

# Modeling and Forecasting of Provision of Energy Security of Ukraine with Energy Resources

Andrusiv Uliana<sup>1,\*</sup>, Zelinska Halyna<sup>2</sup>, Kupalova Halyna<sup>3</sup>, Goncharenko Nataliia<sup>4</sup> and Bezuhla Liudmyla<sup>5</sup>

<sup>1</sup>*Ph.D. in Economics, Assistant Professor, Department of theory of Economics and Management, Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine.*

<sup>2</sup>*Doctor of Economic Sciences, Professor, Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine.*

<sup>3</sup>*Doctor of Economic Sciences, Professor, Department of Environmental Management and Entrepreneurship, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine.*

<sup>4</sup>*Ph.D. in Economics, Assistant Professor, Department of Environmental Management and Entrepreneurship, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine.*

<sup>5</sup>*Doctor of Economics, Professor, Head of the Tourism and Enterprise Economics Department, Dnipro University of Technology, Dnipro, Ukraine.*

**Abstract:** The article proposes to use the models of provision of the energy security of Ukraine with energy resources in the context of globalization as a descriptive-model representation of the process for describing, analyzing, evaluating, managing and forecasting the state's fuel and energy resources (FER). It has been determined that the shortage of energy resources is mainly caused by their irrational use by all market entities, as well as their noticeable decrease in production within the state. Their import from abroad leads to a weakening of the position of Ukraine's energy independence in the international market. A system of functional dependencies of individual FER determinants is proposed. It has been established that the path to energy independence of Ukraine is impossible without careful and rational use of resources. It has been established that the modeling process acts as a kind of tool for the authorities in shaping energy policy in Ukraine. A model of an organizational mechanism for ensuring the efficiency of the use of fuel and energy resources at various hierarchical levels is proposed, where subjects of regulatory and supervisory activities are represented within each level, their functional relationships and influence are regulated by the current legislation. Forecasting and assessment of energy independence of the national economy of Ukraine until 2035 was carried out.

**Keywords:** Energy resources, provision, Ukraine, model, energy security, globalization.

## INTRODUCTION

Throughout history, mankind has been forced to solve various problems of a natural, climatic and socio-economic nature. Currently, among the key problems of survival are the problems of providing food, providing energy and maintaining a livable environment. Reflecting on the existence of a limit to the growth of energy consumption by human civilization and how to restrain it without compromising the improvement of the quality of life, it should be recognized that it is impossible to give an exhaustive answer to them today. Obviously, in the first half of the 21st century, a radical increase in energy efficiency in all sectors of human activity, as well as the widespread use of the energy potential of renewable sources, will be justified. In today's world, general security and the availability of hydrocarbons, in particular oil and natural gas, are interrelated.

Increased dependence of socio-economic development on the fuel and energy resources endowment necessitates the improvement of the scientific basis for energy policy and energy security of the national economy. A comparative analysis of the production and use of energy resources available in Ukraine during 2015-2020 showed the existence of problems both in the field of extraction and proper use of energy resources by the national economy. This circumstance motivates public authorities to take appropriate and necessary actions to identify, plan and implement the necessary changes in the country and its economy in the field of energy supply and consumption. For a long time, there is an increase in the consumption of electricity in the energy balance of Ukraine. It suggests that it is the fastest growing energy source in final consumption and is closely linked to economic growth. In this context, the issue of finding and identifying ways and mechanisms to ensure the full implementation of measures aimed at providing the energy security of the state becomes relevant. Accordingly, the need for implementation of energy policy in a market economy

\*Address correspondence to this author at the Ph.D. in Economics, Assistant Professor, Department of theory of Economics and Management, Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine; Email: andrusivu@ukr.net

through the development of an appropriate mechanism for energy security of the national economy.

## LITERATURE REVIEW

Many scientists have studied the energy security of countries, but many questions remain unanswered, in particular modeling and forecasting of energy security of Ukraine with energy resources. In the studies of Kneysler et al. (2020) and Arkhypova et al. (2021) models of providing the national economy with energy resources are built. Zelinska et al. (2020) in their article argue that Ukraine's economy is characterized by a shortage of energy resources, which may explain the obsolete equipment and its wear and tear. Andrusiv et al. (2021) argue that the level of use of fuel and energy resources directly depends on effective management decisions. Because the effectiveness of management mechanisms through the implementation of the management process depends on effective innovation. Orlovska et al. (2020) focuses most of its research on technological and organizational innovation. According to our research, it is these innovations that directly affect the rational use and consumption of energy resources. Infrastructure and investment policy are important for energy efficiency (Irtysheva et al., 2020; Ivashkiv et al., 2020; Koshkaldal et al., 2020). Today, Ukraine depends on gas imports from Russia. In addition, the requirement today is to comply with certain EU directives on energy security of the national economy, in which energy audit and energy management are the main instruments for improving it (Nabitz & Hirzel, 2019 and Ari & Sari, 2017). Researchers (Zablodska et al. 2020; Popadynets & Maksymiv, 2016; Rohozian et al. 2020; Hryhoruk et al. 2021; Maksymiv et al. 2021; Zelinska et al. 2021) draw attention to the relationship between a reliable energy supply policy and environmental security and sustainable development. If we talk directly about the provision of energy security with energy resources, then everything depends on effective management decisions at the national level. And, they are usually accepted by managers (Zelinska et al. 2020) and their motivation for it (Popadynets et al. 2021 and Koshkaldal et al., 2020).

Scientists Xu et al. (2022) in their study proposed the main strategies in China, which balance the socio-economic development and resource savings in terms of their consumption. Onyshchenko et al. (2022) argue that one of the main ways to restore and further develop Ukraine's economy is to switch to the use and generation of "green energy", as RES-related projects will be cost-effective and help attract investment. Serio (2021) argues that the gradual integration of renewable energy in the energy sector of developing countries can be accelerated through environmental awareness and appropriate public policies. Sotnyk et al. (2021) propose to smooth out fluctuations in energy consumption by developing green energy, creating smart grids, improving energy efficiency and balancing energy capacity to ensure energy and economic sustainability. Zapukhliak et al. (2021; 2016) propose a mechanism for energy saving business in terms of implementing the concept of sustainable development. In this case, the energy saving mechanism is considered as an organic component of the business management mechanism, which allows to integrate energy saving problems with effective current business management problems.

Therefore, many issues remain unexplored, namely, the rationale and management decisions that affect the interests of the state and the fuel and energy sector in the field of energy security.

The aim of the article is to develop economic and mathematical models of providing the national economy with energy resources and their projection in terms of sustainable development and organizational mechanism which ensure the efficiency of fuel and energy resources usage at different levels of governance.

## METHODOLOGY

To achieve the set goals, the following research methods were used in the work: graphical - to build a model of the organizational mechanism to ensure the efficiency of the use of fuel and energy resources; economic and mathematical method - to build a model of energy security according to the formulas of the additive and multiplicative convolution; statistical - for processing economic information on fuel and energy resources; forecasting - to determine the normative assessment of the level of energy security of the national economy by adaptive and multiplicative convolution; theoretical generalization - for a deeper study of the issue of ensuring the energy security of Ukraine with energy resources.

## RESULTS AND DISCUSSION

To ensure uninterrupted electricity supply to consumers as a component of Ukraine's energy security, operational security standards for the operation of unified energy system and quality indicators of electricity distribution and supply services are introduced, the main provisions of which are: 1) creating conditions for reliable operation of electricity networks and connections between the unified energy system of Ukraine and the energy systems of other states; 2) planning of measures for expansion of main and interstate electric networks; 3) substantiation of modes and engineering factors of the electric networks equipment operation; 4) development of auxiliary measures to ensure the stable functioning of the unified energy system of Ukraine.

For further active energy saving policy, the "Energy Strategy of Ukraine until 2035" was adopted, in which the main tasks and directions are proclaimed: formation of an integrated and effective system of management and regulation in the fuel and energy sector, development of competitive relations in the energy markets; creation of preconditions for radical reduction of energy consumption of domestic products due to introduction of new technologies, progressive standards, modern systems of control, management and accounting at all stages of production, transportation and consumption of energy products; development of market mechanisms of energy saving stimulation in all sectors of the economy; development of energy export potential, mainly due to electricity, through modernization and renewal of generating capacities, power lines, including interstate ones; development of domestic energy engineering, instrument making and energy complex, as a prerequisite for the competitiveness of Ukrainian enterprises in energy projects, including international ones; regulatory and legal support for the implementation of the goals of the Energy Strategy, taking into account the existing international obligations provided by the Energy Char-

ter Treaty, the Kyoto Protocol, numerous bilateral international agreements, as well as the requirements of European energy legislation, etc.

A significant reserve for improving energy efficiency and energy security of the economy is 30-35% of the energy saving potential of countries with an average level of material prosperity, which can be realized through technical and technological modernization of the economy and energy management system. However, it can be reduced to 10 - 20% through the implementation of energy efficiency programs, after which it will stabilize at this level. Constant improvement of equipment and technologies allows to increase the energy efficiency of previously created ones, and market, administrative, financial, political barriers in the introduction of energy-saving technologies constrain the realization of the existing potential (Simkiv et al., 2021).

For a more thorough analysis of energy security of the national economy, we form models of energy security according to the formulas of additive and multiplicative convolutions:

$$E_i^k = \sum_{j=1}^n \left( w_j \frac{E_{ij}^{k-1}}{E_{ij}^{k-1}} \right), \quad (1)$$

$$\sum_{j=1}^n w_j = 1.$$

where  $w_j$  - specific weight of each criterion (indicator).

The implementation of additive convolution makes it possible to determine the absolute level of energy security and the contribution of each of the determinants in its formation. The use of the share in the supply of primary energy ensures that the impact of structural changes in the fuel and energy balances is taken into account. Let's build a model of energy security of the national economy, provided that the weight of all criteria is equal, will acquire the following review:

$$ES_1 = \frac{ED + EI + ES + ER + ES}{5}. \quad (2)$$

where,  $ES_1$ - energy security of the national economy;  $ED$ - energy dependence;  $EI$ - energy efficiency;  $ES$  - energy security;  $ER$  - energy reliability;  $ES$ - economic stability.

With additive convolution, low values of indicators can be compensated by high values of other indicators. In the case of multiplicative convolution, the total scalar meter should be determined by the following dependence:

$$E_i^k = \prod_{j=1}^n (E_{ij}^{k-1} / \overline{E_{ij}^{k-1}})^{w_j}. \quad (3)$$

We consider it expedient to forecast the energy security of the national economy until 2035, as the adopted Energy Strategy of Ukraine for the period up to 2035 "Security, energy efficiency, competitiveness" allows us to choose this period for forecasting. The assessment of the qualitative level of energy security of the national economy requires a comparison of the actual values of the determinants and the general indicator with the normative ones, which will allow assessing the achievement of the normative or planned level.

Normative assessment level of energy security of the national economy (by additive convolution) in table 1.

**Table 1. Normative Assessment Level of Energy Security of the National Economy by Additive Convolution.**

| Determinants    | Ukraine |       |       |       |
|-----------------|---------|-------|-------|-------|
|                 | 2021    | 2025  | 2030  | 2035  |
| for electricity | 0,011   | 0,014 | 0,015 | 0,021 |
| for nature gas  | 0,022   | 0,023 | 0,026 | 0,027 |
| Energy security | 0,427   | 0,436 | 0,456 | 0,423 |
| danger          | 0,111   | 0,113 | 0,110 | 0,105 |
| insufficient    | 0,226   | 0,224 | 0,221 | 0,215 |
| sufficient      | 0,339   | 0,326 | 0,331 | 0,312 |
| safe            | 0,410   | 0,409 | 0,399 | 0,388 |
| absolute        | 0,452   | 0,447 | 0,440 | 0,425 |

Source: calculated by the authors on the basis of commercial data.

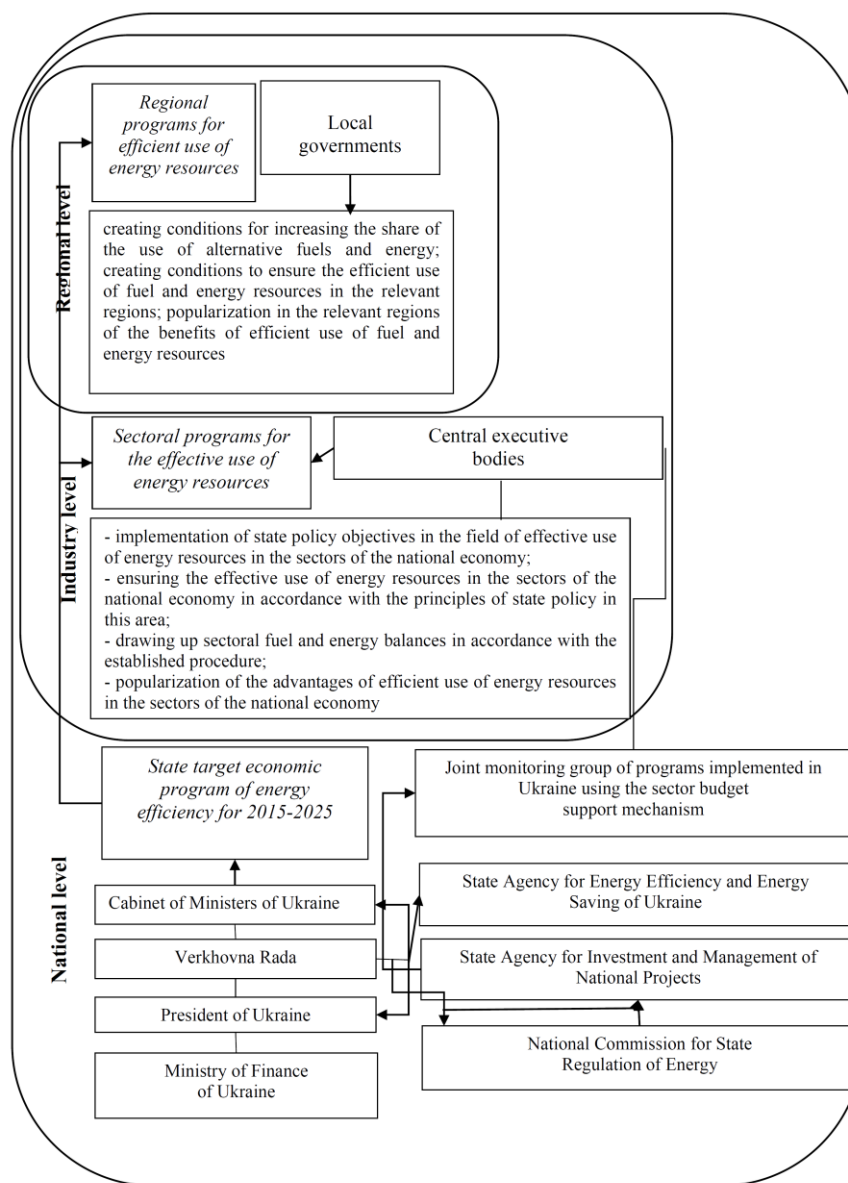
Exceeding the normative level for 2020-2025 by the determinant of energy security of Ukraine's economy for natural gas characterizes a sufficient level of energy security and the possibility of replacing this resource by using alternative fuels and energy, diversifying suppliers and increasing its own natural gas production. If the determinants of energy security, determined by multiplicative convolution, reach the value "1", it indicates local energy security for this type of FER, and if approaching zero - the local energy security for a particular type of resource. To substantiate this approach, we determine the normative level of energy security and its determinants by multiplicative convolution relative to the indicators of the baseline scenario of energy strategy, national and regional programs, energy balances of Ukraine (Table 2).

**Table 2. Normative Assessment of Energy Security of the National Economy Multiplicative Convolution.**

| Determinants    | Years |       |       |       |
|-----------------|-------|-------|-------|-------|
|                 | 2021  | 2025  | 2030  | 2035  |
| for electricity | 0,621 | 0,632 | 0,604 | 0,637 |
| for nature gas  | 0,475 | 0,575 | 0,625 | 0,663 |
| Energy security | 0,281 | 0,353 | 0,366 | 0,413 |
| danger          | 0,069 | 0,088 | 0,091 | 0,103 |
| insufficient    | 0,139 | 0,177 | 0,183 | 0,206 |
| sufficient      | 0,210 | 0,265 | 0,274 | 0,310 |
| safe            | 0,53  | 0,318 | 0,329 | 0,372 |
| absolute        | 0,289 | 0,353 | 0,366 | 0,413 |

Source: calculated by the authors on the basis of commercial data.

According to the threshold values of the energy security level (0 - critical energy dependence; 0.25 - energy dependence;



**Fig. (1).** Model of the organizational mechanism for ensuring the effectiveness of the use of fuel and energy resources.  
Source: authors' own development.

0.5 - insufficient level; 0.75 - sufficient level; 0.9 - safe; 1.0 - absolute) in all periods except 2018 and in relation to all regulatory indicators, a critical energy dependence level of the national economy can be traced by additive convolution, and in 2018 - the situation was characterized by significant energy dependence.

To ensure the energy security of the national economy, national projects should be implemented on the basis of the public-private partnership model, when priority is given to investors' funds over budget ones, project management is used in public administration, personal responsibility and partnership with the world's best companies (Andrusiv et al. 2021; Mandryk et al. 2020; Sergiienko et al. 2020). Therefore, it is advisable to identify priority projects in the field of energy security:

1) new energy, within the framework of which the projects such as "LNG Ukraine" – creation of liquefied gas supply

infrastructure to Ukraine; "Energy of Nature" and "Water and Coal Fuel" – construction of a complex of wind, solar and small hydropower plants, production of solid alternative fuels are being implemented;

2) a new quality of life that combines the programs "Clean City" – a system of complexes for the processing of solid waste; "City of the Future", "Warm House" provide the formation of a strategic plan and system of city development projects;

3) new infrastructure, or "Technopolis", involves the creation of infrastructure for innovative development and high technology.

Based on the above, it is advisable to develop a model of organizational mechanism (Fig. 1) to ensure the efficiency of fuel and energy resources, which characterizes the formation of energy security and its implementation through a set of

methods and forms of regulation, which involves deregulation through the distribution of functions, tools and ways of influencing at the national, sectoral and regional institutional levels and coordination of the main directions due to the system of state, national, regional plans and programs in the field of energy efficiency and energy saving.

The model of the organizational mechanism of energy security of the national economy is determined by the Energy Strategy of Ukraine and tactics of energy security, which is reflected in the set of state, sectoral and targeted regional programs on energy efficiency and energy saving. They define the main indicators for monitoring threats and opportunities for energy security and development of the country's energy system.

Each of the functional levels of the organizational mechanism model is characterized by its specific architectonics and structure, which includes supervisory authorities and subjects of energy saving.

Within each level, subjects of regulatory and supervisory activities, their functional relationships, and impacts regulated by the current legislation are represented.

## CONCLUSIONS

It has been determined that the shortage of energy resources is mainly caused by their irrational use by all market entities, as well as their noticeable decrease in production within the state. Their import from abroad leads to a weakening of the position of Ukraine's energy independence in the international market. A system of functional dependencies of individual FER determinants is proposed. It has been established that the path to energy independence of Ukraine is impossible without careful and rational use of resources.

Forecasting and assessment of the energy independence of the national economy of Ukraine until 2035 was carried out, based on the state's vital documents in the field of energy independence and energy efficiency. A model of the organizational mechanism for ensuring the efficiency of the use of fuel and energy resources has been developed. Its special feature is the visualization of its structuring by national, sectoral and regional institutional levels of supervisory and regulatory activities. The distribution of functions, powers, and instruments of influence by subjects was carried out and their interaction was regulated through a system of a state, national, regional, and sectoral plans and programs for deregulation and decentralization of Management in the field of energy efficiency and energy saving.

This model makes it possible to accelerate the introduction in industry and the field of efficient technologies and equipment, innovative energy-saving projects, the development of regional programs based on the principles of a market economy or encouraging the population to save energy resources, subject to return on investment or cost savings. Of course, economical consumption of energy resources by the population needs appropriate incentives. The incentives we offer include: - alignment of domestic tariffs and prices for energy resources with world prices; setting domestic prices for energy resources at a level not lower than the cost of their production and investment costs in the modernization and reconstruction of production facilities; stimulating the intro-

duction of modern efficient systems for accounting and controlling the costs of energy resources through tariff regulation; termination of the provision of subsidies to the population to pay for the cost of utilities; providing preferential loans to the population and enterprises for the implementation of energy-saving measures and the transition to the use of alternative fuels; renewal of the "green tariff" for enterprises using alternative energy sources; stimulating the reduction of unproductive losses of fuel and energy resources through a progressive reduction in specific norms and an increase in fees for exceeding them; lending to associations of co-owners of apartment buildings for the implementation of energy saving measures; encouraging competition in energy markets and strong antitrust regulation; transition to prepayment for the consumption of fuel and energy resources for all categories of consumers through the introduction of automatic lending by commercial banks; provision of concessional state financing for the implementation of energy-saving projects that provide for saving fuel and energy resources and increasing production volumes; abolition of double examinations of equipment when obtaining permission by the manufacturer (supplier) for its use and by the employer - for use in production, which leads to double costs; exemption from taxation of part of the profit received through the introduction of energy-efficient and energy-saving technologies.

In the future, further research will be aimed at an in-depth study of the situation on the energy market of Ukraine to develop effective measures to strengthen its energy independence and security.

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