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Optimization of Balance Components of Fuel and Energy Resources for Organizational and Economic Support of Energy Efficiency in Ukraine

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ABSTRACT

In this paper the general fundamentals of the formation of the balance of fuel and energy resources were determined and the main components of the general energy balance were substantiated. It was formed according to the indicators from the state energy statistics of Ukraine, and on the basis of the obtained data the analysis of energy flows was carried out. Mathematical substantiation of its support on the traffic of energy flows from their extraction (production), transformation and final consumption was offered. The algorithm for compiling the overall energy balance was detailed to eliminate possible discrepancies between the indicators during the final operations of the balance sections. In order to ensure timely response to unsolved problems in the energy sector of Ukraine, it is proposed to implement a constant monitoring of the energy balance as a whole and by partial indicators. The use of a new algorithm for optimizing the balance of fuel and energy resources (FER) for individual balance sheet items was proposed. A model of organizational and economic mechanism was developed to study the functional interactions of international organizations in the field of energy independence, administrative and financial institutions, fuel and energy entities and the national economy, which are subjects of all hierarchical levels of energy security. It reflects the equivalence of two main aspects of energy security of the national economy: ensuring the stability and efficiency of the fuel and energy complex on one hand, and the formation of energy efficient consumers through the introduction of innovations and energy saving technologies, on the other.

Keywords: energy balance, efficiency, flow, consumption, fuel and energy resources, energy efficiency

INTRODUCTION

The growing dependence of socio-economic development on the provision of fuel and energy resources necessitates the improvement of scientific bases for the formation of balances of fuel and energy resources. Due to the globalization of the national economy, the availability of fuel and energy resources, uninterrupted supply and efficiency of their use determine sustainable development and energy security constitute important components of national security. Consumption of energy resources is currently characterized by a growing trend. According to the statistics in recent years, it has increased by 11% (Survey of Energy Resources, 2020). This fact can be explained by the following: 1) increase in the population of the planet and the corresponding growth of the role of energy resources in human life; 2) irrational use of energy resources by consumers, both households and businesses that use energy resources for the manufacturing of their products.

Energy balance (EB) is one of the main tools for the formation and implementation of energy security in the country. It is based on quantitative indicators of extraction, production and final consumption of energy resources of the country for a certain period of time. The general energy balance (GEB) is informative since the initial data can be used for calculation of the efficiency of fuel and energy consumption. Thus, SEB becomes a kind of information support tool for further calculations of partial indicators for assessing the efficiency of energy resources, and control of energy flows at all stages from their extraction to consumption.

The research on the optimization of the balance of energy resources as well as the development of organizational and economic mechanism to ensure energy independence of Ukraine has become particularly on time in terms of transformational transformations in the state economy.

LITERATURE REVIEW

Many scientific publications of foreign and Ukrainian scientists are devoted to the issues of energy independence and the formation of energy balances: in particular, Matsumoto et al. (2018) argue that for the countries of the European Union it is vital to ensure their energy independence (due to the geopolitical considerations and ongoing reforms of energy markets). Bompard et al. (2017) developed a number of methods for assessing the energy independence of the Baltic States. In the proposed methodologies, they take into account the following three indicators: "adequacy", "security" and "economic factor" to assess the energy independence of the Baltic States in the current and future scenarios: medium-term (2020), long-term (2030) and show that the consumption of energy resources needs to be reduced. Radovanovic et al. (2017) proposed the calculation of the Energy Independence Index. It is based on environmental and social indicators. Scientists, Andrusiv et al. (2020) and Yemelyanov et al. (2019) have modeled the conditions under which economic growth is accompanied by a decrease in the level of dependence of the economy on energy imports. Yang et al. (2020) recommend stopping the subsidies for fossil fuels. In case this proposed energy policy is successfully implemented, Ukraine's fossil fuel-based energy system will be transformed into a highly efficient zero-carbon energy system by 2050. Cantor et al. (2016) examine the trade-off between energy efficiency and economic growth. They point to the continuity of these concepts and argue that the country's welfare depends on energy efficiency. Nyman (2018) argues that the policy pursued by governments on energy independence has a direct impact on global warming, and therefore it must be balanced. The scientific heritage of Burlov et al. (2021) was the substantiation of the mathematical model of energy efficiency by optimizing the components of the energy balance. Different scenarios of economic development have been studied by the scientists from China, in particular Suo et al. (2021). They proposed the CN-EES model, which has the ability to forecast energy needs in different scenarios of economic development in the long run, reflecting uncertainties (2021–2050). Incekara & Ogulata (2017) argue in their work that energy resources have today become a major factor which determines the country's position in a globalized world. The issue of energy efficiency, in particular FER, is addressed by the work of Ukrainian scientists, whose main focus was on the analysis of energy balance items, modeling and forecasting their use on the national level. In particular, scientists (Andrusiv et al. 2021; Kneysler et al. 2020; Zelinska et al. 2020) in their research proposed a algorithm for the use of FER. It was established that the economy of Ukraine needs investment infusions, and is characterized by imperfect organizational, economic and financial mechanisms. All this in combination with the irrational use of energy resources by enterprises and the population affects the low level of their use Zelinska et al. (2021). Scientists Popadynets et al. (2016) and Rohozian et al. (2017) in their research paid attention to the issues of optimizing the balance of energy resources. On the whole, the great interest of scientists around the world in the issue of energy efficiency and rational use of energy resource can be seen, and it proves the urgency of the problems associated with energy independence of the state.

Taking into account the interests of all participants in the energy market, namely: the state, households, businesses, communities, it is required to improve the various mechanisms of production and economic activities, including organizational, economic, legal, financial, motivational, as well as the adoption of flexible and balanced management decisions as the basis of energy independence of the state. In addition,

further research is needed on the formation of unified approach to the planning and use of the energy balance in order to avoid differences between the revenue and expenditure parts of the energy balance.

THE PURPOSE OF RESEARCH

The aim of the work was to improve the scientific principles of optimizing the overall energy balance in terms of determining its most advantageous characteristics in physical and conditional dimensions, based on indicators of existing forms of state statistical reporting and taking into account international standards and recommendations of IEA and Eurostat, its mathematical support and developing a visualized model of organizational and economic mechanism of energy independence of Ukraine, which takes into account the distribution of functions, forms and methods of regulation by hierarchical institutional levels of organizational and legal regulation in energy efficiency and energy conservation.

METHODOLOGY DESCRIPTION

In order to achieve this goal, the following research methods were used:

- theoretical generalization – for a deeper study of energy resources and their impact on the national economy;
- graphic – to build a model of organizational and economic mechanism for energy independence of Ukraine;
- statistical analysis – for the analysis of the data on the total primary energy supply in Ukraine and final consumption of fuel and energy by types of energy resources.

RESULTS AND DISCUSSION

The energy balance of the state is a system of indicators that reflects the full quantitative correspondence of production, income and use (including costs and losses for their transportation, conversion, storage and balance) of all energy sources in the economy as a whole or in its individual components (region, industry, enterprise) for a certain period of time to identify the real state of energy supply of Ukraine by FER, and to eliminate imbalances and shortcomings in energy supply (Korchemlyuk & Arkhypova, 2016; Arkhypova &Pernerovska, 2015).

According to the form of compilation, the energy balance is defined as a consolidated statistical report on the production and receipts of types (sources) of energy, costs and uses, showing the origin and types of use of all energy sources used in the country during the year. In this balance, all types of energy are expressed in a common unit of account and show the relationship between costs. The energy balance should be the basis of a mutually agreed upon and transparent system of accounting for production, receipt, transportation, storage, distribution and consumption (use) of energy resources for information support and justification of decisions in the formation and implementation of effective public policy, reliable needs of the economy and population.

On the basis of the purpose of the study, the authors attempted to analyze the energy balance and find out how it is formed, and what indicators are included in its composition. According to the methodological provisions (Energy balance of Ukraine, 2020) the general energy balance includes the types of energy resources that are received naturally or by their transformation, import and export. Volumes of fuel were given in natural and conditional measurements, calculated by caloric coefficients of coal or oil equivalent. Electricity and heat generated by thermal power plants, boilers or other equipment that use fossil fuels were converted into conventional fuel at the actual specific fuel consumption for their supply. Nuclear energy, hydropower, energy from non-conventional sources were converted at the average rate of actual specific electricity consumption of public power plants running on fossil fuels. The energy balance of Ukraine for 2019, formed according to the format recommended by the general provisions of Eurostat (Energy, Electrisity and Nuclear Power for the period up to 2030) was considered as an example. According to the balance of 2020, the indicators of natural gas consumption were determined taking into account the tasks of the Cabinet of Ministers to provide the population, enterprises, institutions and organizations with natural gas.

In the energy balance of Ukraine, starting from 2010, the volume of energy supply tends to decrease (despite fluctuations in some years), from 144.2 million tons (2010) to 122.5 million tons in 2018. In 2019, there was a

further decrease: the resource part to 117.3 million tons, and the cost up to 120.7 million tons. Thus, the statistical discrepancy of the energy balance amounted to 3411.0 thousand tons. During 2020, there was a further trend to reduce the total supply of energy resources to 116.4 million tons. In 2021– 2022, a further reduction in the total supply of energy resources to 115.0–114.1 million tons is forecast (Fig. 1).

As can be seen from Figure 1, the share of natural gas in the structure of energy supply decreased from 46.5% in 2017 to 34.8% in 2019. In 2020, the share of natural gas will be further reduced to 33.9%. In 2021, the share is expected to decrease to 29.5%, and as a result of the implementation of short-term measures to replace natural gas with others, it is projected to decrease to 28%. Since 2010, the dominant source of energy supply in the energy balance was coal, the share of which gradually decreased to 34.6% in 2019. In 2020, the share of coal, coal products and peat is at 37.6%. In 2021, it is projected to decrease to 35.0%. The reason for the reduction in the share of coal and coal products was destabilization and military action in eastern Ukraine (in the Luhansk and Donetsk regions).

The share of nuclear energy in the structure of energy supply in 2018 decreased to 18.5%, and in 2019 was at 21%. The main reason for this was the reduction of energy production by the nuclear power plants themselves and the purchase of electricity abroad. A further decrease in the share of nuclear energy in the structure of energy supply is projected in 2021. Its value will not exceed 20% according to the forecast data. As it can be see, oil and petroleum products in the overall structure decreased from 9.4% in 2018 to 8.0% in 2019. According to the forecast for 2021, the share of oil and oil products in the supply structure will not exceed 9.5%. At the same time, during the formation of the energy balance, according to operational data, a significant discrepancy between the volume of supply and consumption of petroleum products, which amounted to 2690 thousand tons. The share of other energy sources (hydropower, solar, wind and biofuels) was not significant and its value for the period 2017–2019 did not exceed 2.5%. It should be noted that during the analyzed period there was a gradual decrease in the final consumption of energy resources, due to the physical reduction of industrial output by the economy of Ukraine (Fig. 2). For example, it is expected that the consumption of energy resources by industry in 2020 will decrease by 27.5%, transport by 8.8%, for non-energy purposes by 37.4% compared to 2016.

Moreover, significant amounts of energy resources are used in the household sector, which in 2019 consumed the energy in the amount of 24,327 thousand tons (33.8% of total final consumption) and road transport 8336 thousand tons (11.6%). In the structure of final consumption of

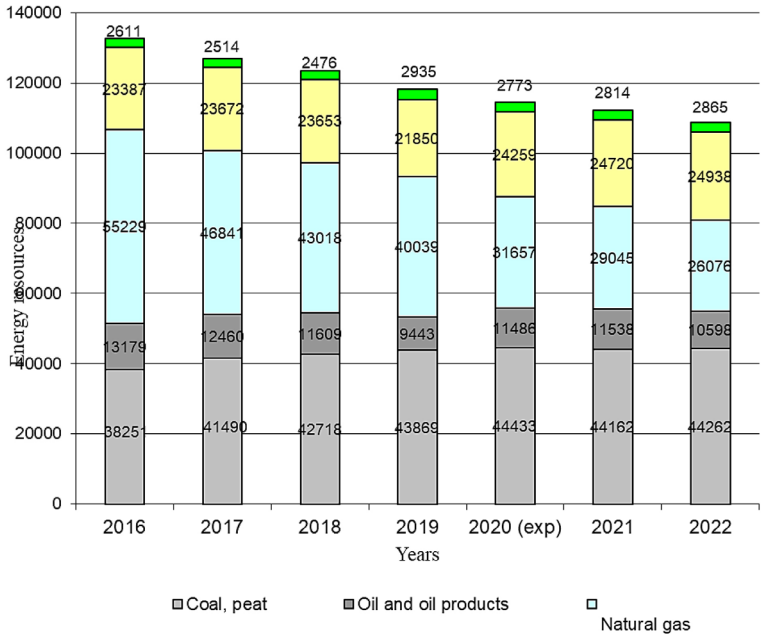

Figure 1. Total primary energy supply in Ukraine for 2016–2022, million tons (based on Energy balance of Ukraine for 2020)

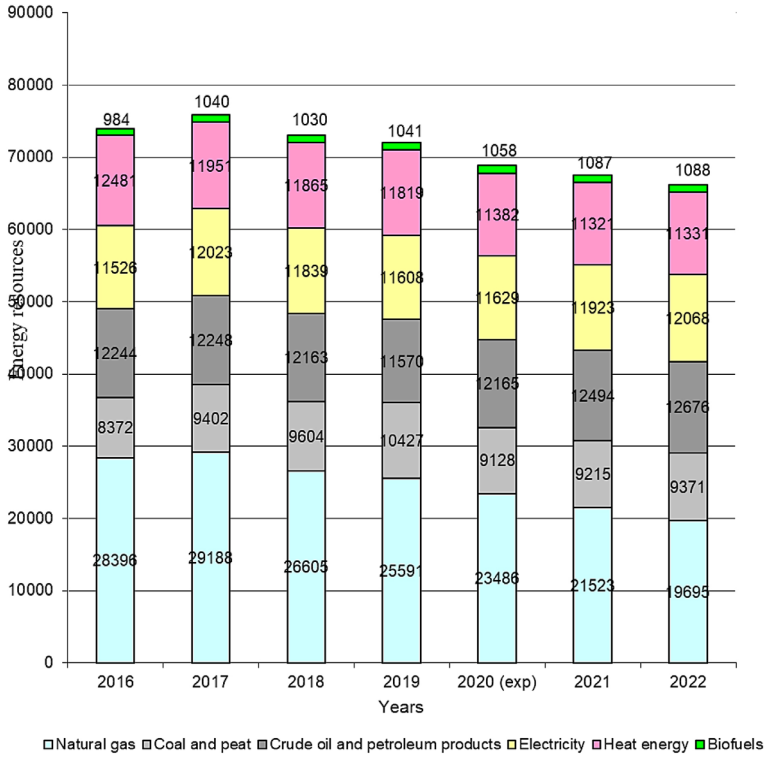

Figure 2. Final consumption of fuel and energy by types of energy resources, thousand tons (based on Energy balance of Ukraine for 2020)

fuel and energy, the largest share fell on natural gas, which will be 33.5% in 2020 against 36.4% in 2017.

The second largest source of energy in the structure of final consumption of fuel and energy is heat, the share of which in 2018 was 16.2% and in 2019 was 16.4%. In 2021–2022, the share of thermal energy is projected to decrease to the level of 14.5– 14.8%. The main reason was the decrease in own coal production and its purchase abroad. Electricity is the third largest source of energy in the structure of final consumption, its share in 2018 is 16.1% against 16.2% in 2019. In 2021– 2022, the share of electricity is projected to increase to the level of 18.2– 18.5%.

As it can be seen from the research, there are differences in the balance of energy resources, which go beyond the relevant accounting. In order to clarify the reasons for this discrepancy, a detailed analysis was conducted and the algorithm for determining individual indicators during the final operations of the balance sheet sections was presented below:

$$P_{g.c.} + P_{t.s.} = P_{c.e.s.} + P_{f.c.} + P_{l.} + P_{c.e.p.} + Ps.d. \quad (1)$$

where: $P_{g.c.}$ the level of energy inflows in the section “Gross Consumption”;

$P_{t.s.}$ the level of energy conversion in the section “Transformation Sector”;

$P_{c.e.s.}$ the level of energy consumption by enterprises of the transformation sector, according to the section “Consumption by the energy sector”;

$P_{f.c.}$ the level of energy consumption in the section “Final consumption”;

$P_{l.}$ the level of energy losses under the article “Losses during transportation and distribution”;

$P_{c.e.p.}$ the level of fuel consumption as raw materials for energy purposes under the article “Consumption for energy purposes”;

Ps.d. energy levels under the article “Statistical discrepancy”.

Algorithms for determining the energy levels of the section “Gross Consumption” are expressed by the equation:

$$P_{g.c.} = Pext + P_{imp.} - P_{l\,exp.} \pm Pc.r. = \sum_{j=1}^{n}\left(\sum_{j=1}^{g} P_{ext}^{i} + \sum_{j=1}^{n} P_{imp}^{i} - \sum_{j=1}^{n} P_{exp}^{i} \pm \sum_{j=1}^{i} P_{c.r.}^{i}\right. \quad (2)$$

where: $Pext$ the level of energy resources extracted or produced in Ukraine;

P_{imp} the level of imported energy resources;
P_{exp} the level of exported energy resources;
$P_{c.r.}$ the level of energy resources at the end of the year;
i and j are, the index of energy resources and the index of articles of the section, respectively.

The section "Gross consumption" does not include the article "Marine bunkering" due to the lack of indicators for it in the state accounting, but the authors considered it appropriate for taking into account.

In the general energy balance, the section "Transformation sector" includes the enterprises related to the processes of conversion of one type of fuel into other types, or types of energy (electric or thermal), or one type of energy into another (nuclear into electric, or electric to thermal). According to this section, the volumes of fuel or energy received for the conversion are recorded with a minus sign, and the volumes of fuel or energy obtained after the conversion with a plus sign. Given the above, the algorithm for this section corresponds to:

$$P^i_{fcon.} = P^i_{faft.} or \sum_{k=1}^{n}\sum_{j=1}^{g} P^j_{fcon.} = \sum_{k=1}^{n}\sum_{i=1}^{n} P^i_{faft} \quad (3)$$

where: $P^i_{f.con.} = P^i_{f.aft.}$ volumes of received fuel and energy resources for transformation and after transformation;
K index of enterprises which convert fuel and energy into other types.

The volumes of fuel and energy received for the conversion are recorded without taking into account their costs for the implementation of technological processes of transformation. These costs belong to the section of the balance sheet "Consumption by the energy sector". The algorithm of energy levels in this section is calculated as follows:

$$P_{e.c.s.} = \sum_{k=1}^{n}\sum_{j=1}^{g} P^i_{e.c.s.} \quad (4)$$

where: $P_{e.c.s.}$ levels of energy consumption in this section.

The algorithms of energy levels of the items "Losses during transportation and distribution" (line 8 of the balance) and "Consumption for non-energy purposes" (line 9 of the balance) are written as follows:

$$P^i_i = \sum_{i=1}^{n} P^i_i \quad (5)$$

$$P^i_{ne} = \sum_{i=1}^{n} P^i_{ne} \quad (6)$$

where: P^i_l and $P^i_{n.e}$ the levels of energy losses and levels of consumption of certain fuels for non-energy purposes, respectively.

The method of forming the section "Final consumption" is determined by the purpose of the developed balance sheets, meaning the formation of general energy balances by region or by type of economic activity. In the balance of this work, the section "Final consumption" includes aggregated groups of economic activities (EA) at the level of sections of the classifier of economic activities:

$$P^i_{ec} = \sum_{s=1}^{n} \sum_{i=1}^{n} P^i_{ec} \quad (7)$$

where: $P^i_{e.c.}$ the level of energy resources for a particular foreign economic activity;
s the index of foreign economic activity.

The balance sheet item "Statistical discrepancy" is the result of an imbalance between the resource part of the balance sheet and the expenditure part. The values of the levels of certain types of energy resources in this article may have signs "plus" or "minus", to the effective column:

$$P_{s.d.} = \pm \sum_{s=1}^{n} P^i_{en.l.} \quad (8)$$

where: $P^i_{en.l.}$ energy levels.

With the help of the above equations of energy balance, its sections are balanced among themselves according to the articles above.

Relevant services, organizations and institutions of Ukraine are invited to analyze the indicators of the country's energy balance, namely, to solve the following problems: 1) identification of ways to optimize the energy balance of Ukraine by solving the optimization problem using «Search for a solution»; 2) compilation and analysis of the forecast energy balance of the country, its constant monitoring and updating due to all changes and current trends; 3) development of

the main directions of the policy for optimization of the energy balance by reducing the consumption of energy resources; 4) ensuring the openness and transparency of the domestic energy market; 5) realization of the potential of energy efficiency and energy saving (Popadynets et al 2020; Ivashkiv et al 2020); 6) ensuring the reliability of energy supply, taking into account the objectives of climate policy; 7) support for the growing role of electricity and distributed generation; 8) development of safe nuclear energy; 9) optimization of tariff policy and implementation of compensatory measures; 10) growth of innovation in the development of energy markets (Kupalova et al 2020). In order to implement the above and based on the Energy Strategy of Ukraine until 2030, a visualized model of effective organizational and economic mechanism for energy independence of the national economy was proposed (Fig. 3), which reflects the interaction of market actors in the implementation of sustainable energy development.

This model includes economic, administrative, financial, legislative and regulatory forms, levers, incentives and methods of regulation and the model of innovative development of the energy system (includes fuel and energy complex (FEC) and FER consumers).

The effectiveness of the proposed model of organizational and economic mechanism for ensuring the energy independence of Ukraine significantly depends on the financial security in the context of a general shortage of financial resources.

The proposed model allows studying the functional interactions and interactions of international organizations in the field of energy security and sustainable development, administrative and financial institutions, fuel and energy entities and the national economy, which are subjects of all hierarchical levels of energy security of Ukraine. It reflects the equivalence of two main aspects of energy security of the national economy: ensuring the stability and efficiency of the fuel and energy complex and the formation of energy efficient consumers by introducing innovations, energy saving measures and technologies. The proposed model also takes into account the dependence on the institutional environment of international organizations in the field of energy security (Zapuhlyak, 2016). The effectiveness of the studied model is ensured by limiting the use of administrative regulation and the spreading of economic methods and levers as well as the adaptation of the current legal framework to the rules

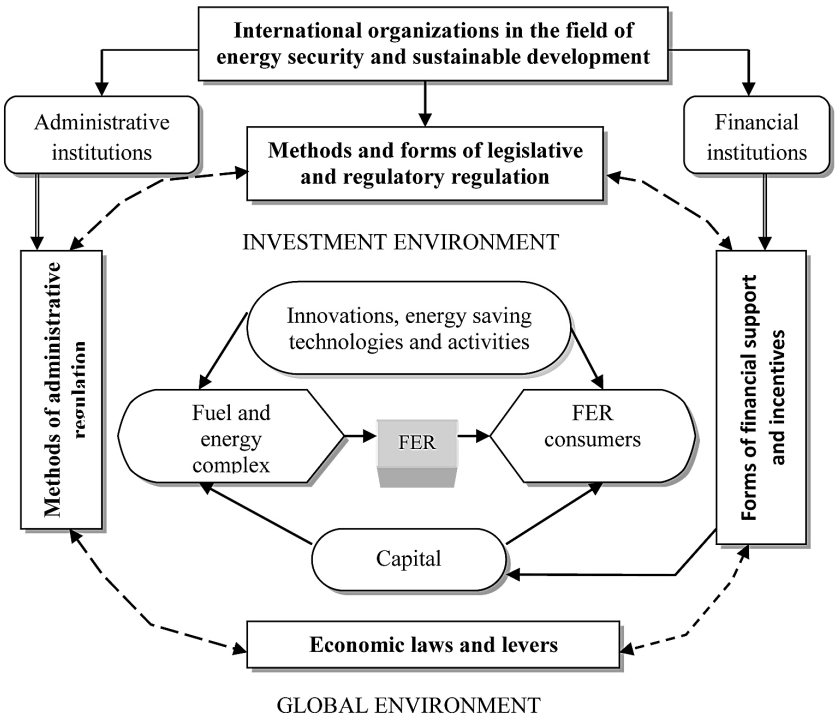

Figure 3. Visualized model of organizational and economic mechanism of energy independence of Ukraine

of international law in the energy and economic spheres. The distribution of functions, forms and methods of regulation by national, sectoral and regional institutional levels of organizational and legal regulation in the field of energy efficiency and energy saving was proposed, which allows developing an organizational and legal mechanism to ensure the efficient use of energy resources.

CONCLUSIONS

Thus, the results of the study identified general provisions for optimizing the formation of the components of the overall energy balance, which by their content and form meet the requirements of international standards and recommendations of the European Economic Commission at the UN. The balance sheet has all the recommended sections with relevant articles, taking into account the list of fuels and energy that are most commonly used in the country's energy sector. Volumes of fuel and energy in the balance sheet are presented in physical and conditional measurements, and their recalculation was carried out according to the caloric equivalents provided by State Statistics Committee of Ukraine for each year. However, it should be noted that the above-mentioned overall energy balance is not the result of direct surveys of respondents. It is formed according to the determinants of current reporting forms in energy, which usually do not ensure full compliance with the indicators obtained from the results of surveys in accordance with the developed forms of balance.

The mathematical support for the traffic of energy flows from their production, conversion and final consumption was improved, which allows calculating energy efficiency indicators and using them in the development of forecast balances to eliminate the differences between balance sheet sections and individual items. It is substantiated the necessity of analysis the energy balance of the country in order to be able to save energy resources and manage them effectively in the future. Considering the resource constraints, global trends towards energy decentralization, the Ukrainian government should focus on promoting local initiatives, including small and medium enterprises and energy cooperatives, improving the efficiency of energy use by energy-consuming installations, completing the installation of instrumental metering of supply and consumption of energy resources and services for the population.

The comprehensive nature of energy security is determined by the need for clear planning and coordination of public authorities, which should be aimed at reforming energy markets, integration of Ukraine's energy sector into EU energy markets and the European energy security system; increase energy efficiency; creating the conditions for reliable energy supply and transit of energy resources; increasing the resilience of the energy sector to negative external influences, etc.

A model of organizational and economic mechanism is proposed, which allows to studying the functional interactions and influence of international organizations in the field of energy independence and sustainable development, administrative and financial institutions, which are subjects of all hierarchical levels of national energy security.

The issues related to ensuring Ukraine's energy independence in an aggressive environment (including the COVID-19 pandemic), the formation of a unified approach to energy assessment and the practical application of the proposed algorithm for assessing energy balance in some sections will be the subject of further research.

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