Forecasting Energy Efficient Development of Gas Industry in Region

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Abstract. In the study, the energy efficient development of the gas industry in the region is in essence a mater of finding options for developing the gas industry (GP) and the regional economy in the context of the set of indicators proposed by the author. The set of indicators includes: socio-economic criteria, reflecting the growth of the well-being of the population and the potential of the region's economy; energy indicators characterizing the efficiency of the gas industry's branches of gas production, processing, transportation and supply, as well as rational use of all types of energy resources. The author developed the industry model of the gas industry as part of the regional economy model and proposed a methodological tool for forecasting various energy consumption options and increasing energy efficiency in gas production, processing and transportation. Modeling tools for forecasting the energy efficiency of the gas industry in the region can be used by regional authorities to make management decisions in improving energy efficiency and security in the region. The proposed model was tested on the statistical material of the Tyumen region.

Introduction

At present, increasing energy efficiency is becoming increasingly relevant both in the European Union and in Russia (European Commission on Energy for 2020-2030). The content and goals of energy-efficient development of the European Union were defined [1]. It is planned to increase energy efficiency at all stages of energy production. Performance obtained from energy efficiency should exceed costs; therefore, EU measures focus on sectors where the savings potential is greatest, for example, reducing the cost of heating and cooling residential and industrial buildings, which account for half of the country's energy consumption.

According to the Energy Strategy of Russia [13], energy efficiency development means the creation of a sustainable and self-regulating system for ensuring energy security, taking into account the optimization of the territorial structure of production and consumption of fuel and energy resources (FER). The target energy indicators of the strategy assume: a reduction in unit costs for the production of fuel and energy resources, an increase in the production of basic energy resources, an increase in primary energy exports, a reduction in the specific emission of pollutants into the air, a decrease in the level of greenhouse gas emissions, a reduction in the specific energy intensity and electrical capacity of gross domestic product, and others.

Researchers are still making great efforts to identify the correct relationships between the indicators of general economic efficiency and the efficiency of energy solutions [1, 5, 8, 9-11]. Efforts are also continuing to further expand the concept of the efficiency of the regional fuel and energy sector, in particular the application of multi-objective (multicriteria) approaches, reflecting not only the economic but also the social demands of society for energy (for example, nuclear) [2-3].

In this regard, the task of energy-efficient development of the region boils down to the choice of coordinated options for the development of the gas industry, in which the best state of the selected system of economic indicators and energy parameters is achieved for purposes that characterize the development of the regional economy as efficient. At the same time, economically effective development (growth of GRP and welfare of the population) is balanced with increasing efficiency of production processes, transformation, distribution and final consumption of all types of fuel and energy resources.

To solve this task, it is necessary to use model-forecasting tools that allow regional authorities to carry out scientifically based forecasts of the consequences of management decisions, to formulate optimal options for energy-efficient development of the region and assess their implementation.

1 Methodology for forecasting energy-efficient development of the gas industry in the region

The purpose of the study is to develop a forecast tool for making managerial decisions by regional authorities

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based on improving the energy efficiency and security of the region's economy. In accordance with the goal, the following tasks were solved:

- formation of a set of sectoral indices of energy-efficient development of the gas industry in the region (socio-economic indicators reflecting the growth rates of the population's well-being and the potential of the region's economy, energy indicators characterizing the efficiency of gas industries in gas production, processing, transportation and supply, and rational use of all types of energy resources);
- development of the industry model of the gas industry as part of the regional economy, using the example of the Tyumen region, which allows one to reconcile forecast energy consumption and energy efficiency in gas production, processing and transportation;
- development of forecast tools that allow one to find the optimal options for the development of the gas industry (GP) and the economy of the region, in the context of the complex of economic and energy efficiency indicators proposed by the author.

1.1 Statement of the problem

The solution of the problem of energy-efficient development of the region is reduced to finding the best options for the development of the gas industry (GP) and the economy of the region, in the context of the complex of indicators proposed by the author. Let us form a system of indicators of energy-efficient development of the region:

$$L = [L_{sozec}, L_{ener}]^T, \quad (1)$$

where

L_{sozec} - vector of socio-economic development indicators for the region;

L_{ener} - energy vector.

We denote

$$L^0(t) = [L^0_{eozec}(t), L^0_{ener}(t)]^T \quad (2)$$

as a vector of target values, characterizing the development prospects [0, t_T] at points $t = t_1, t_2, \ldots t_T$; a vector of target values, characterizing energy indicators L^0(t) and meeting the strategy of energy-efficient development of the region. Inclusion of the vector of "energy efficiency" L^0_{ener}(t) in the model of the region's economy (2) increases regional development.

Mathematically, the task of increasing energy efficiency in the region can be represented in the form of multicriteria optimization:

$$\|L(V,t) - L^0(t)\| \to \min_{V(t) \subset D_v}; \quad t = t_1, t_2, \ldots t_T; \quad (3)$$

$$L(V,t) = C_O(S,V,t); \quad (4)$$

$$dS(t)/dt = C_s(S,V,t); \quad (5)$$

$$S(t) \subset Ds(V,t) \quad (6)$$

where $C_O(V,t)$ - dependence, which allows one to determine $L(t)$ various options for the development of the economy of the region and the gas industry:

$$V(t) = \begin{bmatrix} V_{sozec}(t) \\ V_{ener}(t) \end{bmatrix}, V(t) \subset D_V, \quad (7)$$

where $V_{sozec}(t)$ - vector of regional economic development indicators; $V_{ener}(t)$ - vector of indicators for the development of the gas industry;

Dv - set of administrative decisions;

$S = [s_1, s_2, \ldots, s_n]^T$ - vector of regional resources;

$C_s(S,V,t)$ - model of the region's economy;

$Ds(V,t)$ - resource constraints.

Determination of the chosen system of indicators (1) and target values (2) is carried out by solving task (3) - (6) in the form of finding an energy efficient option for the development of the gas industry in the region. The formation of a set of socio-economic indicators L_{sozec} is based on the proposals of the OECD [14] and Stiglitz-Sen-Fitoussi [6]. Commission includes the following elements: economic well-being of the population, quality of life and a sustainable socio-economic status.

Table 1. Indicators of economic development.

Direction	Indicators
1. Level of welfare of the population in the region	1. Level of monetary income of the population, %. 2. Indicator of replacement of pension incomes, %. 3. Income level of the population is lower than the subsistence minimum, %. 4. Differential income ratio of the population. 5. Number of housing stock per capita, square meter. 6. Birth rate, person. 7. Infant mortality rate, person. 8. Life expectancy, years. 9. Number of pre-school educational institutions, places / 1000 children. 10. Crime rate, %. 2) 11. Total expenditures on education, % in GRP.
2. Potential for the reproduction of the regional economy	12. Share of employed in the number of able-bodied population, %. 13. Unemployment rate, %. 14. Factor of accumulation of fixed capital, % in GRP. 15. Factor of depreciation of fixed assets, %. 16. Growth of gross regional product, %. 17. Amount of intermediate consumption in the volume of production, %. 18. Share of innovative products, % in GRP. 19. Increase in exports, %. 20. Level of income from own production in the structure of the budget of the region, %. 21. Lack (deficit) of the regional budget, %. 22. Public debt, % in GRP

Source: compiled by the author

The proposed set of indicators of economic development contains 2 groups of parameters characterizing the welfare of the population and the potential of the regional economy (Table 1).

The indicators of energy efficiency reflect the main criteria for energy-efficient development of the region: energy intensity, energy saving, energy security.

The energy indicators used in this study are described in terms of production and consumption of fuel and energy (Table 2).

Table 2. Indicators of energy-efficient development of the gas industry in the region.

Subjects	Indicators
1. The gas industry (SOE)	1. Growth in gas production in the region, %. 2. Share of renewable energy sources in the production of the gas industry, %. 3. Energy intensity of the gas industry, kg of equivalent fuel / USD. 4. Fuel capacity in the production of electrical energy, kg of equivalent fuel / kW-h. 5. Fuel capacity in the production of thermal energy, kg of equivalent fuel / Gcal. 6. Specific losses in the gas industry, % in FER. 7. Losses in electrical networks, % of electricity production. 8. Losses in heat networks, % of heat production. 9. Coefficient of capacity utilization in gas production, processing and transport, tons of equivalent fuel. 10. Coefficient of depreciation of fixed assets in the gas industry, %. 11. Level of investment activity in the gas industry, %.
2. The real sector of the economy (without GP)	12. Level of energy intensity reduction in the real sector of the economy per year, %. 13. Share of self-energy supplying organizations, %. 14. Proportion of organizations that meet environmental standards, %.
3. Organizations and institutions of state property	15. Level of a decrease in the energy intensity of the public sector (kg of equivalent fuel / USD), %. 16. Consumption of FER in the expenditures of the regional budget, %.
4. Households	17. Level of consumption of fuel and energy resources per capita (kg of equivalent fuel / person), %. 18. Level of electricity consumption per capita (kg of equivalent fuel / person), %. 19. Level of household fuel and energy expenditures, %. 20. Share of household FER expenditures in the subsistence minimum, %. 21. Degree of deterioration of residential buildings, % 22. Energy consumption level of residential buildings (kg of equivalent fuel / square meter), %
5. In general, the regional economy	23. Energy intensity level of GRP (kg of equivalent fuel / USD), %. 24. Share of primary energy production in gross fuel consumption, %. 25. Indicator of self-sufficiency of fuel and energy resources, %. 26. Regional Energy Efficiency Indicator. 27. Share of the most used type of FER in gross consumption, %. 28. Amount of energy saving in energy-saving measures.

The supplier of energy resources is the gas industry. Consumers of energy resources are subjects of the region's economy:

- real sector of the economy (without GP);
- organizations and institutions of state property;
- households;
- other indicators of overall regional effectiveness.

This set of indicators when assessing the energy efficiency of gas industry development in the region allows one:

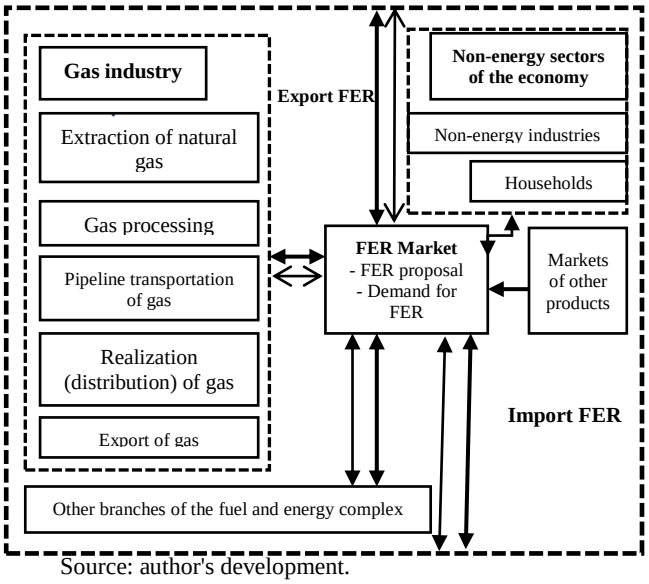
- to identify and assess the role of the gas industry in the overall energy efficiency of the region;
- to identify areas of energy-efficient development of the gas industry in the region from the perspective of the subjects of the region's economy.

1.2 Development of a model for the development of the gas industry in the region

In the model of gas industry development, the regional economy includes a set of economic entities by types of economic activity of OKVED with the input of agents: "households", "public authorities", "external environment", and "market management" responsible for the market equilibrium of supply and demand [14].

The subjects of the regional economy produce the main products sold on the domestic or foreign market. In the model of the regional economy, the following elements are involved: intermediate consumption goods and services (including fuel and energy resources used for processing, transformation and end use); investment and consumer goods and services, including types of fuel and energy resources used by the population; infrastructure services in the region; public services; labor services.

Agents in the model of the region's economy engaged in the production, transformation and processing of fuel and energy resources are included in the model of the gas industry, consisting of three spheres (Figure 1). Figure 1 shows flows of fuel and energy resources (FER) and cash.



Source: author's development.

Fig. 1. A model of the gas industry as an integral part of the regional economy model.

The following fuel and energy resources are used in the gas industry model: natural gas, dry gas, liquefied gas, gas processing products, electric and thermal energy.

The activity of agents in the model of the regional economy is described in two directions of production functions as the agents forming the market supply and the formed demand for intermediate products (including fuel and energy resources). Let us imagine the aggregate production function of an economic entity $i \in Vgp$, belonging to the gas industry and forming money and resource flows:

1 - flow of produced fuel and energy resources:

$$Y_i^{out}(t) = \min\{Y_i^{prog}(t), Y_i^{poten}(t), Y_i^{dem}(t) + \Delta Y_i(t)\}; \quad (8)$$

2 - flow of input production resources:

$$Y_i^g(t) = A_i(t) Y_i^s(t); \quad (9)$$

3 - cash flow from the sale of fuel and energy resources:

$$d_i^s(t) = (Y_i^{out}(t) - \Delta Y_i(t)) P_I^T(t); \quad (10)$$

4 - cash outflow for the supply of intermediate products and production resources:

$$d_i^g(t) = Y_i^g(t) \hat{P}_I^T(t). \quad (11)$$

where $Y_i^{out}(t)$ – vector-column for the actual production of energy resources for i agent (in-kind);

$Y_i^{prog}(t)$ – vector-column of the predicted production of energy resources;

$Y_i^{pot}(t)$ – potential production volume of the i agent, depending on the state and use of production resources;

$Y_i^{dem}(t)$ - the vector of demand for energy produced by the i agent;

$\Delta Y_i(t)$ - energy production growth rate vector of the i agent;

$Y_i^g(t)$ - vector-column of purchased intermediate products and production resources;

A_I - matrix i of agent costs, intermediate products and production resources per unit of produced energy resources;

$d_i^s(t)$ - revenue from sales of energy resources;

$d_i^g(t)$ - costs of the agent for the acquisition of intermediate products and production resources;

$P_I(t)$ - vector-column of prices of energy resources produced;

$\hat{P}i(t)$ - vector-column of energy prices for consumers in the market.

The potential release of the i agent can be calculated as follows:

$$Y_I^{pot}(t) = C_I \sqrt{p_I(t) h_i(t) r_i(t)}, \quad (12)$$

where C_i - a vector characterizing the scale of production of fuel and energy resources with indicators of production factors; $p_i(t)$ - cost of fixed assets of the i agent; $h_i(t)$ - number of employees; $r_i(t)$ - increase in labor productivity.

In the model of the regional economy in the markets of conventional products and hydrocarbon markets, the equilibrium state supports the commodity-sector balance (TSB), formed on the basis of the system of national accounts [14]. The balance is designed for all conventional products used in the model and fifteen kinds of fuel and energy resources. For example, the balance of the type j of fuel and energy resources $(j \in J_{T \supset P})$ can be represented as:

$$y_j^{s1}(t) + y_j^{s2}(t) + y_j^{s3}(t) + y_j^{s4}(t) = y_j^{out}(t) - y_j^{exp}(t) + y_j^{imp}(t) - \Delta y_j(t). \quad (13)$$

In the left part of expression (13), the demand for fuel and energy resources of j type in the region's economy is presented in the form of: production of electric and thermal energy (y_j^{s1}), gas processing (y_j^{s2}), consumption as non-energy raw materials (y_j^{s3}); final consumption (y_j^{s4}). Components y_j^{s1}, y_j^{s2} represent the costs for the acquisition of fuel and energy resources by agents that are part of the gas industry. The values y_j^{s3} and y_j^{s4} represent the volume of consumption of type j of hydrocarbons at oil and gas chemical enterprises and the volumes of consumption of type j of energy resources in all agents of the region's economy.

On the right side of the balance sheet (13) there is the volume of the supply j of energy resources on the regional market: y_j^{out} - volume of production of type j of energy resources at all enterprises of the gas industry in the region; y_j^{exp} - export of type j of hydrocarbons; y_j^{imp} - import of type j of energy resources; Δy_j - change of type j in energy resources.

In a value form, the balance expression for the type j energy resources can be represented as:

$$(y_j^{s1}(t) + y_j^{s2}(t) + y_j^{s3}(t) + y_j^{s4}(t)) \hat{p}_j(t) = (y_j^{out}(t) - y_j^{exp}(t) - \Delta y_j(t)) p_j(t) + y_j^{imp}(t) \hat{p}_j(t) + \Delta d_j \quad (14)$$

where $\hat{p}_j$ - average consumer price the type j of energy resources in the hydrocarbon market; p_j - average producer price the type j of energy resources; Δd_j - type j energy surcharge.

Balance ratios (13) - (14), represented in the model of the gas industry, are part of the overall commodity-sector balance sheet and allow the inter-balance relations to simulate the interaction of the gas industry with the regional economy.

The developed model was tested on the statistical material of the Tyumen region. Approbation was carried out by calculating the exogenous parameters of the model in accordance with the actual values of similar parameters. Thus, for example, the indicators of technological matrices A_i and B_i are subjects of the economy, coefficients of elasticity of energy production costs, prices and natural and climatic factors.

The balance of the gas industry (13) and (14) was adjusted in accordance with the methodological developments of the Ministry of Energy of the Russian Federation and Rosstat [2], which do not differ from the world methodology of balancing the IEA / Eurostat [1, 4,

7, 12, 15].

The model developed makes it possible to forecast the balanced development of the gas industry in the regional economy and to choose the optimal energy-efficient option for the development of the gas industry in the region.

Conclusion

In difficult geopolitical conditions, energy-efficient development of a strategically important gas industry in the country at the regional level implies the use of modern systems to support management decisions that take into account the implementation of energy-saving measures in the fields of gas production, processing and pipeline transport. Since managerial decisions in the economy of the region and branches of the gas industry often do not correlate, the choice of the best relations between the indicators of general economic and energy efficiency should be carried out using multicriterion optimization problems. In such tasks, the guidelines for energy-efficient development of the region are set as the chosen system of energy indicators. Based on regulatory documents, the author developed a system of energy indicators describing the development of the gas industry and the regional economy, taking into account the optimality of energy intensity, energy efficiency, energy saving and energy security.

The methodology developed by the author for forecasting the balanced development of the economy and the gas industry, through which the forecasts of the production of energy resources and energy consumption in the gas production, processing and transportation sectors are coordinated within the framework of the construction of a regional TEB. The novelty of this methodology is that the gas industry acts as the main link in the fuel and energy balance of the region, which in turn is part of the overall regional product-sector balance sheet and allows simulating the mutual influence of the gas industry and the rest of the economy through inter-balance relations.

The methodology of forecasting and strategic planning of the region's energy-efficient development proposed in the course of the research is aimed at supporting the management decisions of regional authorities in order to improve the energy efficiency and security of the regional economy. This required the adjustment of the model tools in the region's statistics. Thus, the model toolkit is tested on the statistical material of the Tyumen region. The main problems were: the incomplete reporting data, their inconsistency, as well as the transition of domestic statistics in 2017 to a new classification of economic activities [14]. To solve the problems of incompleteness and inconsistency of the data, a tool was developed for supplementing and balancing data.

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