RISKS OF HEAT AND POWER SUPPLY BY GAS-FIRED UNITS WITH DIFFERENT RATED CAPACITIES

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OAO «Promgaz»

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Abstract

In the context of continuous development of decentralized heat and power supply the problem of identifying and analyzing risks of heat and power production by small and ultra-small (SUS) combined cycle units (CCU) becomes acute. We compare such risks with those of heat and electricity production by gas-fired (GF) big combined cycle heat and power (CHP) stations with capacity exceeding 300 MW.

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Content

1. Introduction
2. Technical aspects of risks of power production by GF CCU as associated with economics, human factor and industrial development of the regions
3. Concept of assessing risk in heat, power, hot water and steam production by SUS CCU. Methodology for the calculation
4. Assessment of energy safety risks of heat and power production by GF SUS CCU in different Russian regions
5. Benefits of power production by CCU in terms of energy safety of the regions
6. Conclusions

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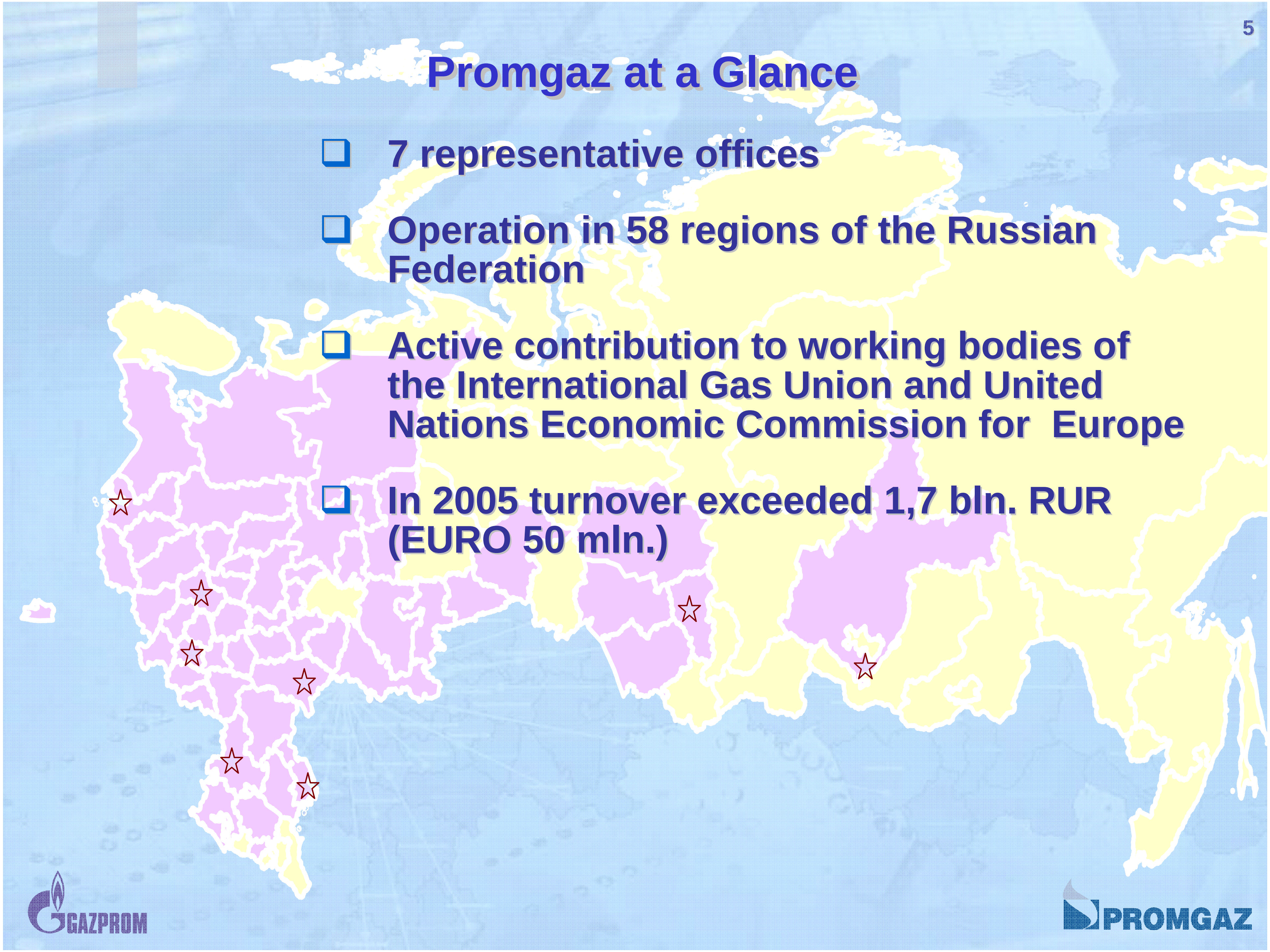
Promgaz at a Glance

- Major Gazprom center in the field of natural gas distribution and utilization
- Major Russian research and engineering center
- Considerable scientific potential, including 26 Doctors of Science and 76 Candidates of Science
- Personnel totaling 714 people
- Gazprom is the principal shareholder (98,71% of the stock)

Promgaz at a Glance

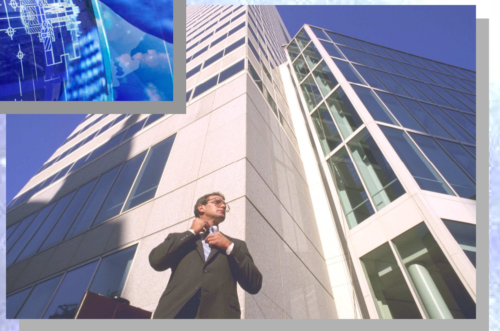
- 7 representative offices
- Operation in 58 regions of the Russian Federation
- Active contribution to working bodies of the International Gas Union and United Nations Economic Commission for Europe
- In 2005 turnover exceeded 1,7 bln. RUR (EURO 50 mln.)



Competitive Advantages of Promgaz

- Integrated approach to projects development
- Availability of scientific and human resources from different Russian industries
- Affiliation with Gazprom
- Well-established relationships with Administrations of the Russian Regions
- Flexible organizational structure
- Exclusive scientific developments

Mission of Promgaz



Development and implementation of complex fuel-and-energy projects on the basis of applied scientific research and advanced technologies

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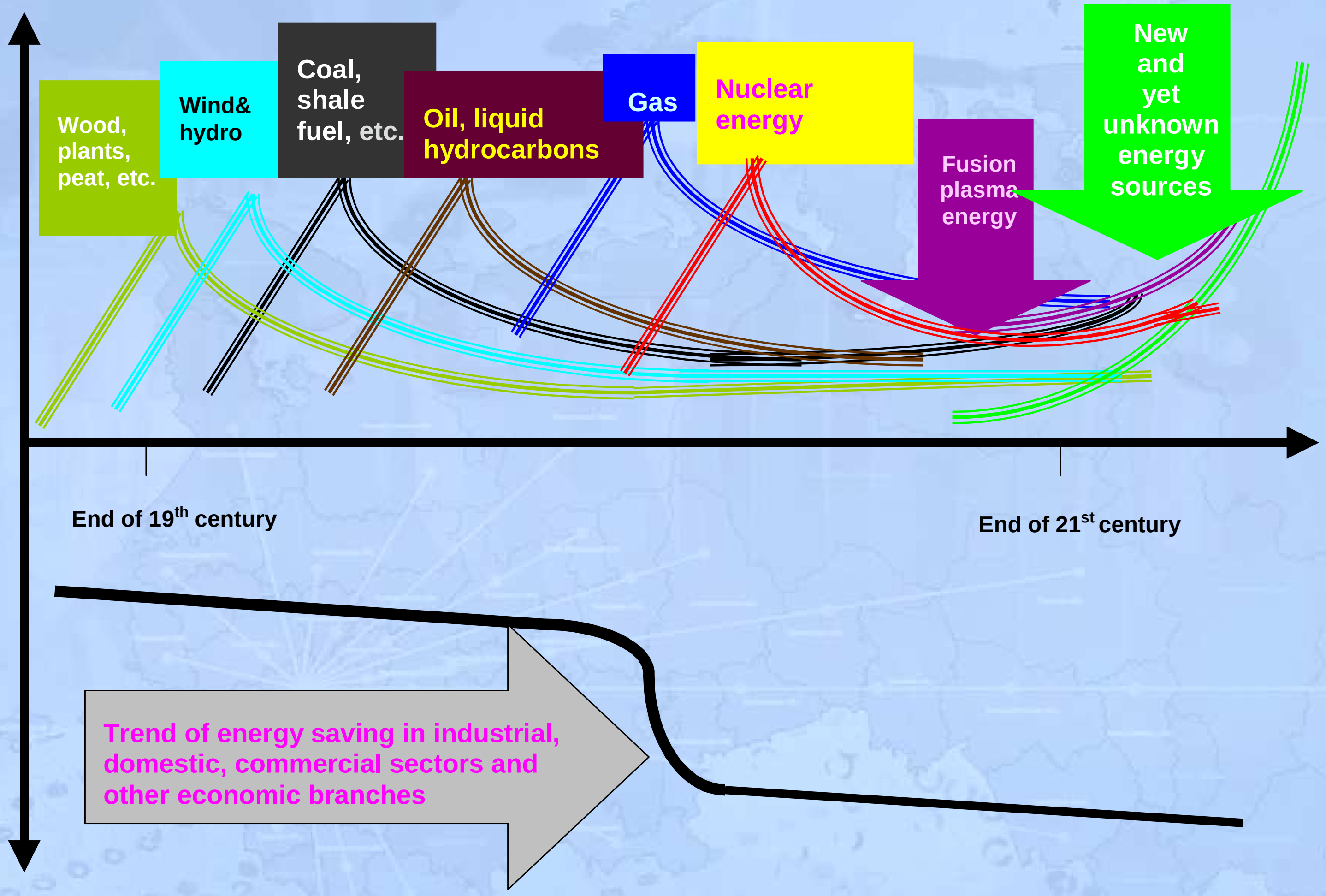
The Main Activities

- Regional power industry, improvement of energy efficiency, risk assessment
- Gas supply and distribution in the regions of Russia
- Reconstruction, technical re-equipment, life-time extension of gas-distribution systems
- Investment efficiency
- Non-conventional hydrocarbon resources
- Energy services & maintenance works

Aspects of Risks of Power Production by GF CCU as Associated with Economics, Human Factor and Industrial Development of the Regions

- Will gas be used for electricity and heat production tomorrow?
- Evaluative risk concepts
- Improvement of energy safety criteria & indices
- Weak point analysis of risk and residential energy safety

What are Consumer’s and Region’s Priorities in Energy and Fuel Utilization ?



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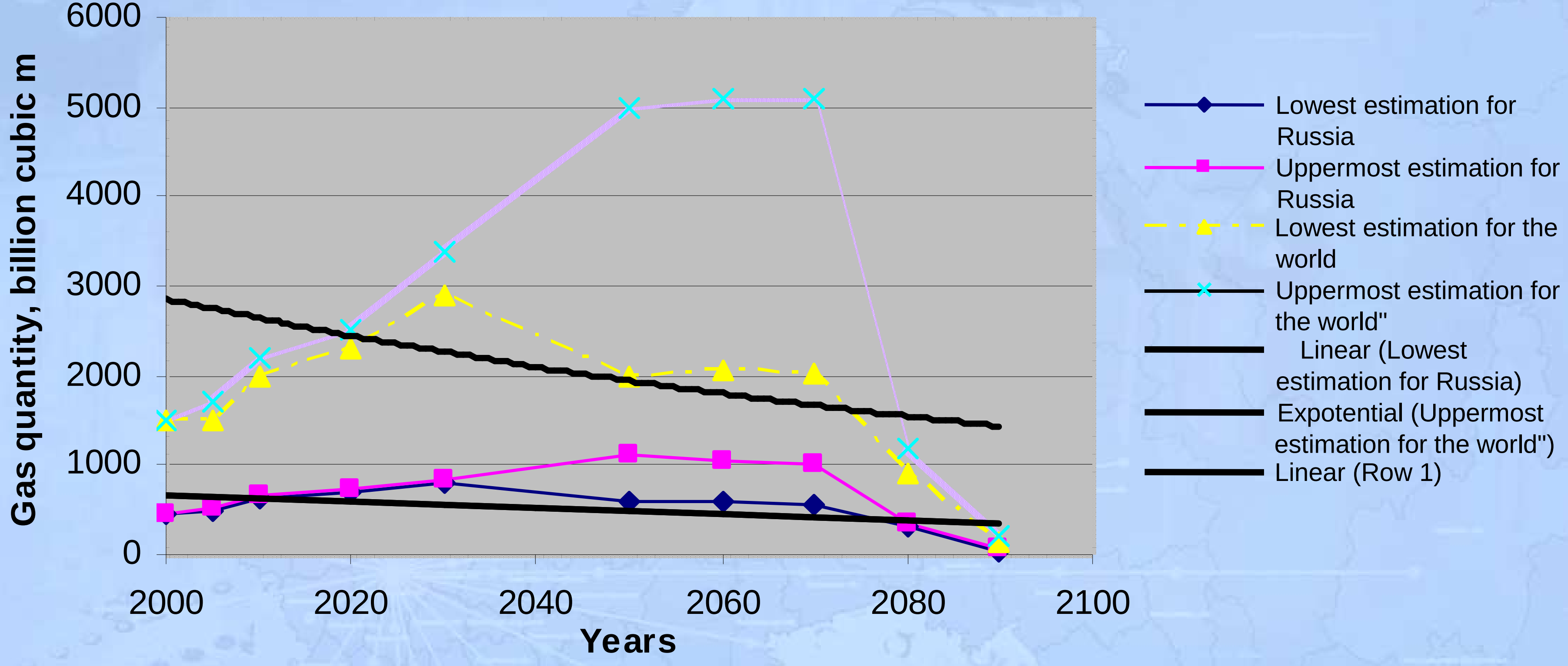
Gas in the House of Tomorrow: Expected Consumer Gas Supply



Evaluative Risk Concepts

Generally collective risk means here possible number of persons deadly injured in natural and industrial perils within a specified period of time. GF SUS CCU associated collective risk is equal to the number of fatalities and serious injures within a specified period of GF SUS CCU operation, for example deaths caused by low-probability failures or natural disaster.

Acceptable collective risk of heat and power production by GF SUS CCU equals the risk acceptable for community in economic, social, insurance terms.

For Russia such risk makes 10^{-6} –10^{-8} of possible deaths per person per 1 year of one GF SUS CCU operation.

Improvement of Energy Safety Criteria & Indices

- Today the highest GF-SUS-CCU-caused risk for gas suppliers and consumers is associated with low pressure gas pipelines operation

- This risk equals probability of human injury (death, maims) at the territory adjacent to the pipeline or to the gas-using equipment. This risk is individually specified for negative factors of the “gas supplier - gas consumer” engineering system

- Professional risk (risk for personnel of industrial, agricultural, transportation objects) and free-accepted risk (risk for the residents) is defined here by a formula:

$$R_{\text{risk}} = P_{\text{probability}} \times S_{\text{total costs}}$$

Risk - R is multiplication of two functional values.

The first value is quantitative value (P) of danger occurrence for the natural gas supplier and/or consumer as multiplied by total costs (S) of threat (failure) consequences mitigation and damage.

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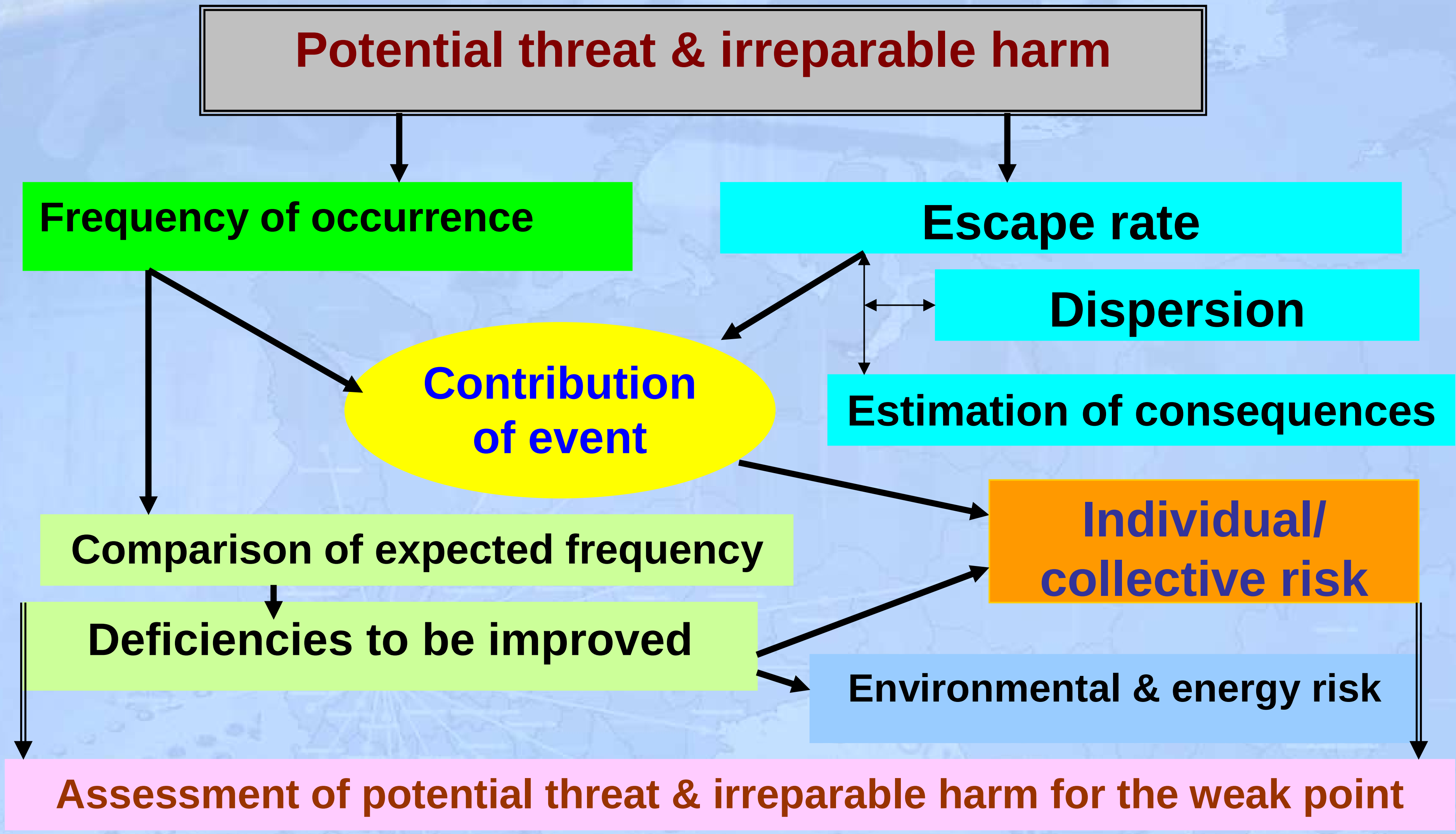
Risk Weak Point Analysis



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Concept of Assessing Risk in Heat, Power, Hot Water and Steam Production by SUS CCU: Calculation Methodology

- Why Promgaz can develop adequate models to forecast world energy and ecological risks of heat and power production at example of Russian regions
- Concept of risk assessment
- Methodology for the risk calculation

Why Promgaz Can Develop Adequate Models to Forecast World Energy and Ecological Risks of Heat and Power Production at Example of Russian Regions

- Average density distribution of industrial facilities and population corresponds to various groups of countries in Europe, North and South America, Asia. Provision for energy resources and gas on separate territories of Russia also corresponds to worldwide provision.
- Requirements and expectations of regional gas consumers (collected data on results of filled-in questionnaires of Russian regions and of other countries according to classification groups of Russia are given) associated with the results received from filled-in questionnaires of other countries.
- Energy saving tendencies - substitution of natural gas in fuelling centralized heat and power produced by big CHP stations by coal and nuclear energy.
- The share of non-conventional heat and power sources (wind, solar, thermal and others) could compete with gas only in separate local regions, but integrally in Russia will not give considerable contribution to fuel and energy balances of the regions. We could expect similar tendencies world-wide too.

Why Promgaz Can Develop Adequate Models to Forecast World Energy and Ecological Risks of Heat and Power Production at Example of Russian Regions

Comparative analysis of the Saratov Region's and of Poland's territorial indices:

Index	Saratov Region	Poland
Population - density	12,723 mln. men - 102 men/кm^2	38,678 mln. men – 124 men/кm^2
Gas networks' length	25343 km	116 625 km
Energy consumption per capita	3 700 kW/person	3 250 kW/person
Share of natural gas and other gas fuels in the energy balance of domestic and commercial heat supply in the given region	Urban districts 43% Rural districts 32%	Urban districts <30% Rural districts <30%

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Concept of Assessing Risk in Heat, Power, Hot Water and Steam Production by SUS CCU

***Energy safety* problems of gas applications introduction are classified in two main groups:**

1. Risk and probability of gas supplier's industrial threats and natural perils occurrence

2. Risk of gas consumer's energy safety threats occurrence

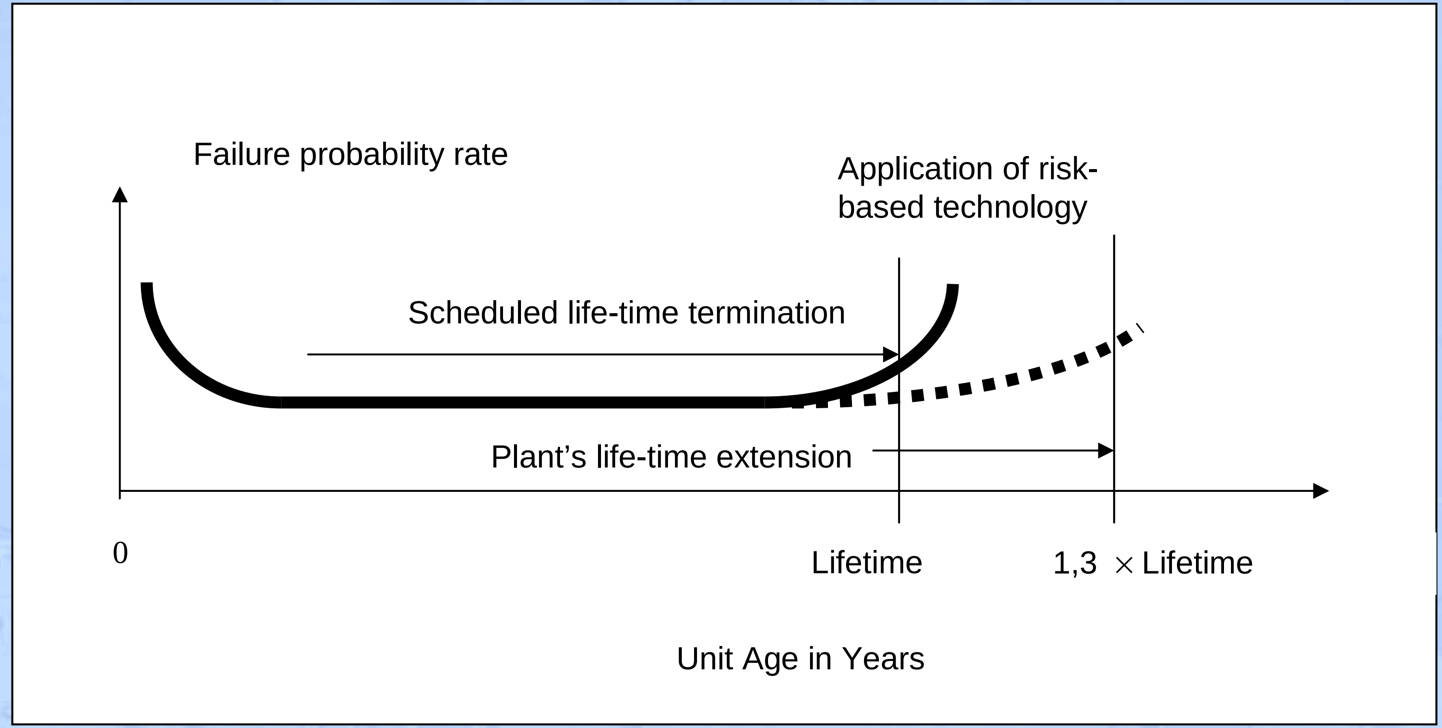
To identify expected risk of gas-to-power utilization we need the model:

- to forecast gas consumption in order to satisfy industrial, commercial and domestic consumers
- to forecast consumers' demand in special equipment for conversion of gas energy to heat and power energy
- to forecast energy safety of regions and countries
- to make up other forecast estimates and improve living standards all over the world

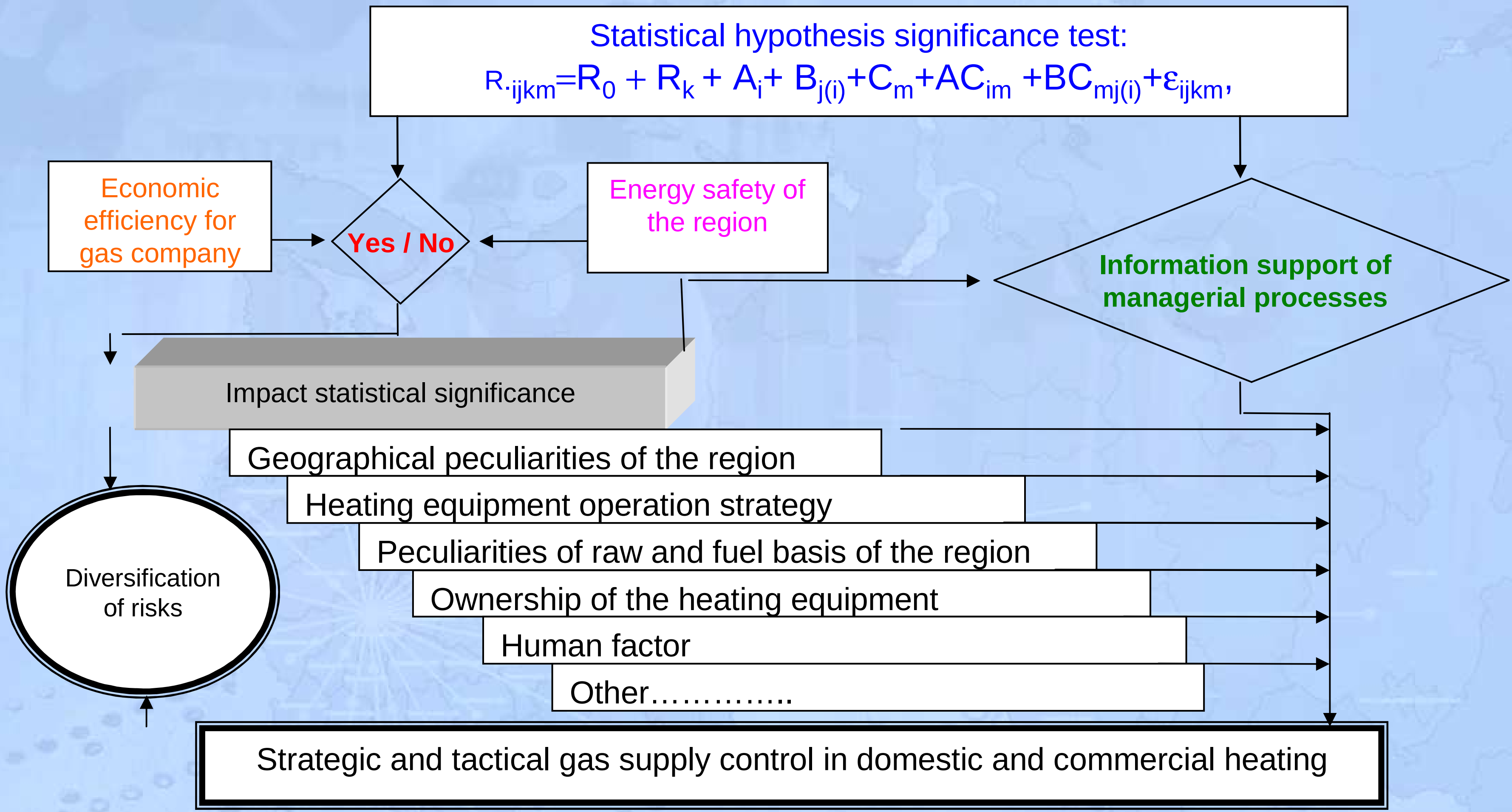
Concept of Assessing Risk in Heat, Power, Hot Water and Steam Production by SUS CCU

Development of multi-factor economical-mathematical model to forecast and analyze energy and environmental risks of heat and power production by GF units

$$R_{risk} = P_{probability} \times S_{total\ cash}$$



Development of Multi-Factor Economical-Mathematical Model to Forecast and Analyze Energy and Environmental Risks of Heat and Power Production by GF Units



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Risk Methodology for Calculation of Energy Safety Threats

The mathematical model defines gas supplier safety condition in terms of the gas distribution network destruction:

$$\sum_{m=1}^{m_1}\sum_{i=1}^{i_1}\sum_{k=1}^{k_1}\sum_{n=1}^{n_1} n\int_0^{2\pi} d\theta \int_0^{r_1}\{R_i(t_{m,k},r,\theta)\prod_{j=1}^{i-1}[1-\int_0^{\kappa_1} R_i(t_{m,k},r,\theta)]\,p_n(t_{m,k},r,\theta)\}\,r\,dr\,I_k(t_{m,k})\cdot Y_i(t-t_{m,k})<[K];$$

$$\sum_{m=1}^{m_1} K_m < [K], \qquad K_m = F_m \sum_{k=1}^{k_1} R_q(t_{m,k})\cdot n_q(t_{m,k})\cdot I_k(t_{m,k})\cdot Y_i(t-t_{m,k}),$$

$$R_q(t_{m,k}) = \sum_{i=1}^{i_1} S_i(t_{m,k}, r_1)/F_m,$$

$$S_i(t_{m,k}, r_1) = \int_0^{2\pi} d\theta \int_0^{r_1}\{R_i(t_{m,k}, r, \theta)\prod_{j=1}^{i-1}[1-\int_0^{r_1} R_i(t_{m,k}, r, \theta)]\}\,r\,dr$$

$$n_q(t_{m,k}) = \sum_{n=1}^{n_1} n\cdot p_n(t_{m,k}, r_q, \theta_q)$$

Accumulation of Benchmark Data to Forecast and Analyze Energy and Environmental Risks of Heat and Power Production by GF Units

Questionnaire surveys for estimation of situation,

trends and priorities in residential gas use:

➢ Questionnaire 1	“Domestic and commercial use of gas: existing situation”
➢ Questionnaire 2	“Expected residential gas demand”
➢ Questionnaire 3	“New technolog ies for residential gas use”
➢ Questionnaire 4	“Life cycle of domestic and commercial gas equipment”
➢ Questionnaire 5	“Trends and expected improvements of heat producing domestic and commercial gas equipment”

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Generation of Initial Data to Forecast and Analyze Energy and Environmental Risks of Heat and Power Production by GF CCU

Short Questionnaire on District Heating

Issues Covered:

- Industrial, domestic and commercial use of gas: existing situation
- Expected residential gas demand
- New technologies for residential gas use
- Life cycle of industrial, domestic and commercial gas equipment
- Trends and expected improvements of heat producing industrial, domestic and commercial gas equipment

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Domestic and Commercial Use of Gas: Existing Situation

Questions	Answers, please choose the acceptable variant
Share of natural gas and other gas fuels in the energy balance of residential heat supply in the given region	**Urban districts** **A - <30%; B - <50%; C - >50%** **Other (please, specify)** **Rural districts** **A - <30%; B - <50%; C - >50%** **Other (please, specify)**
Existing relations between central and decentralized gas heating in the given region	Urban districts Rural districts
Respective shares of liquefied and natural gases as used for residential heating in the given region	**Urban central heating** **Rural central heating** **Urban decentralized heating** **Rural decentralized heating**
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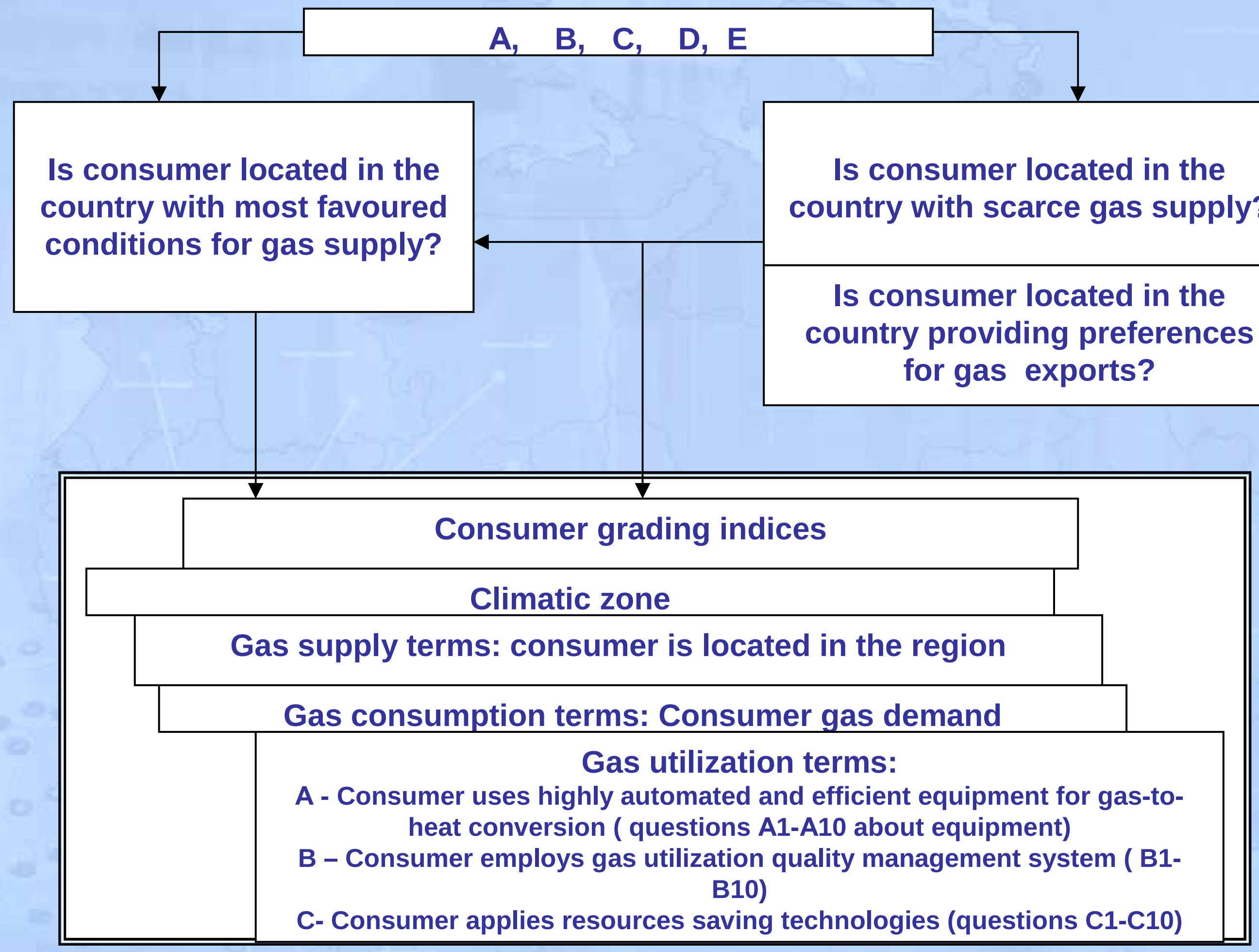
Application of Presented Model to Make Forecasts on Gas Consumption and Energy and Environmental Risks

Algorithm for questionnaires and surveys organization



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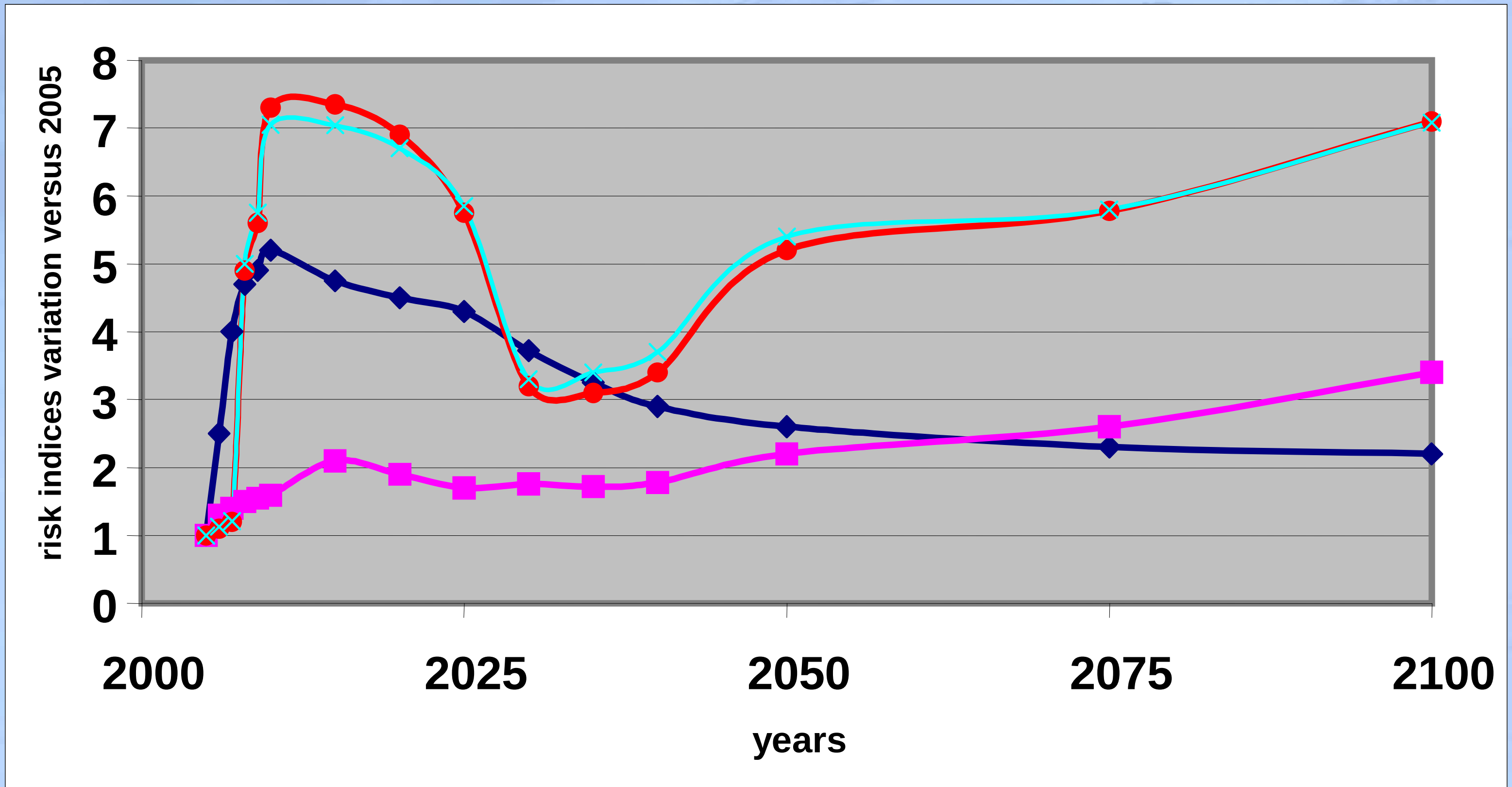
Assessment of Energy Safety Risks of Heat and Power Production by small GF CCU in Different Russian Regions



Expected energy safety risks indices in the North- West Federal District

- ● - Consumer's risk in the situation of gas demand monotonous linear law increase
- ● - Supplier's risk in the situation of gas demand monotonous linear law increase
- x - Consumer's risk in the situation of gas-to-power demand decrease
- ● - Supplier's risk in the situation of gas-to-power demand decrease

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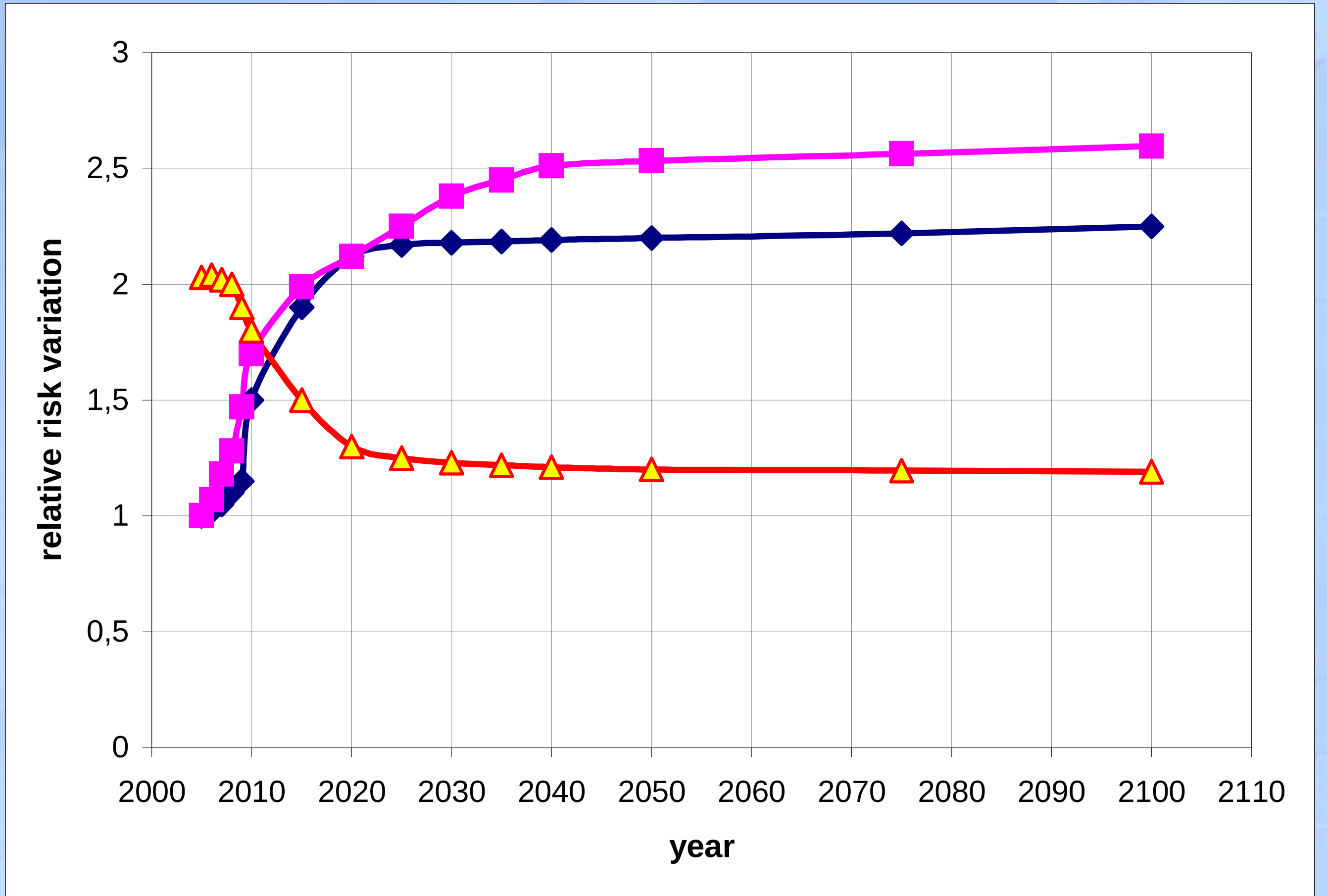
Analysis of Energy Safety Risks in Different Regions of RF



Expected energy safety risk indices in the North-West Federal District

- △ - Risk of heat and power production on SUS CCU
- ◆ - Risk of heat and power production on big CHP stations implementing combined (steam and gas) thermodynamic cycle of heat engine
- ■ - Risk of heat and power production on big CHP stations with ordinary steam turbine

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Model Development

The territories (countries) were conditionally divided into 5 groups:

The first group **contains territories characterized by high density of population, for example, Moscow region and Germany, where exist developed gas networks and electric power grids, own local gas fields and advanced industry.**

The second group **contains territories and countries where exists advanced industry, but own gas fields and other fuel recourses are practically absent. The example of such territories is the Kaluga Region of Russia and the Ukraine.**

The third group **unites territories and countries where exists advanced industry, high density of population and heat and power energy supplies by other sources, for example, by nuclear stations. The share of gas in domestic sector of such territories is small yet. The example of such territories is the Tver Region of Russia and Taiwan.**

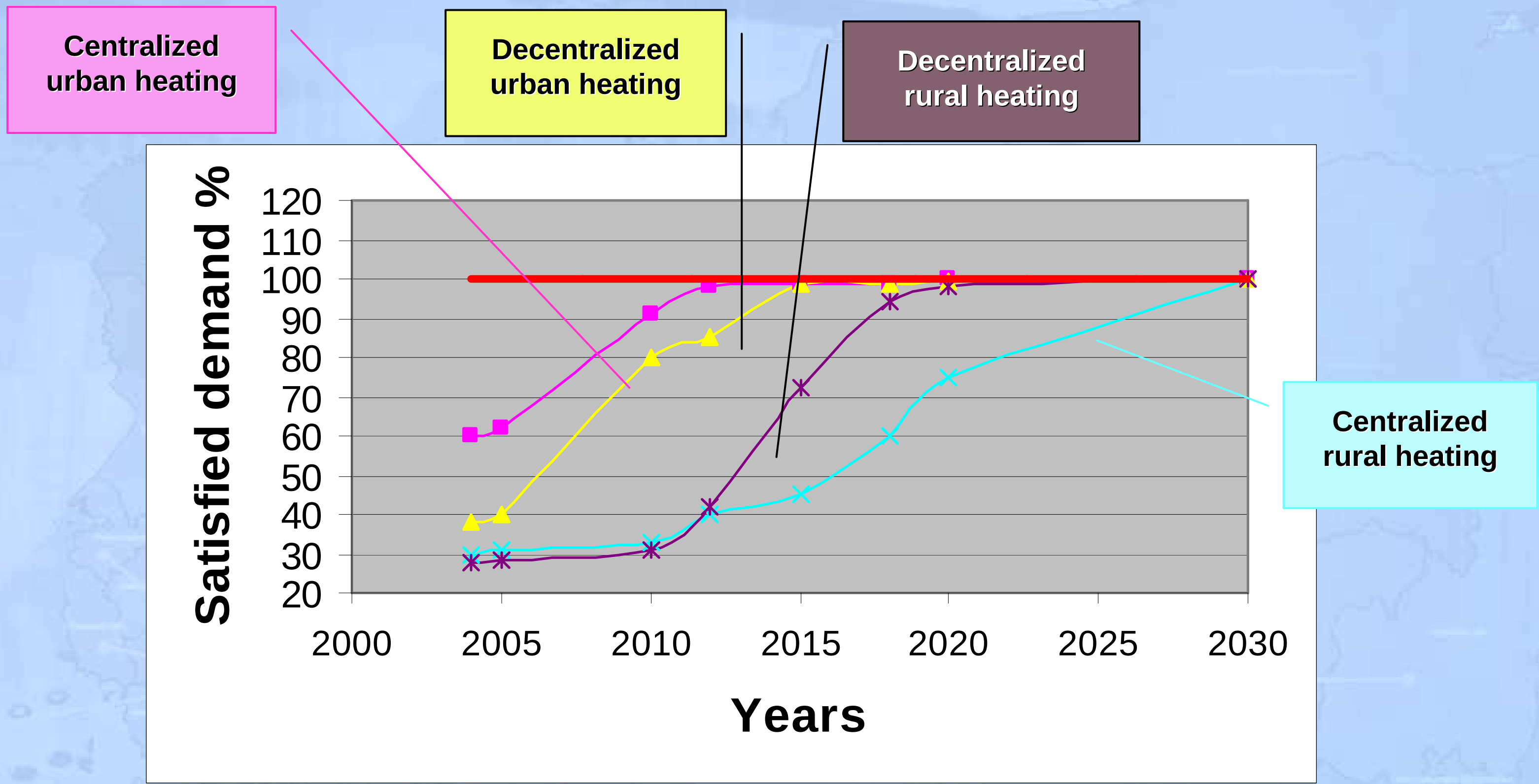
The fourth group **includes regions with low density of population, large-scale gas fields and excess of gas fuel. The example of such territories is northern regions of Russia, Turkmenistan and Bolivia.**

The fifth group **of territories includes regions with low density of population and without producing gas fields, where rural population prevails and industry remains underdeveloped. The example of such territories is Kalmykia in Russia and Mongolia.**

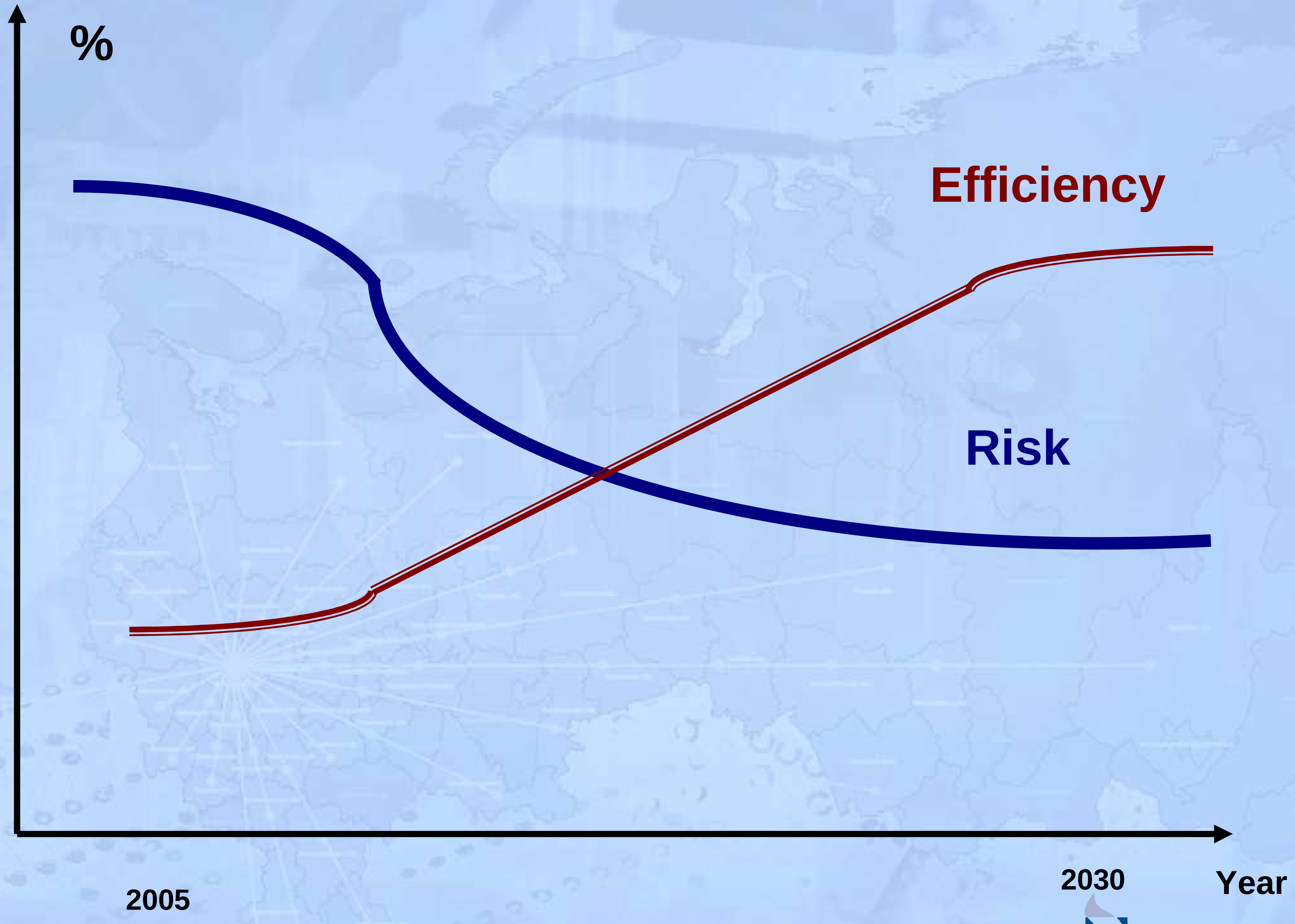
At the same time the territories of listed groups were divided into two typical for every country sub-groups – urban and rural territories.

All groups were analyzed taking into consideration climate conditions (average annual temperature, winter period, etc.).

Application of the Presented Model



Efficiency and Risks of Decentralized Heat and Power Production



Conclusions

Expected structure of regional energy balances in RF:

- Gas share of 45-50%
- Nuclear power share of 16-20%
- Coal share of 15-20%

According to risk forecasts analysis, prospective ratio of GF SUS CCU to big CHP stations capacity is in the interval of 0,65-0,35

Calculation of gas consumer and gas supplier risks pursues 5 goals:

1. Clear priorities identification for consumer and supplier
2. Analysis of initial terms of gas supply and use to provide for efficient and safe gas consumption. Monitoring of gas supplier’s and gas consumer’s risks
3. Programming of corrective interference in case of gas supply and consumption scenario variation. Risks monitoring as based on virtual IT systems and technologies
4. Improvement of existing «gas supplier – gas consumer» regional system, including change of gas consumption terms and volumes to improve energy safety
5. Correction of interference impacts over “gas supplier – gas consumer” system

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Thank you for your kind attention

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