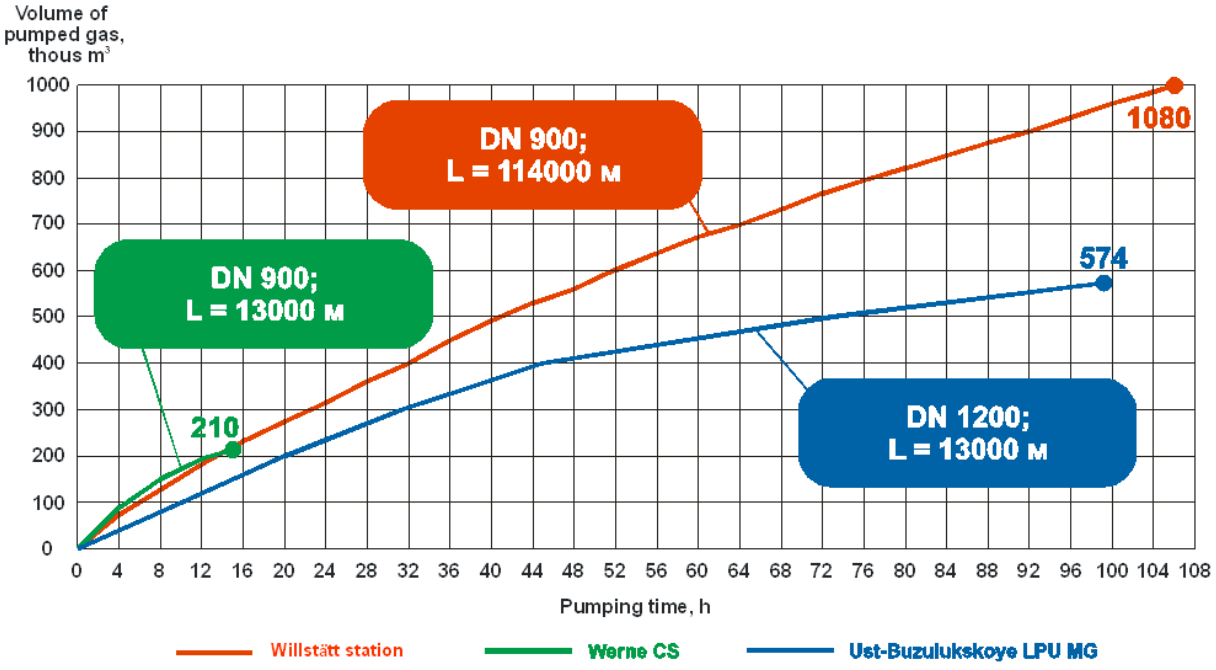



Fig. 7: Cross-plot of gas pressure in pipe and gas pumping time
at Ust-Buzulukskoye LPU MG, Werne CS and TENP pipeline at station Willstätt

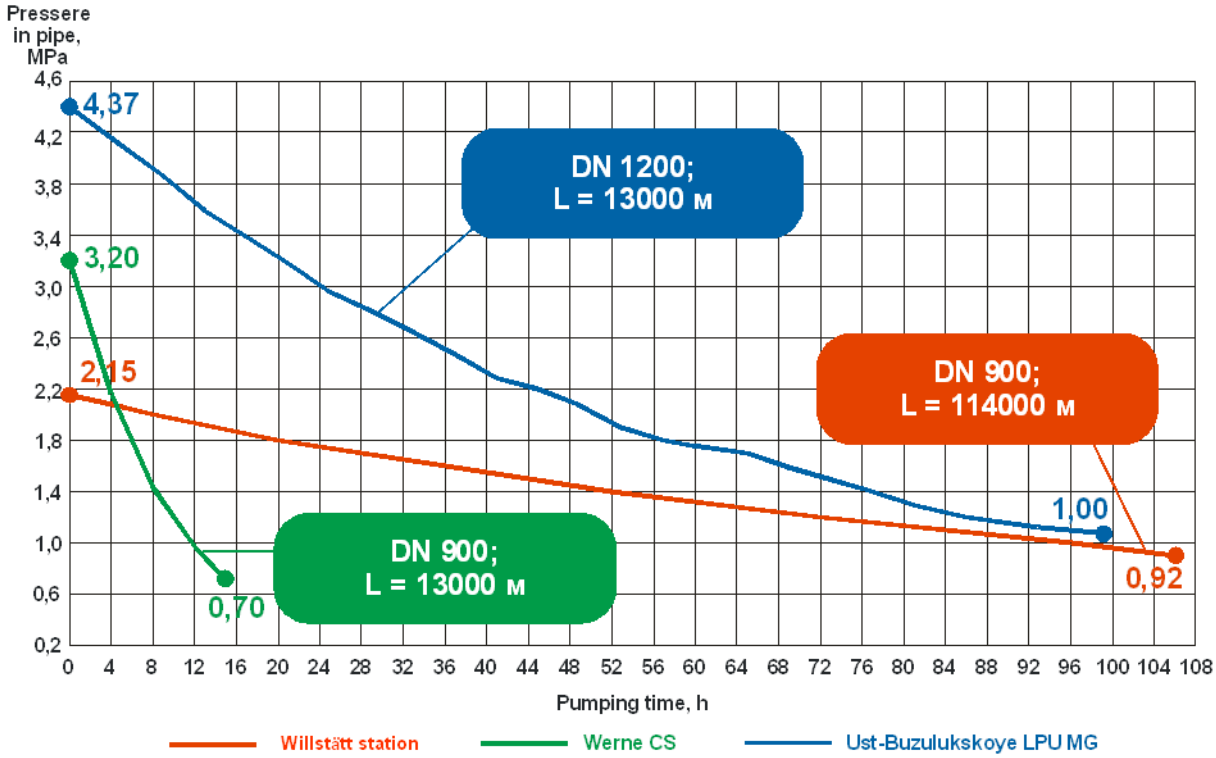



Fig. 8: Cross-plot of pumped gas volume and gas pumping time
at Ust-Buzulukskoye LPU MG, Werne CS and TENP pipeline at station Willstätt

Estimated cost of pumping of 1000 $m^3$ of gas proves economic feasibility/unfeasibility of using Gazag MCS at Gazprom's gas transmission companies (it depends on internal

estimated (trade) price of gas used for own process needs of Gazprom's gas transmission companies).
The volume of natural gas saved due to gas pumping with the use of OGE/LMF MCS on two sections in Germany in 2010 amounted to about 1,5 mln $m^3$ of gas (≈ 24 kt $CO_{2eqv.}$). Correspondingly, apart from the cost of saved gas, the potential revenue from avoided emissions will amount to about 360 thous. € (according to EEX Leipzig on 15.06.2011: 1 t $CO_{2eqv.}$ = 15 €). In 2011 MCS allowed to save 10 mln $m^3$ of natural gas (depending on purchase price at MCS; however according to some estimates MCS price and the price of saved gas are comparable).
In 2012 experts from Open Grid Europe developed projects that will help to save at least 5 mln $m^3$ of natural gas. However annual saving is planned to achieve 8-10 mln $m^3$ of natural gas.
To compare MCS manufactured by Gazag and OGE/LMF E.ON Ruhrgas AG Table 6 provides calculated data for OGE/LMF MCS for gas pumping conditions of Ust-Buzulukskoye LPU MG.

Table 6 – Results of comparison of MCS manufactured by Gazag and OGE/LMF for gas pumping conditions of Ust-Buzulukskoye LPU MG.

| Gas pumping conditions (Ust-Buzulukskoye LPU MG) | | |
|---|---|---|
| Initial pressure in cut off section of gas main, MPa | 4,37 | |
| Final pressure in cut off section of gas main, MPa | 1,00 | |
| Average pressure in receiving section of gas main, MPa | 4,5 | |
| Diameter of cut off section, mm | 1200 | |
| Length of cut off section, m | 13000 | |
| Volume of saved gas, thous. $m^3$ | 573,67 | |
| Volume of gas left in gas main, thous. $m^3$/t | 166,90 | |
| Cost of saved gas, thous. € | 35,6* | |
| Revenue from reduction of payments for methane emissions, thous. € | 1,5 | |
| Comparison of gas pumping indicators | | |
| MCS manufacturer | Gazag | OGE/LMF |
| Data | Test | Calculated |
| Number of MCS of the same design | 1 | 1 |
| Number of modules in MCS | 2 | 1 |
| Number of runs to deliver MCS | 2 | 1 |
| Gas pumping time, h | 99,25 | 38,00 |
| Cost of services for gas pumping, thous. € | ---** | 90 |
| Cost of MCS of the specified design, thous. € | 1298,3 | 2000,0 |
| Note: cost calculated according to CB rate for 20.06.11: 1€ = 39,8913 RUB; 1$ = 28,1778 RUB<br>* According to the internal (trade) price for gas used by Gazprom transgaz Volgograd for own process needs – 2475,00 RUB/1000 $m^3$, 2010.<br>** No reliable data from the manufacturer. | | |

As can be seen from Table 6, it is more preferable and effective to use MCS manufactured by OGE/LMF due to close-together arrangement of compressor unit (module) based on Mercedes Benz 1848 ACTROS truck unit.
Estimated time for gas pumping by OGE/LMF MCS amounted to 38 hours (2,5 times less as compared to the actual pumping time of Gazag MCS), which means that OGE/LMF MCS is more effective in operation.
Nevertheless gas pumping by OGE/LMF MCS in Russia is very expensive and for Ust-Buzulukskoye LPU MG the price of pumping services amounted to about 90 thous. €, which is two times higher than the price of gas lost during repair operations without MCS.
Thus, the use of MCS is economically and environmentally feasible.

*Reduction of gas leaks at process facilities* is done by introduction of advanced control and measurement tools, which detect and measure such leaks; sealing of ball valves by ball locks with advanced sealing compounds, etc. Insulation coatings of the new generation are applied on gas pipelines. Such coatings are based on polymer-bituminous and polyurethane mastic compounds with improved protective performance and service life of 25–30 years, which helps to significantly increase the period of safe and failure-free operation of gas pipelines. The system of diagnostic inspection of gas pipelines is also applied. It helps to save Russian gas industry up to 200 mln US dollars per year by preventing possible accidents and gas losses.

Large-scale projects are performed in Russia to inspect process equipment for methane leaks into the atmosphere. Instrumental examination is the most reliable method to detect methane emissions with leaks from the surface process equipment. Planning of methane emission reduction measures is done simultaneously with implementation of organizational measures and current programs on service maintenance, modernization and repair. There are also measures taken to register, control and manage methane emissions at facilities:

- timely and regular preventive control of the process equipment of gas distribution networks;
- providing personnel (operators) with advanced control and measurement equipment for timely detection and liquidation of leaks;
- registration of leaks, when it is not possible to eliminate them immediately after detection;
- updating repair and modernization programs with account of obtained data on detected and measured methane leaks;
- defining priority for leaks elimination depending on the volume of methane leak;
- use of new designs of sealed vent stacks and valves;
- use of advanced sealing materials to reduce and eliminate methane leaks from shutoff and control valves.

The use of remote control of the linear sections of gas mains for natural gas leaks (laser device, thermal detectors) allows to timely detect and eliminate such leaks.

Results of our studies on actual and future situation on the Russian gas market showed that gas transmission sector has the largest opportunities for reduction of GHG emissions. About 60 % of GHG emissions reduction can be achieved in the gas transmission system, especially on compressor stations. Forecast of emissions depends on the future trends in production of natural gas used in Europe and Russia, upgrading equipment and infrastructure, and achievements in the international structure of gas supplies.

Measures based on the vast Russian and international experience show that there are large possibilities for technical optimization to reduce GHG emissions, and they proved to be cost-effective for gas companies, where capital expenditures are paid off by lower production resp. transmission costs and/or carbon credits.

Today Gazprom implements innovative technologies for reduction of GHG emissions within the scope of energy-saving programs. The company has also defined investment potential and the most prospective projects to attract investments. This is the use of renewable energy sources (wind power generators and power stations with solar cells) in the northern regions; use of mobile CS on gas pipelines for gas pumping, well surveys without release of gas into the atmosphere, etc.

Reduction of GHG emissions due to the use of renewable energy sources will become additional credit source for investors, which will allow to achieve significant progress in effective resource and power saving in the gas industry of Russia.

## Conclusions

Taking measures to reduce GHG emissions (carbon dioxide and methane as the main component of natural gas) is one of the most important issues today due to the relevance of the global climate change problem.

Large-scale comprehensive investigations carried out by gas companies of Russia and other countries showed that reduction of GHG emissions may be profitable, technically and economically feasible. All sectors of the Russian gas industry have significant potential to reduce GHG emissions and many technologies available to achieve this purpose, including reduction of natural gas losses with simultaneous reduction of methane emissions. Such measures can be both very simple and low-cost, such as elimination of methane leaks by depressurization of the process equipment, and large-scale, for example, gas pumping with the use of mobile compressor stations.

Improvement of energy performance and resource saving are the top priorities of the Russian gas industry, which bring profit to the company.

Gazprom actively participates in implementation of the corporate system of GHG emissions management. Results of comprehensive joint studies carried out at Gazprom's facilities provided extensive and reliable data on estimation of GHG emissions in the Russian gas industry.

Introduction of pilot projects on GHG emission inventories, cost-effective technologies and practices aimed at reduction of methane emissions into the atmosphere may help to save gas, reduce atmospheric emissions and strengthen revenue position of companies. The global and regional experience shows that upgrading of technologies and equipment and improvement of management and operation procedures can help to achieve reduction of methane emissions in oil and gas industry, which in its turn will give positive economic and environmental results.

Gazprom implements innovative technologies on reduction of GHG emissions within the scope of corporate energy-saving programs. The company defined the most attractive projects for investments, such as the use of mobile CS for gas pumping, optimization of the operation of gas transmission system with the use of different gas transmission system optimization softwares, such as: Astra, Magistral, Volna, electric start-up and other technologies, which help to reduce methane emissions. By 2015 gas industry of Russia plans to reduce GHG emissions by 40% compared to 2005. Reduction of GHG emissions with the help of innovative process solutions will help to make a step forward in the rational use of resources and power in the gas industry of Russia.