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A Multi-criteria Model for Structural Gap Assessment in the Forecast Fuel and Energy Balance: A Systemic Management Approach

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Abstract
The article examines the fuel and energy balance (FEB) as a tool for systemic management of all economic subsystems that influence the formation of the energy balance structure. *The goal of the study* is to develop a *conceptual* model for generating a forecast FEB, ensuring full alignment of fuel and energy sectors with macroeconomic targets by selecting the most effective management decisions at the national, regional, and district levels. *A distinctive feature* is the rationale for a multi-criteria assessment of the impact of management decisions in the fuel and energy sector and related sectors on the structural parameters of the forecast FEB. This will enable a quantitative analysis of the impact of alternative management decisions (program measures) on the key elements of the forecast FEB. This article presents a mathematical model for calculating the integral value of a structural gap in individual FEB subsystems caused by a specific decision option or set of program measures. It also presents a developed mathematical model for calculating the integral indicator of structural changes in FEB subsystems caused by the implementation of specific management decisions or development programs.

Keywords - Fuel and energy balance, Forming, System, Programs, Goals, Structure, Strategy, Energy security.

1. Introduction

To ensure the stability of the global energy balance in the context of dynamic geopolitical transformations and economic instability, factors such as reliable energy infrastructure, accelerated technological development, and the formation of sustainable partnerships between states are becoming critical. These elements are becoming a system-forming foundation capable of mitigating the risks of destabilization in the energy security of any country. The fuel and energy balance should be viewed as a tool that, through optimization of its structural elements over the forecast period, allows for more rational solutions to both national and global energy security challenges.

In the modern global community, energy balance management issues are becoming a key priority on the global agenda. This is driven by the interdependence of national economies and the shared challenges associated with the energy transition, as well as the development of the digital economy. Effective management of the global energy balance requires not only coordinated efforts to stabilize energy markets, but also the joint development of standards, the exchange of advanced technologies, and the creation of mechanisms to prevent energy supply crises.

In the context of global energy trends, the stable dominance of traditional energy sources in the global energy balance is observed, while the dynamics of demand for these energy sources remains positive, demonstrating a projected growth of 1% in 2025. At the same time, an accelerated increase in global electricity demand is recorded, with the growth rate in 2025 estimated at 3.3%, exceeding the projected growth of the global economy as a whole, which is 3.2% (Novak, 2025). This disproportion in growth rates is due to a combination of factors, among which the key ones are the mass adoption of energy-intensive computing technologies and artificial intelligence systems, the spread of electric vehicles, and the accelerated pace of electrification and robotic automation of industrial production and the social sphere.

International practice shows a diversity of strategic approaches to ensuring energy security and affordability, with different countries pursuing different measures to achieve these goals. Some countries, particularly those importing fuel and energy resources (FER), prioritize the development of renewable energy sources and measures to improve economic energy efficiency. Meanwhile, other countries focus primarily on ensuring sufficient reserves of traditional fuels, viewing this approach as the foundation for maintaining energy supply stability and economic development (World Energy Outlook, 2025).

Decisions made by energy policymakers are always crucial to addressing various national and energy security risks. Therefore, in current conditions, the issues of managing the economic security of the country and regions are being updated through the formation of the fuel and energy balance and the change of its status from a formal statistical document to an effective flexible management tool.

The accelerated development of the energy transition has prompted various countries to develop measures aimed at finding primary resources that will reduce CO_2 emissions. This, in turn, has directly affected the structure of the global energy balance. Klavdienko (2025) analyzes the structure of global primary energy consumption by energy source (**Table 1)**. Structural changes in primary energy consumption that occurred in the global energy sector from 2000 to 2023 had a restraining effect on total CO_2 emissions. One promising solution for decarbonizing the global energy sector is the implementation of CCUS (Carbon Capture, Utilization, and Storage) technologies. This solution is also reflected in the FEB and influences changes in its structural elements over the forecast period.

Table 1. Structure of global primary energy consumption for 2000-2023, %.

Types of energy sources	**2000**	**2010**	**2020**	**2023**
Fossil fuels, including:	***85.6***	***86.9***	***82.3***	***81.5***
- oil	39	33.1	31	31.7
- coal	24.9	29.5	26.8	26.5
- gas	21.7	23.7	24.5	23.3
Renewable sources	***7.8***	***7.9***	***13.6***	***14.5***
Nuclear fuel	***6.6***	***5.2***	***4.3***	***4***
Total	100	100	100	100

Source: calculated by Klavdienko (2025) based on: BP Statistical Review of World Energy (2022). 71-st Edition. London. UK.2022; Energy Institute. Statistical Review of World Energy. 2024 73-Edition; Our World in Data. GCDL. 2024

The rapid economic growth currently observed in a number of countries is largely energy-intensive, and national energy systems must be prepared for this. Decisions made at the state and individual company levels must be coordinated to more efficiently meet growing energy demand. India is among the countries demonstrating a steady trend toward increasing energy consumption, which is statistically confirmed by the 26.6% growth in primary energy use between 2012 and 2021 (Seregina, 2023). In global energy consumption rankings, India ranks third, behind only China and the United States, while its share of global energy consumption is approximately 6%. However, it should be noted that fossil fuels account for over 90% of the country's primary energy resources (oil – 27%; coal – 57%; natural gas – 6%; renewable energy – 5%; hydropower – 4%; nuclear energy – 1%) (Seregina, 2023). In the context of the energy transition, which presupposes an increase in the share of low-carbon and carbon-free energy resources in the FEB, it is necessary to develop appropriate management solutions. One such solution is the development of partnerships for energy dialogue, for example with Russia.

Thus, the energy balance plays a key role in substantiating decisions in the energy sector, and accordingly, the development of methodological issues in its formation will allow for the preventive development of program measures aimed at building a national energy policy in the context of emerging global trends.

The analysis of the retrospective period showed that in Russian practice there was a slight decrease in interest on the part of the state and industry departments in the formation of a consolidated FEB. It directly affected the decrease in the effectiveness of assessing the balance of the FEB structure and its impact on the energy intensity of gross domestic product (GDP) and gross regional product (GRP).

The renewed interest in the formation of relevant FEB and attempts to use this tool in the formation of long-term development strategies for the state and individual regions can be linked with the issue of the Order of the Ministry of Energy of the Russian Federation dated October 29, 2021 No. 1169 "On Approval of the Procedure for Compiling Fuel and Energy Balances of Regions of the Russian Federation and Municipalities"[1], according to which the rules for compiling actual and forecast fuel and energy balances by executive authorities of the regions of the Russian Federation and local self-government bodies of municipalities were established. The document recorded the interest and need for the formation of not only an actual, but also forecast FEB, which means that it can act as a tool for managing the energy security of socio-economic systems. The study of the future state and the provision of the desired structure in the forecast period allowed us to assume that the development of strategic documents aimed at ensuring the sustainable development of the regions, their energy security and, as a result, the entire country will correlate with the long-term programs being developed and implemented. The structure of the forecast FEB is influenced by many factors that need to be taken into account, for example, the formed trend towards optimizing the structure of the Russian electric power industry (Bashmakov, 2022a; Kapitonov et al., 2022; Salnikov and Frantsuzova, 2021; Selivanov and Shakhnov, 2022; Semin et al., 2019), as well as various investment projects implemented by fuel and energy companies and aimed at increasing certain types of fuel resources (Salko et al., 2022). However, practice has shown that the process of forming forecast FEB turned out to be quite complex and not fully developed methodologically, requiring additional research and preparation of appropriate methodological recommendations for different levels of government. A unified systemic approach has not been formed to address this issue, and the practice developed during the Soviet period, when the role of FEB was significantly greater than today, was not timely updated.

In connection with the above-mentioned, it seems necessary and possible to develop methodological aspects of the formation of forecast FEB and ensure the achievement of its predictive structure through the more active use of a program-oriented approach and methods of multi-criteria optimization. In addition, the formed system of the FEB structure management can be in demand at various management levels when achieving a sufficiently wide range of strategic and tactical goals.

1.1 Goals and Objectives of the Study

To solve the methodological problems of forming forecast energy balance sheets and ensuring their consistency with the strategic documents of the energy sector, the study sets a goal and a number of tasks that need to be solved.

[1] Order of the Ministry of Energy of the Russian Federation No. 1169 dated October 29, 2021 "On Approval of the Procedure for Drawing up Fuel and Energy Balances for the Subjects of the Russian Federation and Municipalities". – URL: https://www.garant.ru/products/ipo/prime/doc/402941176 (date of access: 22.02.26)

The goal of the study is to develop a conceptual model for forming a forecast energy balance sheet that allows for the full alignment of the fuel and energy sector with macroeconomic targets by selecting the most effective management decisions at the national, regional, and district levels.

To achieve this goal, it is necessary to fulfill the following tasks:

- to study the accumulated experience of forming the fuel and energy balance;
- to identify the possibility of managing the structure of the fuel and energy sector based on the use of the program-oriented approach and methods of multi-criteria optimization;
- to identify the area of practical use of forecast FEB in the formation of strategic trajectories for the development of socio-economic systems (regions and the country as a whole), as well as possible solutions aimed at raising the status of FEB as one of the effective tools for analyzing the effectiveness of the functioning of the country's economy and its fuel and energy sector specifically.

The scientific novelty of the research lies in the development of a scientific and methodological approach to the formation of forecast fuel and energy balances and their inclusion in the management cycle of ensuring the state's energy security.

The study was conducted on the basis of a systemic analysis of trends emerging in the field of FEB management, both in a retrospective context and in the current and forecast periods. The methodological basis is represented by a program-oriented approach, comparative analysis, as well as methods of multi-criteria optimization.

1.2 Study Progress

The article consists of six sections. Section 1 presents the background and rationale for the study. Section 2 provides a comprehensive analysis of the scientific literature, assessing the current state of knowledge on the development of a fuel and energy balance and identifying key research trends in international practice. Section 3 describes a conceptual model for developing a fuel and energy balance. Section 4 presents the mathematical formulation and testing of a multi-criteria assessment model using the example of an autonomous area. Section 5 discusses the key ideas and potential limitations to the practical implementation of the proposed conceptual model for developing a fuel and energy balance. Finally, Section 6 concludes the study and suggests directions for future research.

2. Literature Review

Over the past decade, interest in the use of the FEB as a tool for managing the balanced development of the fuel and energy complex and related industries has grown globally. However, methodological challenges prevent the balance from being integrated with strategic planning documents and integrated into a system for assessing the fuel and energy complex's mutual influence on other economic sectors. Consequently, various aspects of developing a unified toolkit for formulating the FEB are becoming increasingly important. Scientific publications highlight the development of specific methodological aspects that suggest the use of more precise analysis and forecasting methods across structural elements, as well as at the regional level. **Table 2** summarizes some aspects of the FEB formation explored in the scientific literature.

Table 2. Some aspects of FEB formation explored in scientific literature.

S. No.	Aspect of comparison	Description of the methodological aspect	Source
1.	FEB formation taking into account the possibilities of digitization of processes	Using artificial intelligence tools to improve the quality of solutions to systemic problems in the energy sector, achieving consistency in the FEB at various levels.	Makarov (2021)
2.	The problem of FEB reliability, taking into account the specific features of individual territories	Using more advanced methods of econometric analysis is possible for aggregated models of the fuel and energy balance.	Dobrodey (2015)
3.	Methodological aspects of forecasting the heat and energy balance of a region	To take into account the territorial specialization of production, a block of main types of products has been identified, which allows for the reflection of physical indicators of the region's energy efficiency.	Romanova et al. (2008)
4.	Systemic assessment of energy efficiency indicators of regional economies based on the FEB	A system of models combining boiler-furnace fuel balance models and consolidated FEB is used. The impact of structural changes in the FEB on the energy efficiency of the regional economy is studied.	Saneev et al. (2013)
5.	Long-term energy planning at the regional level	This paper examines an energy system optimization model for Piedmont developed within the open-source TEMOA project (TEMOA-Piedmont). The model takes into account local specificities of energy production and consumption and helps identify barriers and opportunities for energy transition. The methodology adopted within the TEMOA-Piedmont project for developing each model sector varies depending on the structure of the available data. An overview of the main sectors, subsectors, needs, technological indicators, and demand factors in the region is provided, which can serve as the basis for multi-criteria optimization of the energy balance at a regional level.	Kavei et al. (2025)
6.	Forecasting electricity consumption taking into account nonlinear relationships in the energy consumption structure	A model for forecasting electricity consumption as a key structural element of the energy balance was developed based on the Deep Energy Predictor Model (DEPM). A hybrid model was proposed that combines the strengths of XGBoost for classification and Deep Neural Networks (DNN) for Deep Learning (DL) capabilities. The model takes into account the temporal dynamics and stochastic nature of energy consumption.	Ragupathi et al. (2024)
7.	Using time series models to forecast energy demand, consumption and production	It is noted that classical models such as Moving Average (MA), Exponential Smoothing (ES), and Autoregressive Integrated Models (ARIMA) are still widely used to forecast energy consumption and network load structure. A transition to intelligent forecasting algorithms as an alternative to traditional linear models is justified, including Fuzzy Time Series (FTS) models, Case-Based Reasoning (CBR), Gray Prediction Models (GPM), and the Prophet model. The paper presents an extensive analysis of forecasting models and characterizes their application in the context of the electric power industry.	Mustafa and Al-Yozbaky (2025)
8.	Energy planning models aimed at forecasting energy supply and demand	An analysis of forecasting methods used in 483 energy planning models was conducted.	Debnath and Mourshed (2018)
9.	Categories of model blocks for energy planning	Six categories are distinguished, namely energy information systems, macroeconomic models, energy demand models, energy supply models, modular and integrated models.	Nguyễn (2005)
10.	National models, transition to multi-agent models	This article examines a national model of the global energy sector using the Russian GEM-Dyn model, which is somewhat similar to the MESSAGE model. It is noted that this model is not equivalent to the GEM-E3 (General Equilibrium Model for Economy, Energy, Environment), developed by the European Commission in the 1990s. The Global Energy Model (GEM) is a linear optimization model with a detailed description of the technologies for extracting, converting, transporting, importing, exporting, and consuming electricity. Models such as the TIMES global energy simulation model, the GTAP computable general equilibrium model, the MERGE-GCAM-DICE-MESSAGE integrated models of climate change economics, and the prospects for developing multi-agent models are discussed in more detail.	Sidorenko and Savin (2014)
11.	Multi-Energy Systems (MES), the feasibility of moving away from centralized control and the impact on the energy balance are analyzed	Multi-Energy Systems (MES) are considered a promising solution to emerging challenges in the electric power industry. In MES, various energy sources are integrated at various levels through a combination of generation, storage, and conversion technologies, enabling the balancing of energy sources within the system and optimized resource allocation. It is noted that there is a lack of research in the scientific literature devoted to the analysis of multi-objective planning and management in the energy sector. The following models are considered: exhaustive method; evolutionary multi-objective optimization on weights; evolutionary multi-objective optimization on system configuration.	Tangi and Amaranto (2025)

Table 2 continued…

12.	Building scenarios based on the Global Business Network (GBN) method, foresight technologies	The methods under consideration are aimed at the development of effective resource conservation strategies by energy companies in conditions of environmental uncertainty.	Alizadeh et al. (2016)
13.	Strengthening the influence of social factors in scenario development in the energy sector	It is noted that when constructing scenarios in the energy sector, preference is given to technological and economic quantitative data with minimal inclusion of social factors. The feasibility of expanding the influence of social factors in scenario models by incorporating the population's preferences for energy use in everyday life is substantiated.	Kaviani and Strengers (2023)
14.	Mathematical optimization in energy systems	Optimization functions in the energy sector are considered by incorporating various limiting variables (e.g., a key performance indicator in the form of CO2 emissions). Based on the factors influencing goal achievement and the potential for multi-objective optimization, subcategories are identified: environmental, technical, economic, social, multi-objective, and subsidies.	Sporleder et al. (2022)
15.	Optimization of decentralized multi-energy systems	The MANGO (Multi-stAge eNerGy Optimization) optimization model is discussed. It is based on the strategic value of investment flexibility, which allows for optimal investment allocation. Several aspects of multi-objective optimization are explored.	Mavromatidis and Petkov (2021)

Thus, the conducted content analysis on the research topic revealed a high interest in the methodological aspects of developing a forecast FEB and its individual structural elements. Moreover, a few publications demonstrate the feasibility of using artificial intelligence at various stages of forecast FEB development. However, assessing the impact of management decisions made in the energy sector on the forecast FEB structure is not fully addressed in the scientific literature and requires further study.

3. Description of the FEB Formation Model

The proposed model is structured to provide a clear understanding of the stages involved in integrating a systemic and program-oriented approach into the process of developing a fuel and energy balance. The process takes into account not only the assumptions about the future need for intelligent forecasting based on big data and artificial intelligence, but also accumulated historical experience. The structuring and interconnection of subsystems in the FEB management system prepares for the possibility of reducing the task of managing the structural elements of a fuel and energy balance to a multi-criteria optimization problem.

3.1 Analysis of the Historical Experience of FEB Formation

The accumulated experience of forming a consolidated fuel and energy balance dates back to the Soviet period. A retrospective analysis shows that on a regular basis, the FEB was formed every five years from 1960 to 1990. In the following years, due attention was not paid to this issue, as well as to the development of methodological aspects of its formation. At the moment, scientific research in this area has resumed, not only at the level of ministries and departments, but also by individual research teams, as well as scientists actively conducting research activities in higher educational institutions (Osinovskaya and Lenkova, 2015; Osinovskaya, 2017; Osinovskaya, 2022; Sidonsky et al., 2022).

Foreign practice on the issue of the formation of a consolidated energy balance developed differently and since 1970, all conditions have been created for its formation. At first, fairly aggregated, and then increasingly detailed unified energy balances began to form abroad in the context of primary and supplied energy. They have been developed both in individual countries and by a number of international organizations (the United Nations, the International Energy Agency, etc.) (Gasho, 2023).

The world's major centers of consumption of fuel and energy resources in conditions of limited fossil fuel reserves effectively use the energy balance as a tool for managing economic security in the presence of sufficiently similar fuel and energy systems. These are China, Japan, the Republic of Korea, and Taiwan. The existing structure of the FEB allows us to draw attention to a significant share of resource imports, including high-tech imports of liquefied natural gas, and a high share of coal consumption. All these countries use modern technologies, including nuclear power and renewable energy sources, but the policies of these countries regarding modern energy technologies differ (Akimov, 2021).

The difficult geopolitical situation, as well as the conditions of the escalated energy crisis currently observed, explain why some countries search for opportunities to participate in the diversification of energy resources to foreign markets. This means that the structure of the fuel and energy balance will change one way or another at the level of states participating in the process of energy diversification, which can be taken into account when forming forecast FEB through the implementation of program measures based on the established priority goals in the field of energy security (Gasumov et al., 2023).

Therefore, the FEB must be transformed into a flexible and adaptive long-term planning tool capable of effectively ensuring the country's and economic entities' energy security in the face of changing external and internal factors. The methodological basis for developing a forecast FEB should be based on the principles of a program-oriented approach. Its practical implementation involves the use of multi-criteria optimization methods at various stages of balance formation to align competing goals and constraints.

Fuel and Energy balance represents the reporting and forecast balances of production, processing, transportation, transformation, distribution and final consumption of all types of FER, including the final stage of their utilization by consumers at the federal, regional and sectoral levels[2].

The fuel and energy balance can become the basis for making managerial decisions at different levels of government, as well as for justifying strategic directions for the development of individual industries and companies. These decisions can regulate the volume of use of various types of fuel and energy resources both in the direction of their increase and reduction, redirect investment support to companies and various economic entities that affect the priority subsystem of the fuel and energy complex in the present and future period, which in turn can lead to the emergence of new production capacities in the field of fuel and energy complex and so on.

3.2 FEB Formation Based on a Systemic and Program-Oriented Approach

The methodological basis for the formation of a consolidated FEB is close to the format used in international practice for the development of energy balances, and is based on a significant amount of forecast information, with which, at the moment, there is a number of unresolved issues. According to the approved methodology the development of the FEB is justified by the opportunity of receiving information support based on existing statistical forms of primary reporting.

One of the important factors influencing the FEB formation is the level of economic growth in a country or an economic entity, as it directly affects the level and dynamics of demand for energy resources, and it plays a significant role in the FEB formation. At the same time, it should be noted that the demand for energy resources should correlate with the achieved level of energy efficiency in the use of energy resources at the time of the FEB formation. If we consider the forecast FEB, then it is necessary to evaluate technological solutions that help maintain or increase the energy efficiency of resource use.

[2]The State Duma Committee on Energy held parliamentary hearings on the topic "Formation of Russia's and Regions' Fuel and Energy Balances: Problems and Solutions"– 13.11.23. – URL: http://komitet-energo.duma.gov.ru/novosti/d13df1f4-fe3c-40fa-8730-ced3e1057147 (date of access: 22.02.26)

The state program aimed at energy conservation and energy efficiency improvement sets targets for reducing the energy intensity of GDP by 35% by 2035 with an annual growth of the country's economy by 3-5%[3]. This means that, returning to the FEB formation based on the program-oriented technology, it is necessary for regions to develop and implement program measures to achieve the desired level of the designated indicators and ensure the achievement of goals set at the state level.

At the moment, not all regions show the consistency of the implemented programs with the targets in the field of energy conservation. E. Gasho's work shows that only 22% of regional programs formed in accordance with federal Law No. 261-FZ "On Eenergy saving and increasing energy efficiency, and on amendments to certain legislative acts of the Russian Federation" are oriented to the needs of the fuel and energy balance (Gasho, 2023).

The model of FEB formation based on a systemic and program-oriented approach is shown in **Figure 1**. It is advisable to consider the process of FEB formation as a dynamic system with input and output parameters.

At the input, information is needed on the target structure of the fuel and energy balance and the available volumes of all types of resources reflected in the balance sheet, which can be broadly divided into three groups: renewable, non-renewable, and nuclear energy. At the same time, more and more studies are being built around ensuring an increase in the share of alternative energy sources, which will directly lead to a change in the structure of the energy balance (Cantarero, 2020). Programs of active involvement of renewable energy sources in the energy balance with the help of an expanded mechanism of state support, reducing the resource intensity of the introduction of renewable energy technologies into the energy sector of Russia, are considered (Magasheva and Lomakina, 2023).

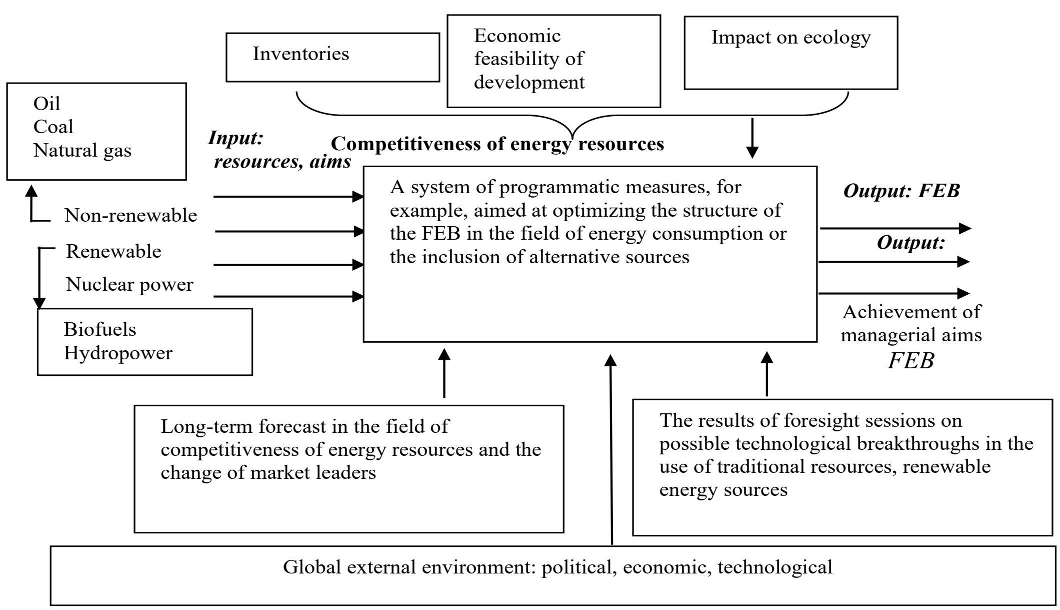


Figure 1. The model of FEB formation based on a systemic and program-oriented approach.

[3] Decree of the Government of the Russian Federation dated September 9, 2023, No. 1473 "On Approval of the Comprehensive State Program of the Russian Federation 'Energy Saving and Increasing Energy Efficiency'". – URL: https://base.garant.ru/407632842 (date of access: 22.02.26)

Forming an information field relative to available resources is also a rather difficult issue today due to the lack of a single information space and the accumulation of information from different subsystems. A solution can be found through the active introduction of digital technologies and the creation of a digital space that allows for reliable, prompt collection of primary information on industries and sectors of the economy involved in the FEB formation. The problems of information support of the FEB formation process are also considered in the works of such authors as E. Gasho, at the level of parliamentary hearings in the State Duma, and others (Gasho, 2023). The output is to obtain a current or forecast FEB depending on the context in which the system of program measures aimed at achieving goals was considered. A retrospective context allows us to get a static FEB reflecting the current situation. Consideration at the stage of forming long-term programs, for example, at the regional level, allows us to get a forecast FEB at the output.

The formation and implementation of program measures do not happen in isolation from the external environment, but in close cooperation with it, which necessitates taking into account the competitiveness of energy resources included in the balance, the possibility, speed and expediency of their mutual substitution, as well as the political and economic situation in the country and in the world. The technological independence of key industries responsible for certain types of fuel and energy resources has a special impact on the FEB formation. For example, oil production directly depends on the quality of reserves, the production technologies used, the possibility of developing hard-to-recover reserves, the share of which is growing annually, as well as the demand for innovative technologies (Guliyev, 2024).

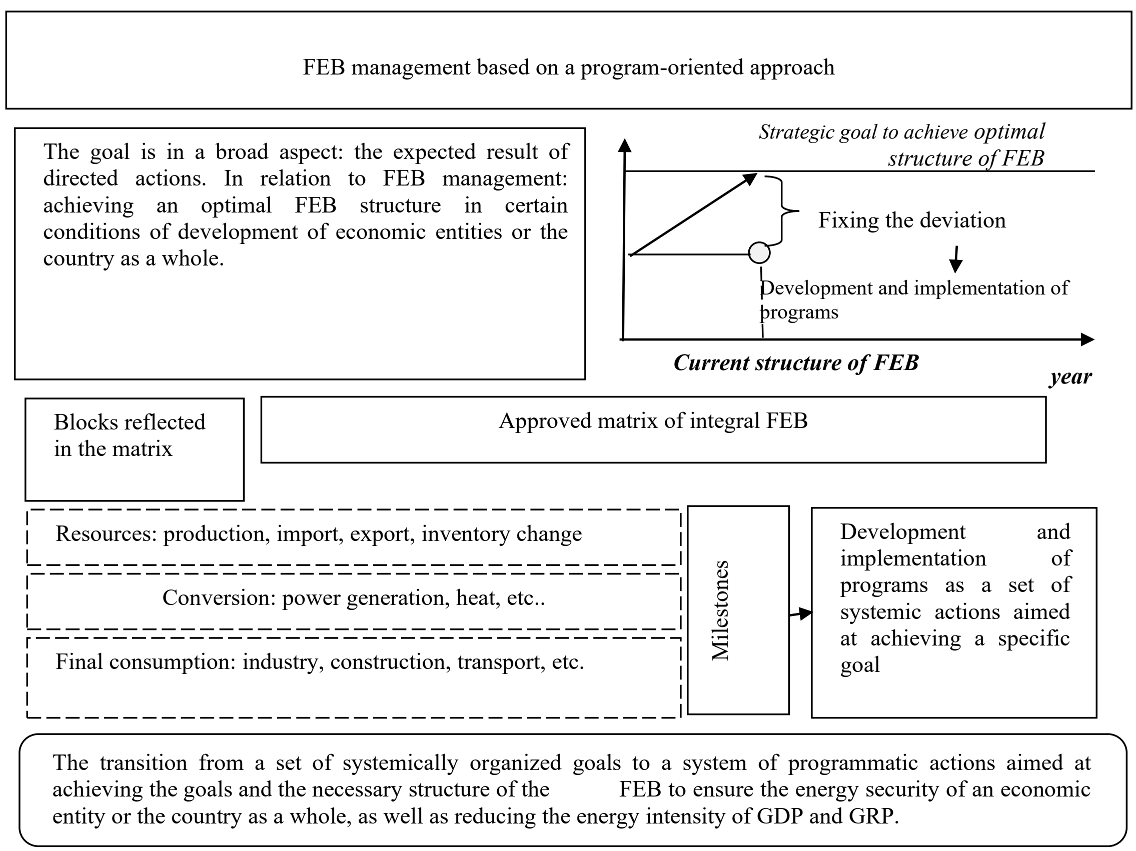


Figure 2. FEB management based on a program-oriented approach.

The key trend that can be traced in publications regarding the development of methodological basis for the FEB formation involves the formation of realistically implemented measures at different levels (federal, regional, sectoral, industry enterprises and companies) in order to ensure the achievement of the parameters of the forecast FEB. These are interrelated components of a single system contour "The level of energy security of the country – forecast FEB (target) – program measures – forecast FEB (degree of achievement of target parameters)". This makes it possible to use the program-oriented approach more actively in the development of predictive FEB and the need for constant methodological development of its practical application.

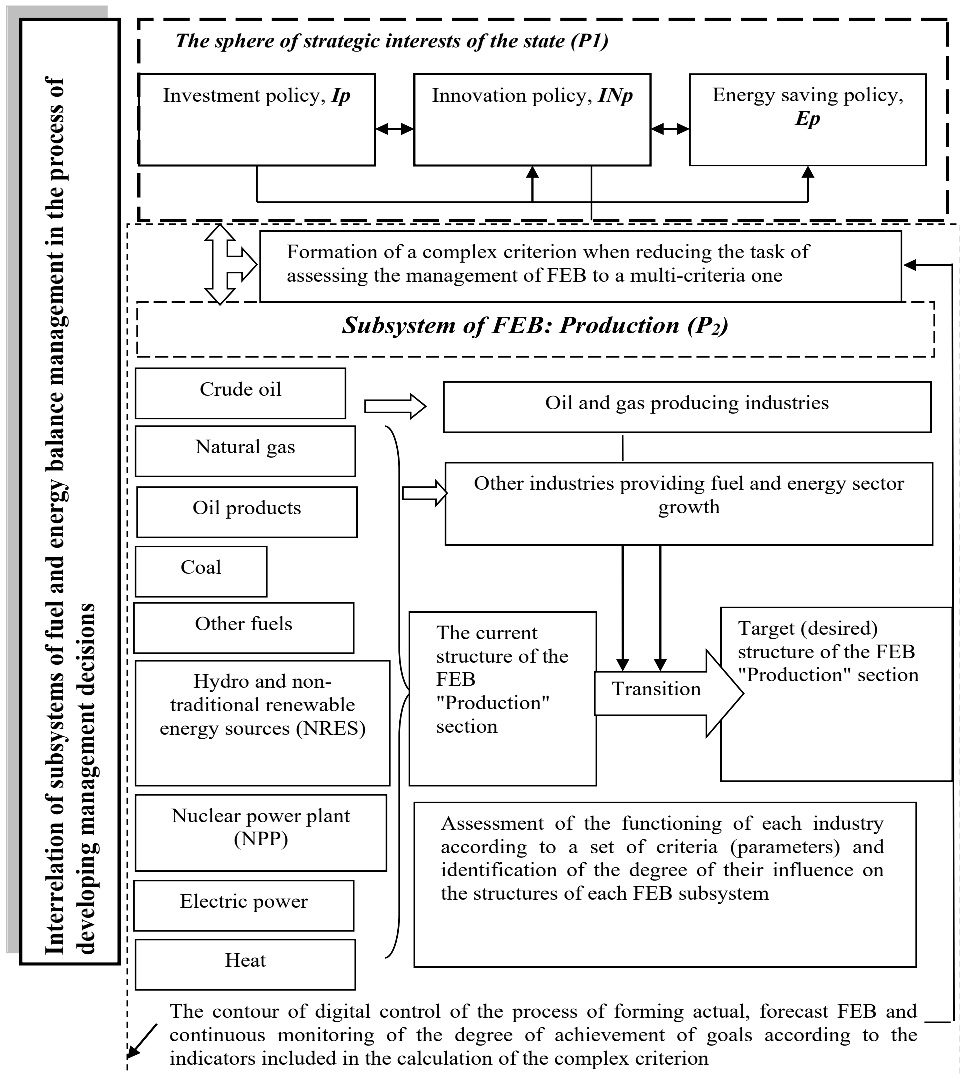
The idea of applying a program-oriented approach in the context of fuel and energy balance management is reflected in a formalized form in **Figure 2**. The target for all subjects developing FEB should be designated as achieving the optimal FEB structure in a certain period of time (current, short-term or long-term). In this case, optimality is considered as the desired state in certain conditions of the external and internal environment. If they change, the parameters of the optimal structure require revision and, if necessary, adjustments.

The starting point in the practical use of the program-oriented approach is the study of retrospective FEB and the assessment of the current structure, as well as the factors and conditions that had a significant impact on its formation. The results obtained are compared with the targets in the field of supply and consumption of fuel and energy resources, recorded in strategic documents at the state level. Each economic entity eliminates the identified gap by developing appropriate program measures with different lead times, accompanied by the playback of different scenarios of the development of the external environment and scenario parameters that affect the FEB structure. Thus, the forecast FEB is formed. The result is a transition from a set of systemically organized goals to a system of programmatic actions aimed at achieving the goals and the necessary structure of the FEB to ensure the energy security of an economic entity or the country as a whole, as well as reducing the energy intensity of GDP and GRP.

3.3 Identification of System Components for the Multi-Criteria Assessment of the Structural Dynamics of the FEB

Based on the methodology for the formation of forecast FEB using a program-oriented approach, the possibility and expediency of reducing the assessment of the effectiveness of balance sheet management to a multi-criteria task can be pointed out. The use of a multi-criteria approach to optimizing various FEB subsystems is systematically explored in research. For example, Husain et al. (2024) examines alternatives and criteria for selecting renewable energy sources in India, taking into account financial, technical, environmental, and social aspects. The paper identifies criteria that should be minimized and those that should be maximized. Voropai and Stennikov (2023) discuss the issues of multiple criteria and aggregation in the hierarchy of forecasting models in the fuel and energy complex, including the formation of a fuel and energy balance.

The degree of achievement of goals for various FEB blocks and the effectiveness of program implementation can be assessed by a set of indicators (criteria). There can be quite a lot of criteria, and they can evaluate the achieved result in both technological, economic, social, energy and resource conservation, and other aspects. The resulting efficiency can be structured for various economic objects, which complicates obtaining a systemic and comprehensive idea of how much the set goals have been achieved. The solution may be to reduce the task to a multi-criteria assessment and obtain a comprehensive criterion that allows us to generally judge the dynamics of development and effectiveness of FEB management both at the regional and state levels. **Figure 3** shows a fragment of the structuring and interconnection of subsystems in the FEB management system for the purpose of forming a multi-criteria assessment model.



Source: compiled by the author

Figure 3. Structuring and interconnection of subsystems in the fuel and energy balance management system.

When forming a complex criterion, it is advisable to take into account such blocks as "Achieving the strategic interests of the state and individual economic entities in the field of energy balance", "Resources", "Transformations", "Final consumption". At the same time, each block includes different directions, so, for example, the zone of strategic interests may include the achievement of interests in the field of investment and innovation policy, ensuring technological independence, obtaining and implementing resource- and energy-saving technologies, trends emerging in the energy sector (Gitelman et al., 2020; Makarov, 2021).

In general, this task is quite difficult both from the point of view of information support of the process, and from the point of view of forming a system of evaluation indicators for each direction. In this case, it is advisable to talk about the development of a digital control circuit for the process of forming actual and forecast FEB and continuous monitoring of the degree of achievement of goals according to the indicators included in the calculation of the complex criterion.

3.4 Description of the Method for Conducting Multi-Criteria Assessment

To optimize the structural dynamics of the FEB, taking into account the multi-criteria nature of energy systems, we propose considering a method for obtaining an integrated assessment such as the Euclidean distance method. The advantage of this method is the ability to measure the deviation between the current and forecasted FEB structures. The forecasted (target) structure can be formed and included in the assessment system in two aspects. First, as target values for structural dynamics reflected in strategic documents, for example, in the energy strategy developed for the period up to 2050. Second, as a forecast assessment formed taking into account additional factors not fully reflected in strategic documents at the time of calculation. Such factors include: justification of the need for fuel and energy resources due to accelerated technological development; a shift in emphasis towards the energy transition; digitization processes; and the increasing trend of stigmatizing the global oil and gas industry.

To assess structural dynamics, it is necessary to measure the degree of approach to target conditions defined by strategic documents through the development of program measures at the level of the state, region, and companies in the real sector of the economy.

The mathematical form of the described approach is presented as formula 1:

$$d_i = \sqrt{\sum_{j=1}^{n} \omega_j (k_{ij}^{\text{norm}} - b_j^0)^2} \rightarrow min \qquad (1)$$

where, d_i is the integral value of the structural gap (Euclidean distance) caused by the i-th decision option (at the level of the state, region, company) in various subsystems of the FEB; i is a specific management decision considered as an alternative for practical implementation, i=1, 2, …, m; m is the number of alternative management decisions included in the analysis of changes in the structural dynamics of the FEB; ω_j is the significance (weight) of the indicator characterizing the structure-forming element of the FEB, $\omega_1 + \omega_2 + \cdots + \omega_n = 1$; k_{ij}^{norm} is the normalized value of the j-th criterion of the i-th management decision included in the evaluation system of a specific structure-forming element of the FEB, changes in the range [0, 1]; j is the number of the criterion included in the evaluation system of the FEB structural dynamics; j=1, 2, …, n; n is the number of criteria included in the evaluation system of the FEB structural dynamics; b_j^0 is some ideal state of the j-th criterion included in the assessment system of a specific structure-forming element of the FEB (target value reflected in strategic documents or justified in another way).

To ensure the comparability of disparate partial evaluation criteria by reducing them to a dimensionless form in the range [0, 1], the normalization method (formula 2) is used. The need to normalize initial data in multi-criteria problems is reflected in the works (Chen et al., 2021; Mukhametzyanov, 2021; Wang et al., 2024). As part of assessing the effectiveness of the structural dynamics of the forecast FEB, such indicators include the share of renewable energy sources, the energy intensity of GDP, specific CO_2 emissions, investment volume, losses in the power grid, and others. Normalization eliminates the influence of different units of measurement and scales of values on the integral assessment. This approach ensures methodological correctness when aggregating disparate indicators.

$$k_{ij}^{\text{norm}} = \frac{k_{ij} - k_j^{min}}{k_j^{max} - k_j^{min}} \qquad (2)$$

where, k_{ij} is the value of the j-th criterion of the i-th management decision included in the evaluation system of a specific structure-forming element of the FEB; k_j^{min} is the minimum possible value of the j-th criterion from all alternative options of management decisions included in the evaluation system of a specific structure-forming element of the FEB; k_j^{max} is the maximum possible value of the j-th criterion from all alternative options of the management decision included in the evaluation system of a specific structure-forming element of the FEB.

It should be noted that weighting factors, in addition to the expert assessment method, can be determined using hierarchical optimization or pairwise comparison, which allows taking into account the different priorities of interested parties (Prebeg et al., 2016)

3.5 Description of the Criteria of the Multi-Criteria Assessment Model in the Crude Oil Subsystem

To test the logic behind constructing a system of evaluation criteria, a single-product balance of "Crude Oil" was used. The evaluation criteria can be grouped into the following areas: resource efficiency, economic efficiency, environmental sustainability, and energy security (**Table 3**).

Table 3. Fragment of the system of evaluation criteria for the single-product balance "Crude oil".

Evaluation criteria	Evaluation criteria
Evaluation focus: resource efficiency	**Evaluation focus:** environmental sustainability
1. Oil refining depth	9. Specific CO_2 emissions
2. Oil recovery factor (ORF)	10. Associated petroleum gas (APG) utilization
3. Specific energy consumption for oil extraction	11. Reclamation costs
4. Transportation losses	12. Environmental damage index
Evaluation focus: economic efficiency	**Evaluation focus:** energy security
5. Oil production profitability	13. Export diversification coefficient (Kde → **1** — exports are maximally diversified; the economy is less dependent on market conditions for individual goods)
6. Transportation cost	14. Share of domestic consumption (according to the British non-profit organization Energy Institute, in 2024, average daily oil consumption in the world amounted to 101.4 million barrels[4], an increase of 0.7% compared to 2023. Given the trend towards stigmatizing the global oil and gas industry, there should be a decrease)
7. Added refining value	15. Strategic oil reserves
8. Share of high-tech products	16. Dependence on technology imports

The proposed list of criteria is open-ended and can be reduced or expanded depending on the evaluation objectives and availability of source information. We should note that the presented system of criteria forms an interconnected structure that has a comprehensive impact on the dynamics of structural changes in the fuel and energy balance. Resource efficiency criteria, particularly oil refining depth and oil recovery factor, act as technological drivers of structural changes, stimulating the development of refining capacity and extending the life cycle of hydrocarbon deposits. Economic indicators, such as production profitability and added value from refining, determine the sector's investment attractiveness and create multiplier effects in related industries.

Environmental criteria, including specific CO_2 emissions and the environmental damage index, establish systemic constraints on the development of the oil industry, highlighting the challenges of technological modernization in the context of the energy transition. Energy security indicators, including the export diversification coefficient and strategic oil reserves, ensure geopolitical stability.

[4] Infographic: Top 25 Countries by Oil Consumption. – 26.08.25. – URL: https://www.vokrugsveta.ru/history/infografika-top-25-stran-po-urovnyu-potrebleniya-nefti-id6520746/ (date of access: 22.02.26)

The interaction of criteria generates both synergistic effects and potential conflicts of objectives. For example, maximizing economic efficiency may conflict with environmental sustainability requirements, necessitating the search for compromise solutions through the implementation of innovative technologies and carbon management mechanisms. The structural dynamics of the FEB thus emerge as the result of a complex balancing act between technological development, economic feasibility, environmental constraints, and energy security requirements.

The Euclidean distance method within the framework of a multi-criteria optimization algorithm provides the most appropriate tool for the integrated assessment of a complex multidimensional system—the fuel and energy balance. By calculating the distance between the current state of criteria and their ideal values, determined based on strategic documents and forecast scenarios, a quantitative measure of the structural gap is formed. Minimizing this distance across multiple alternative development scenarios allows for the identification of the optimal trajectory for the structural transformation of the FEB, ensuring the balanced achievement of all target benchmarks.

4. Results

4.1 Building a Conceptual Model for the Crude Oil Subsystem

Due to the fact that reducing the task of managing FEB to a multi-criteria one is a rather complex and time-consuming process, an approbation fragment of building a model is considered on the example of a municipality and in the context of single-product balances: "Coal", "Crude oil", "Oil products", "Natural gas", "Other solid fuels", "Hydropower and NRES", "NPP", "Electric Power" and "Heat".

A fragment of the building of a conceptual multi-criteria model based on the single-product balance "Crude oil" is presented in **Table 4**.

Table 4. A fragment of the building of a multi-criteria model based on the single-product balance "Crude oil": dehydrated, desalinated and stabilized oil, including gas condensate.

<table>
<tr><td>An evaluation block isolated from the structure of a single-product balance</td><td>Multi-criteria model</td><td>Weighting factor</td><td>Note</td></tr>
<tr><td rowspan="2">Energy resources production: (Pen) Wpen is the weighting factor of the "Production Resources" block</td><td>Import (Qimport), tons (↑↓)
Export (Qexport), tons (↑↓)
Change of inventories (Qch), tons (↑↓)</td><td>$p_{1\text{-}import}$
$p_{2\text{-}export}$
$p_{3\text{-}ch}$</td><td>(↑↓) the desired direction of the indicator, depending on the current situation in the internal and external environment of the relevant municipality</td></tr>
<tr><td colspan="3">$Pen = \pm p_{1\text{-}import} * Q_{import} (\uparrow\downarrow) \pm p_{2\text{-}export} * Q_{export} (\uparrow\downarrow) \pm p_{3\text{-}ch} * Qch (\uparrow\downarrow) \rightarrow max$
An additive model is used to obtain a complex criterion.</td></tr>
<tr><td>Primary Energy Consumption (Ppe) Wpe is the weighting factor of the "Primary energy consumption" block</td><td colspan="3">When forming a comprehensive criterion for this block, it is advisable to conduct research on primary energy consumption facilities. In the studied single-product balance of the considered municipality, this block has a value of 0.</td></tr>
<tr><td>Statistical discrepancy (Sd)</td><td colspan="3">When forming a complex criterion, it is advisable to use the Euclidean distance, since this criterion shows how much the option under consideration deviates from some desired value. In this case, the ideal point for statistical discrepancy would be zero. It is also possible to include in the analytical system an analysis of the structure of the positions of the item "Statistical discrepancy" in order to subsequently identify the causes of the discrepancies and take appropriate measures to eliminate them.</td></tr>
<tr><td>Production of: electric energy (Pee) thermal energy (Pte) thermal power plants (Ptes) boiler houses (BH) Electric boiler and heat recovery plants (EBHRP), etc.</td><td colspan="3">Similarly to the considered fragment of the formation of a multi-criteria model for the Pen block, models are formed for all positions of the single-product balance.</td></tr>
</table>

Based on the technology discussed in **Table 4** for combining the evaluation procedures of the FEB of municipalities, and then regions, federal districts and the country as a whole, a single model can be obtained to assess the actual FEB, its structure and substantiate the desired FEB option (structural representation) in the medium and long term. The practical use of this model at the stage of building strategic and tactical goals for the development of systems that affect the FEB, the formation of programs aimed at achieving the designated targets will allow timely monitoring of changes in the FEB (both at the stage of planning program measures and at the stage of their implementation). In turn, this will make it possible to make corrective management decisions more quickly in the process of implementing approved programs and adhere to the approved development trajectory in the field of fuel and energy resources management, and eventually energy security.

4.2 Building a Multi-Criteria Model for an Autonomous Area

To demonstrate the feasibility of constructing a multi-criteria model, the Khanty-Mansi Autonomous Area (KhMAA) of Yugra (Russia), a key oil and gas region in Russia and one of the largest oil-producing regions in the world, was chosen. Based on actual and forecast data for the KhMAA-Yugra, reflected in official documents publicly available online, an assessment database was created (**Tables 5** and **6**). The actual data serve as an objective information base for determining the current state and identifying existing trends. The forecast values set development targets and can be used as an ideal state for each criterion (b_j^0).

Table 5. Selection of initial data from the KhMAA-Yugra (Russia) fuel and energy balance, thousand tons of equivalent fuel.

Indicator	Fact 2021	Fact 2023	Forecast 2030	Rate of increase, % (2023 / 2021)	Rate of increase, % (2030 / 2023)
Fuel and Energy Production	365414040	398220857	334656449	8.98	-8.42
Crude Oil (Production)	308537944	308870133	278993000	0.11	-9.58
Natural Gas (Production)	50069273	47007800	49257830	-6.11	-1.62
Petroleum Products (Production)	6792710	7279972	6392266	7.17	-5.90
Hydropower and Renewable Energy	0	0	0	0.00	0.00
Primary Energy Consumption	67941566	95962889	62948713	41.24	-7.35
Final Consumption	35260814	22980751	29196704	-34.83	-17.20
Exports	363000255	329117386	336058199	-9.33	-7.42
Industry (Consumption)	22760543	12591688	24479118	-44.68	7.55

Table 6. Criteria for multi-criteria assessment for the area.

S. No.	Criterion (desired direction of change of criterion, ↑↓)	2021	2023	2030 (can be taken as b_j^0)*	Note on the criterion included in the model	Criterion weight (determined by experts based on the essential characteristics of the criterion)	
1.	K1 - Oil recovery factor (ORF), shares, ↑	0.28	0.40	0.48	Increasing the recovery factor through geological and technical measures	0.25	The high importance is due to the depletion of reserves and the need for maximum use of the subsoil
2.	K2 - Specific energy consumption, toe/t., ↓	0.22	0.31	0.23	Implementation of resource conservation measures	0.05	Important in the context of the energy transition
3.	K3 - Oil share, %, ↓	84.4	77.6	83.3	The desired change in the direction of the criterion depends on the implemented energy policy and external factors	0.15	The high weight is due to the strategic need to reduce the region's economy's dependence on oil.
4.	K4 - Gas share, %, ↑	13.7	11.8	17.7		0.2	The priority direction of fuel and energy balance diversification corresponds to the role of gas in the structural dynamics
5.	K5 - Utilization of associated petroleum gas (APG), %, ↑	95.5	96	98	Compliance with environmental requirements	0.2	Justified by environmental requirements and significant potential for associated gas utilization in the KhMAA.

Table 6 continued…

6.	K6 - Share of renewable energy sources, %, ↑	0	0	1	Program measures are required to develop the renewable energy sector, especially in the context of the energy transition	0.05	The lower weight reflects the limited renewable energy potential in the KhMAA
7.	K7 - Share of domestic consumption, %, ↑	9.6	5.8	8.7	Development of petrochemistry	0.1	Determined by the importance of creating added value in the region
Total						1	

** The target values correspond to the approved concept for the development of the hydrocarbon resource base in the Khanty-Mansi Autonomous Area (KhMAA) until 2050 (Source: Department of Subsoil Use and Natural Resources of the Khanty-Mansi Autonomous Area-Yugra. – URL: https://depprirod.admhmao.ru)*

To demonstrate the applicability of the proposed methodological framework, we will consider alternative management decisions that can be implemented in the area to maintain hydrocarbon production and implement the principles determined by the energy transition.

1) Intensifying oil production through the development of new technologies.
2) Increasing the degree of rational use of resources in the region.
3) Developing the gas sector.
4) Developing petrochemicals and oil refining (refining depth).
5) Digital transformation of processes in the fuel and energy sector (will optimize production and refining processes).

Table 7 presents data for selecting the best decision option from the perspective of its impact on structural changes in the area's fuel and energy balance.

Table 7. Initial data for conducting a multi-criteria assessment of the selected management decisions.

S. No.	Criterion	Weight	b_j^0	Decision options					Normalized values for decision options					b_j^0(target value)
				1	2	3	4	5	1	2	3	4	5	
1.	K1	0.25	0.48	0.5	0.44	0.42	0.47	0.49	0.9	0.3	0.0	0.7	1.0	0.9
2.	K2	0.05	0.23	0.21	0.24	0.18	0.25	0.19	0.4	0.9	0.0	1.0	0.1	0.7
3.	K3	0.15	83.3	82	78	75	79	81	0.8	0.4	0.0	0.5	0.7	1.0
4.	K4	0.2	17.7	16.5	21	18.5	17	17.5	0.0	1.0	0.4	0.1	0.2	0.3
5.	K5	0.2	98	98.5	98.8	97	98.8	98.9	0.8	0.9	0.0	0.9	1.0	0.5
6.	K6	0.05	1	0.8	1.2	1.3	1.3	1.35	0.0	0.6	0.7	0.7	0.8	0.3
7.	K7	0.1	8.7	9.5	12	10.5	12.5	11	0.2	0.9	0.5	1.0	0.6	0.0
$d_i \to \min$									**0.257**	0.611	0.680	0.457	0.359	

The calculations presented in **Table 6** allow us to determine the optimal management decision based on a set of criteria, which may be considered a priority in the area—that is, maintaining the area's traditional oil and gas sector development vector. Decision 1, based on the set of criteria, demonstrates the minimal gap from the parameters approved in the concept for the development of the hydrocarbon resource base in the Khanty-Mansi Autonomous Area (KhMAA) through 2050.

The practical significance of the proposed approach lies in the ability to proactively simulate system behavior (FEB) based on management decisions, programmatic measures, or scenarios under consideration. Overall, it enables the search for more effective solutions aimed at identifying and exploiting the potential for synergy in intersectoral interactions.

It should be noted that within the proposed multi-criteria approach, the appropriateness of determining weighting factors remains debatable. There is no consensus in the scientific community on how to determine the weight of each criterion included in the evaluation system. According to the authors' logic, it is advisable to determine the weighting based on expert assessments, depending on the priority goals and objectives set out in strategic documents at the national, regional, or company level. However, if there is a need for long-term structural restructuring of the fuel and energy balance, for example, increasing the share of renewable energy, gas, or other fuel and energy resources, then the weighting factors are distributed based on the priority structure in the forecast FEB.

A systemic assessment of the impact of fuel and energy sectors on the structural dynamics of the FEB requires the development of a comprehensive assessment framework that takes into account multiple, multifaceted criteria. To overcome the methodological challenges associated with a large number of disparate indicators, it is proposed to transform the criteria system into a hierarchical (tree-like) structure. Criteria should be aggregated by the following levels: industry affiliation, energy resource types, and territorial division (regions, districts). Weighting factors are assigned both for aggregated groups of criteria and for individual indicators within each group.

The scientific literature pays considerable attention to the issue of justifying criterion weighting factors. In particular, Mukhametzyanov (2021) conducted a comparative analysis of alternative methods for determining weighting factors that eliminate the subjectivity of expert assessments. The author examines objective approaches such as the entropy method, the CRITIC (Criteria Importance Through Intercriteria Correlation) method, and the standard deviation (SD) method, assessing their applicability and robustness in various decision-making contexts.

An important property of multi-criteria models is their high sensitivity to the values of the weight coefficients. Even minor changes in the weight distribution can lead to significant changes in the final ranking of alternatives, emphasizing the importance of a correct and justified choice of weighting method.

5. Discussion

The need to create a unified FEB formation system is increasingly discussed in publications by various authors. Interest in this issue is growing and strongly correlates with the development of information technologies, digitization and the opportunities of using AI. In this direction, the published abstracts of the parliamentary hearings on the topic "Formation of fuel and energy balances of Russia and the regions: problems and solutions (2023)" are of particular interest (https://rosenergo.gov.ru/press-center/news/temu-formirovaniya-toplivno-energeticheskikh-balansov-rassmotreli-na-zasedanii-komiteta-gosudarstven; http://komitet-energo.duma.gov.ru/novosti/d13df1f4-fe3c-40fa-8730-ced3e1057147).

The problems of forming forecast FEB have recently been quite actively discussed in scientific circles, at the state level, by industry analysts and experts. Various aspects of optimizing the FEB structure are traced in publications and are actively discussed in the scientific community (Novikova et al., 2021; Sharkova and Lemm, 2022). Research is also conducted on the variability and dynamics of factors affecting the FEB structure, due to global trends, the political situation in the country and in the world (Akimov, 2021). As an example, we can consider the current situation with Russian commodity exports, as well as general carbon regulation (Bashmakov, 2022b). There are a lot of current studies devoted to compensation for the imbalance between energy production and consumption (Osinovskaya et al., 2020; Sultanguzin et al., 2020).

At the same time, a number of publications note insufficient attention to the issues of forming a single forecast FEB on the part of the state. The compilation of an FEB at the regional level is mandatory, but not always high-quality due to poor information support and lack of necessary competencies, as well as practical skills among specialists involved in its formation (Ratmanova et al., 2009). Attempts are also being made in the field of software development to create an FEB in a graphical representation convenient for analysis with the possibility to optimize various sectors of fuel and energy consumption (Yavorovsky et al., 2022).

Despite growing recognition that digital technologies can address the challenges of developing a unified forecast FEB at a higher level, enabling the calculation of the incremental effects of various measures and achieving a high level of intersectoral collaboration, a gap remains between the conceptual development of theoretical models and their practical digitization. The key challenge lies in collecting the necessary information, consolidating it at the state level, ensuring its security and accessibility for key participants in the forecast FEB development process, and the degree of aggregation of its subsystems. To obtain operational data from direct fuel and energy companies and related industries, as well as consumers of fuel and energy resources, it is necessary to ensure that data is obtained through the digitization of information flows. This means that the digital infrastructure is not ready to digitize the fuel and energy balance, enabling intelligent forecasting based on artificial intelligence, big data analytics, and modeling the behavior of the fuel and energy balance and industries based on changes in key parameters. Maroufkhani et al. (2022) note that despite the well-developed theoretical framework for digital transformation at the conceptual level, few resource extraction industries have developed formal digital strategies. A comparison of Internet of Things (IoT) and artificial intelligence (AI) technologies by Żywiołek showed that they have varying effectiveness at different stages of the energy and resource value chain (Żywiołek, 2025). These technologies may also have different effectiveness in the process of generating a forecast FEB. For example, AI facilitates more accurate forecasting of energy demand and supply (Iftikhar et al., 2024), making it crucial at the stages of fuel and energy production.

In the process of developing the forecast FEB and its subsequent analysis, it is necessary to identify the presence of institutional constraints. These represent a set of systemic obstacles arising from the specific organizational and legal environment within which the energy sector operates. These constraints create structural barriers that significantly impact the quality, completeness, and reliability of information related to the energy sector and related industries within the intersectoral system of interaction. Federal legislation, for example, can be a significant constraint. For instance, activities in the subsoil use and energy sectors are regulated by a number of key regulations, such as the Federal Law "On Subsoil," which establishes the licensing procedure and conditions for the use of subsoil plots, and the Federal Law "On Gas Supply in the Russian Federation." Of particular importance is the Federal Law "On Heat Supply," which mandates the formation of fuel and energy balances at the regional and municipal levels, thereby establishing a formal framework for planning. Any decision made at the regional level must strictly adhere to this federal framework. For example, associated petroleum gas (APG) utilization targets or environmental standards are set at the federal level, and a region cannot relax them, even if doing so is economically feasible from a local perspective. Institutional barriers to joining energy communities are discussed in Dioba's work, where challenges include legislative requirements, economic and technical feasibility, and the need for close cooperation across multiple levels (Dioba et al., 2024). Other issues include political support, funding, public acceptance, insufficient awareness, and the lack of appropriate governance structures.

Therefore, when implementing the proposed methodological approach to developing a fuel and energy balance, it is necessary to consider a number of limitations related to the availability and quality of initial data, which may lead to incomplete information support for the model. Institutional constraints, including regulatory barriers and interdepartmental interactions, create additional challenges in implementing strategic decisions in the fuel and energy sector. Furthermore, the introduction of digital technologies and the involvement of the expert community are associated with challenges related to the technological readiness of infrastructure, personnel shortages, and ensuring consensus among stakeholders on determining weighting factors and development priorities.

To summarize the discussion, it can be noted that, at the moment, there is an increasing interest both from representatives of academic science and from authorities and departmental structures in using the fuel and energy balance as an effective tool for managing the energy security of the country and regions. However, in the methodological aspect, the issues of the formation of forecast FEB have not been worked out in detail, which determines the relevance of research conducted in this area. It should be noted that this issue has been actively discussed at the level of the State Duma of Russia last year (https://rosenergo.gov.ru/press-center/news/temu-formirovaniya-toplivno-energeticheskikh-balansov-rassmotreli-na-zasedanii-komiteta-gosudarstven). The REA of the Ministry of Energy of the Russian Federation actively voices the need to develop a predictive methodology for obtaining long-term forecast balances in the context of fuel and energy complex production and consumption. This means creating methodologies that will meet the high requirements of consistency, accuracy and reliability of the generated forecasts in connection with a detailed study and formation of forecasts regarding energy demand. The structure of the demand forecast should make it possible to track the directions of the use of fuel and energy resources in the long term, as well as consumer groups and possible structural changes in this direction.

The program-oriented approach can be adapted to the goals of FEB formation and management of its structure, as it allows increasing the effectiveness of the program measures taken to achieve the targets indicated in the field of energy intensity of gross domestic and regional product and energy security.

Historically, in order to ensure GDP per capita growth of 1%, it is necessary to reduce the energy intensity of GDP by 0.5-0.8%, and this figure increases as the level of economic development increases (Bashmakov, 2019). Effective FEB management can make a significant contribution to reducing the energy intensity of GDP. The situation in Russia relative to the world community in terms of the energy balance can be traced according to published information on global energy balances (Osinovskaya, 2022).

6. Conclusion

The considered methodological aspects of the formation and management of the fuel and energy balance based on the program-oriented approach are promising and in demand, but at the same time there are a number of problems with the implementation of the considered methods at different stages of the formation of program-oriented plans. The practical implementation of the entire complex of the considered methodological basis is a rather resource-intensive process, both from the point of view of financial support and staffing. Most of the methods are focused on attracting experts or requires significant mathematical apparatus, as well as the active introduction of automation into analytical procedures and digitization in both organizational and managerial processes.

The Foresight technology, which is quite logically integrated into a program-oriented approach, is of significant importance in the formation of forecast FEB and in the justification of its promising structure that meets the needs of the energy security of regions and the country. The full-scale and high-quality implementation of this technology in Russian practice suggests the existence of significant scientific study and validity of this process, which should be ensured by the fact that both the organizers of this process, and the experts have special knowledge in the field of Foresight. At the same time, experts involved in Foresight sessions should be highly qualified, be guided by global trends and trends in the field of exploration, production and processing of hydrocarbons, reduction of energy intensity of GRP and GDP, and other rather important issues. The solution to the problem of staffing high–quality and effective Foresight sessions is associated with the formation of a bank of industry experts. At the same time, we should note the expediency of forming a hierarchical structure of the bank of experts: regional, national, and international levels, as well as with a separate allocation of expert practitioners and experts, and representatives of university science.

Due to the global character of issues related to the FEB formation and management, the complexity of subsystems that have a significant impact on its structure and the scale of targets identified at the state or regional level, it is advisable to consider the application of a systemic approach to solving the tasks in the field of FEB management. It is also advisable to use a combinatorial approach in the context of methodological support for program-oriented planning for more effective achievement of set goals and improvement of the effectiveness of decisions made at various management levels. Transformational issues within the framework of the FEB structure are of a long-term nature and should focus on emerging global megatrends in the field of fuel and energy resource management, scientific and technological progress in priority sectors that influence the FEB in various ways. Special attention should be paid to the analysis of the impact of megatrends in the field of energy and oil and gas industry on individual FEB components and their change in the long term.

6.1 Actionable Recommendations

Based on the conducted research, a number of management decisions are proposed aimed at increasing the efficiency of public administration of the process of forming forecast fuel and energy balances at all levels of the vertical hierarchy.

First, it is necessary to ensure that the status of the forecast FEB is enshrined in a single, unified form established by the Government within the strategic planning system. Implementation of this proposal will give the forecast FEB a legal and regulatory status, confirming its importance as a key element of strategic forecasts and plans.

Second, we need to establish a mechanism for mandatory electronic approval of regional forecast fuel and energy balances with the federal methodology, incorporating the authors' proposals. Establishing uniform forecast horizons for generating forecast fuel and energy balances, covering the short, medium, and long terms, is also necessary.

Third, it should be mandatory for service providers and large consumers to provide initial data into a single information system for the formation of forecast fuel and energy balances.

Fourth, a data verification mechanism for the formation of forecast fuel and energy balances, as well as data verification regulations, should be developed

6.2 Prospects for the Development of the Topic

As part of further scientific research, it is advisable to focus on detailing and enriching the information content of the interconnected modules used to construct the forecast FEB. The key objective is to create a methodological and informational basis for the complete digitization of the FEB development process. The practical significance of this transition lies in achieving greater accuracy in forecast calculations, enhancing the validity of strategic and operational decisions in energy security at all levels of governance, and ensuring closer interaction and engagement of industry participants in the balance formation process.

Conflicts of Interest
The authors confirm that there is no conflict of interest to declare for this publication.

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