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Borysiak O.

*Ph. D. in Economics, Senior Lecturer,
West Ukrainian National University, Ternopil, Ukraine;
e-mail: o.borysiak@wunu.edu.ua; ORCID ID: 0000-0003-4818-8068*

Brych V.

*Doctor of Economics, Professor,
West Ukrainian National University, Ternopil, Ukraine;
e-mail: v.brych@wunu.edu.ua; ORCID ID: 0000-0002-4277-5213*

METHODOLOGICAL APPROACH TO ASSESSING THE MANAGEMENT MODEL OF PROMOTING GREEN ENERGY SERVICES IN THE CONTEXT OF DEVELOPMENT SMART ENERGY GRIDS

Abstract. The transformation of the energy sector towards the development of the green energy sector provides a transition to climate-neutral economic development. In the presence of reserves of natural energy sources, a tendency towards a decrease in their use is monitored as a result of an increase in the share of consumption of green energy obtained from renewable energy sources (e.g. solar, wind). Taking this into account, the role of building an effective management model for the provision of green energy services is growing.

The article proposes a methodological approach to assessing the effectiveness of the management model for promoting green energy services in the context of smart energy network development, based on the use of optimization methods and models. The promoting chain of green energy services is based on the rating assessment of energy service companies, the level of digitalization of business processes of enterprises and the formation of digital skills among consumers of various segments of the energy market, as well as a cybernetic approach to determining the ability to provide innovative energy services.

For this, the peculiarities of artificial intelligence integration into socio-economic processes and the smart energy network constructions have been identified. The analysis of digital technology use level in the promotion of green energy services in the energy market of Ukraine is carried out. The determination of optimization criteria for assessing the effectiveness of the management model for promoting green energy services has been established. The determination of the optimization criteria for assessing the management model is based on obtaining an ecological effect, which made it possible to single out such criteria as maximizing the decarbonization rate of the environment and minimizing energy consumption costs.

The using of such a methodological approach to assessing the effectiveness of the management model for promoting green energy services at energy enterprises will help to ensure a balance between production, distribution, supply of green energy and rational consumption of energy by different segments of consumers.

Keywords: energy efficiency, energy saving, alternative energy, renewable energy sources, green electric power industry, energy enterprises, decarbonization.

JEL Classification D29, L19, M31, Q21, Q40

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Борисяк О. В.

*кандидат економічних наук, старший викладач,
Західноукраїнський національний університет, Тернопіль, Україна;
e-mail: o.borysiak@wunu.edu.ua; ORCID ID: 0000-0003-4818-8068*

Брич В. Я.

*доктор економічних наук, професор,
Західноукраїнський національний університет, Тернопіль, Україна;
e-mail: v.brych@wunu.edu.ua; ORCID ID: 0000-0002-4277-5213*

МЕТОДИЧНИЙ ПІДХІД ДО ОЦІНЮВАННЯ УПРАВЛІНСЬКОЇ МОДЕЛІ ПРОСУВАННЯ «ЗЕЛЕНИХ» ЕНЕРГЕТИЧНИХ ПОСЛУГ У КОНТЕКСТІ РОЗБУДОВИ «РОЗУМНИХ» ЕНЕРГЕТИЧНИХ МЕРЕЖ

Анотація. Трансформація енергетичної сфери у напрямі розбудови сфери «зеленої» енергетики передбачає перехід до кліматично нейтрального розвитку економіки. За наявності запасів природних джерел енергії відстежується тенденція до зменшення їхнього використання в результаті збільшення частки споживання «зеленої» енергії, отриманої з відновлювальних джерел енергії (наприклад, сонця, вітру). З огляду на це зростає роль побудови ефективної управлінської моделі надання «зелених» енергетичних послуг.

Запропоновано методичний підхід до оцінювання ефективності управлінської моделі просування «зелених» енергетичних послуг у контексті розбудови «розумних» енергетичних мереж, що ґрунтується на використанні оптимізаційних методів і моделей. В основі побудови ланцюга просування «зелених» енергетичних послуг закладено рейтингове оцінювання енергосервісних компаній, рівня діджиталізації бізнес-процесів підприємств і сформованості цифрових навичок у споживачів різних сегментів енергетичного ринку, а також кібернетичний підхід до визначення спроможності надання інноваційних енергетичних послуг.

Для цього визначено особливості інтеграції штучного інтелекту в соціально-економічні процеси і побудови «розумних» енергетичних мереж. Проведено аналіз рівня використання цифрових технологій у просуванні «зелених» енергетичних послуг на енергетичному ринку України. З'ясовано визначення оптимізаційних критеріїв оцінювання ефективності управлінської моделі просування «зелених» енергетичних послуг. В основі визначення оптимізаційних критеріїв оцінювання управлінської моделі закладено отримання екологічного ефекту, що дозволило виокремити такі критерії, як максимізація показника декарбонізації навколишнього середовища і мінімізація витрат на енергоспоживання.

Використання такого методичного підходу до оцінювання ефективності управлінської моделі просування «зелених» енергетичних послуг енергетичними компаніями сприятиме забезпеченню балансу між виробництвом, розподілом, постачанням «зеленої» енергії і раціональним споживанням енергії різними сегментами споживачів.

Ключові слова: енергоефективність, енергозбереження, альтернативна енергетика, відновлювальні джерела енергії, «зелена» електроенергетика, енергетичні підприємства, декарбонізація.

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Introduction. The strategic directions of measures to ensure climate-neutral economic development is the supply of green energy, the improvement of energy grids. Accordingly, a specific feature of the planned set of measures in the countries that have joined the implementation of the provisions of the European Green Deal [1] is to ensure the transformation of national energy systems based on energy efficiency and environmental friendliness, i. e. the development of the green energy sector (diversification of alternative sources of energy and ensuring their integration into the grid, the development of green energy service).

The main goals of the Concept of green energy transition of Ukraine to 2050 [2; 3] is an increase to 70% of the share of renewable energy sources in electricity production, the introduction of smart grids, a decrease to 0% of the share of coal-fired thermal power plants in the energy sector, a transition to the use of environmentally friendly transport. In addition, it is predicted that by 2040 half of the world's energy will be consumed in the form of electricity and the share of its production from renewable sources will be 29% in 2040.

Such regularities in the transformation of the energy market indicate that on the way to the implementation of climate-neutral development, the priority orientation is the development of the field of alternative energy, accompanied by the development of a provision complex of high-quality green energy services. In accordance with this, the functioning of enterprises with energy services in countries that have joined the implementation of the provisions of the European Green Deal should be carried out on innovative principles and provide consumers with access to diversified sources of green energy, increase the consumption of alternative energy, provision of services for the implementation of energy efficiency technologies and energy saving.

Research analysis and problem statement. Theoretical and practical aspects of the formation and development of the alternative energy industry, the energy service market, the introduction of energy management are considered in the works, both domestic and foreign scientists, in particular: Sotnik I. N., Mazin Yu. A. [4]; Bachmann J., Novoseltsev A. [5]; Hansen S., Bertoldi P., Langlois P. [6]; Urge-Vorsatz D., Koppel S., Liang Ch. [7]. Taking into account the trend of increasing energy efficiency, energy and environmental safety and, as a consequence, the implementation of international standards for certification of raw materials for biofuel production, the development of the sphere of providing green energy services, in particular the diversification of the activities of energy service companies and energy enterprises [7], the introduction of an energy block-chain network in order to protect the environment and transparent planning the activities of energy service companies in a virtual environment [8].

In the context of the review of the use of innovative marketing communication technologies [9; 10], it is worth noting that ensuring energy efficiency and energy saving requires transformation of the marketing communications management system in the energy market by obtaining feedback from energy consumers by energy producers. In this context, the role of the formation of an omnichannel for promoting green energy services is increasing, which will contribute to the development of effective partnerships between all participants in market relations (from the producer and intermediary to the consumer).

But in the context of the implementation of the European Green Deal, an urgent issue is to ensure the integration of renewable energy sources into existing energy networks by taking into account the peculiarities of the operation of smart grids.

Methodology and research methods. In summarizing the scientific work, we note the urgent need for promoting green energy services by taking into account the peculiarities of the operation of smart grids. The methodological tools used were optimization methods and models, analysis, rating assessment, statistical methods and cybernetic approach. The proposed methodological approach to assessing the effectiveness of the management model for promoting green energy services in the context of smart energy network development is based on the use of optimization methods and models. The promoting chain of green energy services is based on the rating assessment of energy service companies, the level of digitalization of business processes of enterprises and the formation of digital skills among consumers of various segments of the energy market, as well as a cybernetic approach to determining the ability to provide innovative energy services.

The purpose of the study is to develop of a methodological approach to assessing the management model for promoting green energy services by taking into account the peculiarities of the operation of smart grids.

Research results. The general pattern of digital economy projects is the focus on a specific consumer and the comprehensive use of information as a driving resource, taking into account the specific characteristics of a specific consumer in a specific place and the global use of technologies for digital transformation of real business processes. It is important to use the communication model of the energy service market participants, which ensures the provision of high-quality green energy services as a result of taking into account the interests of all consumer segments.

According to a report by the International Energy Agency [11], global energy demand declined by 3.8% in the first quarter of 2020, with most of the impact in March when restriction measures were applied in Europe, North America and other countries due to the spread of COVID-19. The worst hit was global demand for coal, which fell by almost 8% compared to the first quarter of 2019. The demand for oil fell by almost 5%, the demand for gas decreased by about 2%. At the same time, there was a drop in demand for electricity by 20%, primarily for that which was produced from traditional energy sources (oil, gas, coal, nuclear energy). On the other hand, the positive dynamics of growth in demand for electricity from renewable sources, as well as directly to renewable energy sources (solar energy, wind energy, hydropower, geothermal energy), as well as bioenergy (biofuels) and energy production from waste is being monitored. In particular, in the context of statistical data [12; 13] in 2018—2019 in the European Union, there was a trend towards

an increase in electricity production from renewable energy sources, biofuels and waste, and the greatest increase of 104% was achieved in segment of solar power plants.

Table summarize the data on the reserves of renewable energy sources and traditional energy sources, as well as the volume of energy consumption based on renewable sources in Ukraine, indicating the growth of the green energy development dynamics.

Table

Energy consumption from renewable energy sources in Ukraine

	Units of measurement	2013	2014	2015	2016	2017	2018	2019
Total primary energy supply	thousand toe	115940	105683	90090	94383	89462	93492	89072
Total energy supply from renewable sources	thousand toe	3166	2797	2700	3616	3907	4302	4348
Share of energy supplies from renewable sources	%	2,7%	2,6%	3,0%	3,8%	4,4%	4,6%	4,9%

Source: compiled according to data [14].

Such data indicate the need to develop a management model for the provision green energy services through the use of modern marketing tools to promote services. The Internet of Things is the interconnection of several devices such as computers, sensors, electronics and many other software devices, providing a better alternative to the traditional connection system [15]. Distributed Ledger Technologies (DLTs) and blockchain networks within the Internet of Things development serve as the basis for diversifying the development directions of the smart city [16—18].

Such peculiarities of artificial intelligence integration into socio-economic processes have a direct impact on the transformation of the energy sector through the development of smart energy networks. The content of such networks work is to ensure the automation of energy distribution, technology management, which is in the power supply chain, optimization of the pricing policy formation system and feedback from consumers.

In Fig., an algorithm for the operation of smart electric power grids is built on the basis of omnichannel, which implies a transition to the use of renewable energy sources and the inclusion of energy service companies in the chain.

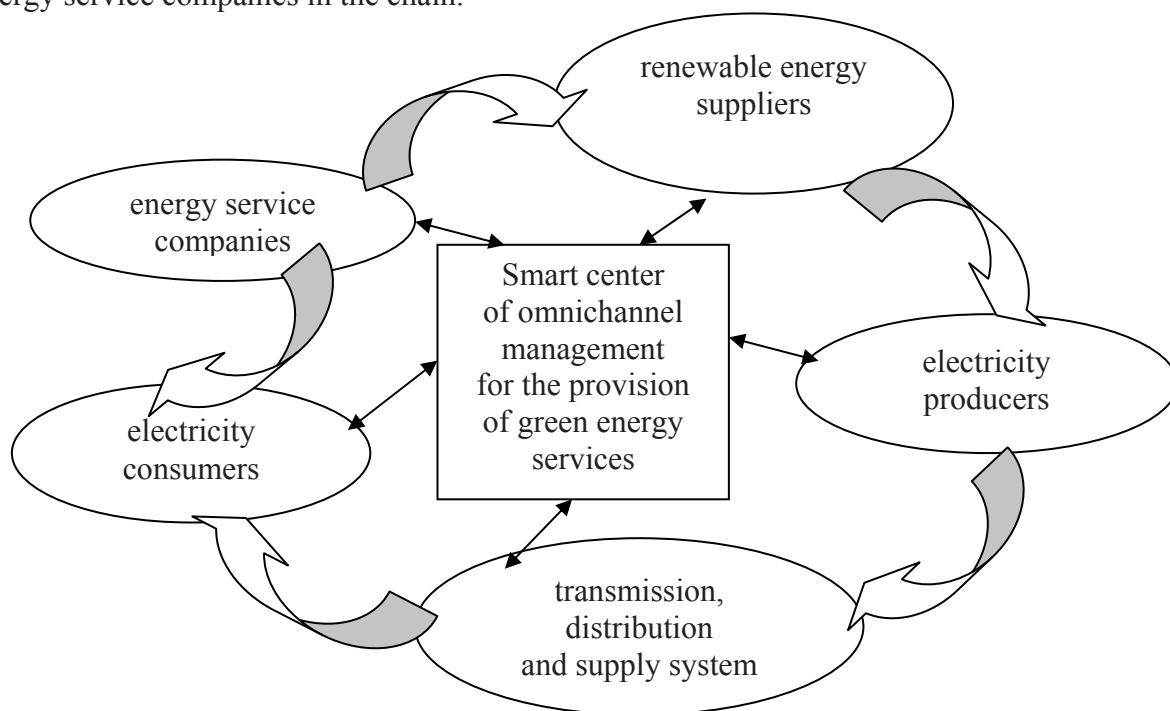


Fig. Algorithm of operation of smart electric power grids based on omnichannel

Source: author’s development.

To understand the operation of smart energy grids, it is necessary to take into account the specifics of the respective energy market functioning. For example, among the difficulties of integrating renewable energy sources into electric power grids, there are unstable production, the complexity of forecasting production (dependence on the climatic characteristics of the territories).

At the same time, we note that in order to increase the energy efficiency of business entities and households by increasing the share of energy production from alternative sources, it is necessary to build an omnichannel for the provision of green energy services based on the interaction of subjects of the energy service market, the electricity market and the alternative energy market. In particular, for this, we believe it is worth focusing on trends in the development of digital technologies, digitalization of business processes and, as a result, to develop digital communication literacy of the population and personnel involved in energy enterprises.

As a result, within digital technologies development, it is of great importance to improve the marketing communication policy of energy service companies based on the digitalization of business processes, in particular: intellectualization of the energy system (development of the Smart Grid system), launching a CRM system to ensure omnichannel in partnerships.

The use of the Smart Grid system is aimed at automating the process of managing production, transmission, distribution of electrical energy, as well as an integrated management system for the entire electrical network of the country. This system contributes to the optimization of energy processes, strengthening of energy security as a result of two-way communication, distributed generation, the prevalence of network topology, prompt response to predictions and prevention (prevention) of accidents, continuous monitoring, self-diagnostics, which contribute to the prolongation of the equipment exploitation period; automatic network restoration, forecasting the development of system accidents, predicting their occurrence; adaptive network allocation; remote equipment monitoring; general power transfer control; the price level for the consumer is displayed in real time [9].

The specificity of constructing the architectonics of the management model for promoting green energy services (see *Fig.*) is to take into account the dynamic development of digital technologies, which leads to the digitalization of business processes in various sectors of the economy.

The promoting chain of green energy services is based on the rating assessment of energy service companies, the level of digitalization of business processes of enterprises and the formation of digital skills among consumers of various segments of the energy market, as well as a cybernetic approach to determining the ability to provide innovative energy services, includes the following stages:

- 1) the offer direction of green energy services and the request for the identification of consumer needs (input);
- 2) synchronization of needs with energy potential;
- 3) testing a prototype of innovative green energy services and monitoring feedback;
- 4) improving the prototype of innovative green energy services;
- 5) provision of innovative green energy services to consumers (exit).

The introduction of such a management model for promoting green energy services serves as an intermediary in the development of smart energy systems. Such a management model will help to ensure a balance between production, distribution, supply of green energy and rational consumption of green energy by different segments of consumers.

The formation of such a smart energy environment also requires an emphasis on defining a methodological approach to assessing the effect of using a management model for promoting green energy services. This presupposes the development of optimization criteria for the effectiveness of the management model.

To optimize the number of such criteria, one can take as a basis the problem of multi-objective optimization, which is written as a vector problem of mathematical programming [19]:

$$F(X) = \{f_1(X), \dots, f_k(X)\} \max, k = \overline{1, K}, \quad (1)$$

$$g_i(X) \leq b_i, i = \overline{1, M}, \quad (2)$$

$$X \geq 0. \quad (3)$$

The selection of optimization criteria for the effectiveness of the management model is based on the principle of resource conservation. With this in mind, for consumers of green energy is the focus on minimizing energy consumption costs. Accordingly, the management model for the provision of green energy services is based on maximizing the ecological (green) effect (decarbonizing the environment) and minimizing energy consumption costs:

$$f(G) = \sum_{i=1}^n g_i s_i \rightarrow \max, \quad (4)$$

$$f(C) = \sum_{j=1}^m c_j e_j \rightarrow \min, \quad (5)$$

where $f(G)$ and $f(C)$ — the functions maximizing the ecological (green) impact of the green energy services provision s_i and minimizing energy costs e_j ; g_i — indicator of the level of decarbonization from the use of green energy services s_i ; c_j — the cost of consuming the relevant type of energy e_j ; n — number of types of green energy services ($i = 1 \dots n$); m — number of types of energy ($j = 1 \dots m$).

These two optimization criteria (minimization of energy consumption costs and maximization of the ecological (green) effect from the provision of green energy services) are unified into the criterion of maximization of the ecological (green) effect from the provision of green energy services $f(G)$:

$$\begin{cases} f(G) = \sum_{i=1}^n g_i s_i \rightarrow \max \\ f(C) = -\sum_{j=1}^m c_j e_j \rightarrow \min \end{cases} \quad (6)$$

$$f(G) = \sum_{i=1}^n g_i s_i \rightarrow \max. \quad (7)$$

Accordingly, using linear programming, we write down such an objective function $f(S)$:

$$f(S) = \sum_{i=1}^n g_i s_i^k \rightarrow \max \quad (8)$$

with restrictions:

$$\begin{cases} \sum_{i=1}^n l_{ij} s_i \leq c_j \\ s_i \geq 0 \end{cases}, \quad (9)$$

where s_i — green energy services; n — number of types of green energy services ($i = 1 \dots n$); k — stochastic coefficient; g_i — indicator of the level of decarbonization from the use of green energy services s_i ; c_j — the cost of consuming the relevant type of energy e_j ; l_{ij} — cost limitation ratio c_j on the consumption of green energy s_i in the system of general energy consumption e_j .

In turn, it is worth noting that the indicator s_i should be considered as a boolean indicator, i.e. it can take values 1 or 0, indicating the integer nature of the linear function $f(S)$.

Thus, we write our linear programming problem in the form of the following equation:

$$f(G) = \sum_{i=1}^n g_i s_i \geq \max$$

$$\begin{cases} \sum_{i=1}^n l_{ij} s_i \leq c_j \\ s_i \geq 0 \end{cases}. \quad (10)$$

To test the rationality of the above suggested methodology for assessing the management model for promoting green energy services, namely solar energy, equation (10) was used, which is solved using the Microsoft Office Excel add-in «Finding a solution» for solving linear problems of mathematical programming, testifies to the validity of the management model for the provision of green energy services in the context of the development of smart energy grids.

Conclusions. Thus, an important direction for Ukraine is the transformation of energy policy in accordance with the European values of sustainable development, the formation of energy efficiency and energy conservation of the economy, the use of renewable energy, strengthening

involves taking into account the aspects of the development of the Internet of Things, the smart development of cities.

This indicates the need to introduce a management model for the provision of «green» energy services in the context of the development of «smart» energy grids, as well as to assess the effective use of such a management model based on the criterion of maximizing the ecological effect (an indicator of decarbonization of the environment). The socio-economic effect of the using such a methodological approach to assessing the effectiveness of the management model for promoting green energy services at energy enterprises: ensure a balance between production, distribution, supply of green energy and rational consumption of green energy by different segments of consumers. As a consequence, the further development of research is to develop innovative human capital management of energy enterprises to ensure the operation of smart grids.

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