Contribution Ukraine's Sustainable Energy Development (Modelling and Forecasting)

Volodymyr Onyshchenko, Olha Komelina, and Igor Shchurov

Abstract Formation and development peculiarities of Ukraine's sustainable energy development and its energy efficiency potential use have been determined. The characteristics of sustainable energy development model are complexity, multilevel, multifactorality, the presence of specific peculiarities and interdependencies of its components, their functions and parameters. The methodology for assessing energy efficiency potential requires non-standard approaches use in the study of external and internal factors impact on the national economy effectiveness to the criterion of energy efficiency. It is important to take into account the dynamics of changes in the vector and the strength of the factors influence depending on the world energy markets, domestic goods and services energy intensity, markets' structure changes and competition conditions. The strategic objectives of Ukraine's sustainable energy development are to increase the level of energy efficiency and ensure the country's energy security.

Keywords Sustainable development · Sustainable energy development · Potential · Energy efficiency · Model

1 Introduction

Problems of energy saving and energy efficiency of the national economy have been widely covered in the works of foreign and domestic scientists. Analytical assessment of recent research in this area shows the diversity of methodological and methodical approaches to the formation of a sustainable energy development model. As a rule, in these researches, the study and structuring of the national economy energy efficiency potential is carried out on the basis of a resource approach to assess the national economy energy efficiency potential [1–10]. In general, scientific works of domestic and foreign scientists highlight different approaches, methods, mechanisms for implementing energy and resource-saving measures at micro, meso and

V. Onyshchenko · O. Komelina (✉) · I. Shchurov
National University «Yuri Kondratyuk Poltava Polytechnic», Poltava, Ukraine

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macro levels, as well as various approaches to energy efficiency management [5, 6]. However, these publications do not provide a systematic understanding of the formation peculiarities of a national economy sustainable energy development model, taking into account its energy efficiency potential [1–3].

Modern domestic and foreign scientists works referring creating a methodology of sustainable energy development require some adaptation to the national economy realities taking into account the actual information on energy resources availability and efficiency, forecasting changes concerning their potential increase, application of strategic management and planning tools.

The purpose of the article is to investigate the peculiarities of forming a Ukraine's sustainable energy development model taking into account the its energy efficiency potential.

Bibliography Review

The concept of sustainable development in modern interpretation began to be actively used in scientific publications, world governmental policy, international documents in the 1980s. In 1992, at the UN World Summit (Rio de Janeiro) with the participation of more than 180 countries, many international organizations and leading scientists, the "Agenda for the XXI Century" was adopted. It created the basis for the formation of sustainable development doctrine as a set of ideas, concepts, positions and postulates of various sciences, in particular philosophy, sociology, economics, ecology, which have already formed the basis of UN documents and individual countries. The main task of the transition to the sustainable development model is to expand the opportunities for economic growth of countries through changes in the relationship system between human being and nature as well as the introduction of a coordinated global strategy for human survival, which aims to ensure long-term continuous development that meets the needs of the people living today, without harming the needs of future generations.

Important aspects of sustainable development are covered in the works of foreign researchers: Jovane F., Yoshikawa H. [11], Onishi A. [12], Blinc R., Zidan'sek A., Slaus I. [13], Clark G. [14], Jegatheesan V., Liow JL, Shu L., Kim SH, Visvanathan C. [15], Goncz E., Skirke U., Kleizen H., Barber M. [16], Hughes B., Johnston P. [17], Kotabe M., Murray J. [18]. The works of domestic scientists Doguntsov S, Dolishny M, Tregobchuk V [19, 20], are connected to the development of basic conceptual provisions of Ukraine's sustainable development.

In the context of Ukraine's European integration strategy implementation and its transition to a sustainable development model, a number of reforms has also been carried out. The National Report "Sustainable Development Goals: Ukraine" provides a vision of the guidelines for Ukraine's Sustainable Development Goals achievement, which were approved at the UN Summit on Sustainable Development in 2015. The increase of energy efficiency level and green energy share in the country's energy balance are strategic objectives of sustainable development of Ukraine.

Currently, the EU countries have developed a pack of documents in the field of energy efficiency ("Energy 2020. A strategy for competitive, sustainable and secure energy: Communication from the Commission to the European Parliament,

the Council, the European Economic and Social Committee and the Committee of the Regions"; "EU Energy Efficiency Policy - Achievements and Outlook"; "EU Energy trends to 2030" [22–24]. The European Commission has adopted a strategy "European Green Deal" in order to make EU's transition to climate-neutral development by 2050. This was taken into account during the formation of the concept and legal framework for sustainable energy development in Ukraine, the Energy Strategy development by 2035 "Security, Efficiency, Competitiveness" and its modernization by 2050, the implementation of active energy reform, regulatory renewal provision for Ukraine and the EU's energy systems integration in 2023.

Main material. Sustainable development national economic model formation is carried out under the influence of economic laws and objective laws at a certain stage of economic development, and the globalization processes which take place in the world economy determine its transformation. An effective national model of sustainable development is able to ensure an appropriate level of population's welfare at a certain stage of social development. In modern conditions, such model formation factors are objective economic, environmental, innovation and investment, technical and technological, social, political, cultural and other processes. In Ukraine, energy security and energy efficiency are key factors in the transition to a sustainable functioning model of the national economy, and its features determine the content of sustainable energy development national model.

Perspective tasks of Ukraine's sustainable energy development on the basis of green energy transition are:

wide implementation of "clean" technologies and on this basis ensuring the transformation of industrial production and export structure with the predominance of goods with high added value;
increase of the economy energy efficiency to the European level and decrease of the energy consumption scale;
maximum deployment of renewable energy sources (hereinafter—RES) and electrification;
transition to environmentally friendly transport;
introduction of a "circular" economy (closed cycle economy);
development of "intelligent" networks and communications;
expansion of bioenergy and natural carbon sequestration technologies;
absorption of CO_2 emissions due to carbon capture, storage and utilization technologies.

The main features of sustainable energy development model are complexity, multilevel, multifactorality, the presence of specific peculiarities and interdependencies of its components, their functions and parameters. The methodology for assessing energy efficiency potential requires non-standard approaches use in the study of external and internal factors impact on the national economy effectiveness to the criterion of energy efficiency and its energy security.

In order to assess the Ukraine's sustainable energy development model, the macroeconomic indicators of the national economy were studied, the dynamics of

vector change and the strengths of key factors influence of its formation were determined (Table 1). In order to assess the peculiarities of such a model formation, energy efficiency indicators and macroeconomic indicators were used.

Analytical data show that in 2007–2019 the economy of Ukraine functioned unstable under internal and external factors influence. This significantly limited the country's transition to sustainable energy development. At the same time, the available statistical base does not allow to take into account the influence of such factors

Table 1 Dynamics of the main macroeconomic indicators of Ukraine (2007–2019, in actual prices, UAH million)

Indicator	2007	2010	2013	2016	2019
Changes in commitments and net wealth					
Net savings	104,146	82,311	−48,293	143,958	51,888
Capital transfers received from other countries	136	95	192	230	72
Capital transfers paid to other countries	−121	−31		−26	−24
Total (changes in net wealth at the cost of savings and capital transfers)	**104,161**	**82,375**	**−48,101**	**144,162**	**51,936**
Changes in assets					
Gross fixed capital formation	198,348	195,927	263,661	368,691	252,071
Fixed capital consumption	−73,071	−115,338	−200,903	−313,522	−122,346
Working capital inventories change	4685	3616	−13,761	148,581	−123,678
Acquisition excluding disposal of valuables	285	375	208	929	156
Acquisition excluding disposal of non-produced non-financial assets		−1414	671	−2144	−24
Net lending (+), net borrowing (−)	−26,086	−791	−97,977	−58,373	45,757
Total	**104,161**	**82,375**	**-48,101**	**144,162**	**51,936**
Energy consumption and energy efficiency					
Final consumption of FER, thousand tonnes of oil equivalent)	85,956	74,004	69,558	51,649	49,359
Energy efficiency indicator (NW increase/FER consumption)	1,212	1,113	−0,692	2,791	1,052
GDP, UAH billion	720,7	1120,6	1522,7	2385,4	3974,6
Energy efficiency indicator (GDP/FER costs)	0,008	0,015	0,022	0,046	0,081
FER final consumption, thousand tonnes of oil equivalent	85,956	74,004	69,558	51,649	49,359
Energy efficiency indicator (NW increase/FER costs)	1,212	1,113	−0,692	2,791	1,052

Source Compiled according to data [25, 26].

as changes in world energy markets, energy intensity of domestic goods and services, changes in the structure of these markets and their competition conditions.

Energy efficiency is the most important criterion for the necessary potential formation for sustainable development of the state. Energy efficiency means the optimal use of fuel and energy resources (FER), taking into account the existing levels of technological development and current environmental requirements. The main indicator of energy efficiency is the specific energy consumption per unit of useful product in all spheres of human activity (economy, technology, life). In the national economy, this indicator is the energy intensity of gross domestic product (GDP). The energy efficiency indicator of GDP is a value that is the inverse of energy intensity, which means the ratio of GDP to the total value of used FER

$$Eei(1) = \frac{GDP}{FERcosts} \tag{1}$$

The GDP indicator cannot be considered as a well-founded indicator of the final result. It does not take into account the social effect of economic activity and the energy factors impact. Some scientists [25] suggest considering the magnitude of the increase in national wealth (NW) to the cost of all energy resources as an indicator of energy efficiency. NW is a more comprehensive indicator, which includes an assessment of natural resources, human (labor resources) as well as social and productive capital of the country; is a comprehensive indicator of life quality, considering income, environmental situation, living potential level, person's moral satisfaction state in life and society.

The energy efficiency indicator according to the second approach is determined by the following way:

$$Eei(2) = \frac{NWincrease}{FERcosts} \tag{2}$$

This indicator more fully reflects the final effectiveness of energy activity—the growth of the NW as an indicator of life quality allows to conduct more reasonable cross-sectoral comparison, and most importantly—to assess the multiplier effect not only of energy costs, pricing, technological modernization, export and import policy, but also the choice of priority areas in the structural as well as social and environmental policy of the country.

In order to identify the formation features of Ukraine's sustainable energy development model, the dynamics of the main Ukraine's macroeconomic indicators for the period of 2007–2019 (Table 1) were considered taking into account its energy efficiency.

The dynamics of change in the studied indicators reflects the lack of a stable and effective state policy to ensure sustainable energy development (Fig. 1).

In order to identify the peculiarities of Ukraine's sustainable energy development model formation, considering the potential of its energy efficiency, appropriate calculations have been conducted and factors that affect the final consumption of FER in the

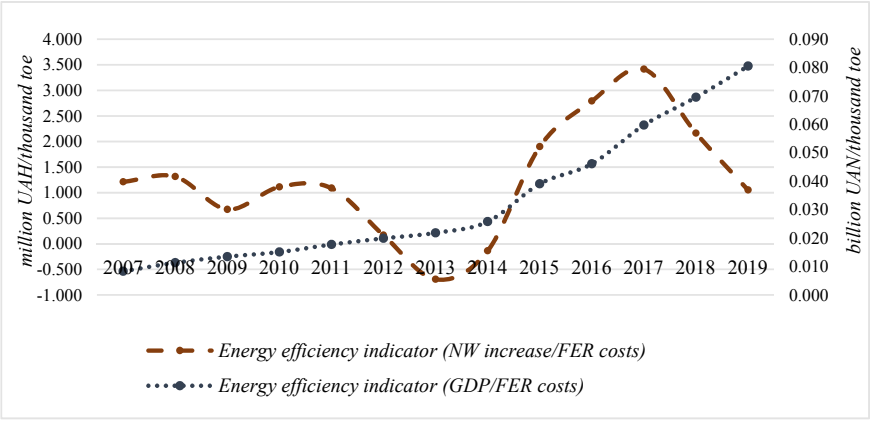

Fig. 1 Dynamics of energy efficiency indicators of Ukraine for 2007–2019

national economy have been selected. The most significant factor is "Capital investments"—an important catalyst for production processes, stable economic development of entrepreneurship and the country in general. The nature of the dynamics of capital investments volume attracted to the national economy, as well as "environmental investments" volume (capital investments and current expenditures for environmental protection) provide an opportunity to assess the threats and opportunities for sustainable energy development. Indicator "household income" shows features of households investment potential formation referring the introduction of energy efficient technologies and energy consumption.

The number of selected factors for constructing Ukraine's sustainable energy development model, considering the potential of its energy efficiency necessitates the use of multiple correlational and regressional analysis to quantify the bonds between statistics that characterize individual social and economic processes (Table 2).

The mathematical form of the relationship between factors and output indicators (regression analysis) has been established and the closeness of this relationship (correlation analysis) has been determined.

The effective indicator Y—final consumption of fuel and energy resources (thousand tons o. e.)—is presented in the form of a power multifactor model

$$Y = a_0 \cdot X_1^{a_1} \cdot X_2^{a_2} \cdot X_3^{a_3} \tag{3}$$

where X1—capital investments and current expenditures for environmental protection, UAH billion;

X2—household income, UAH billion;
X3—capital investments, UAH billion.

The model is built using the MS Excel spreadsheet editor and the "Solution Search" add-on. The solution of dependence (3) is equation:

Table 2 Dynamics of factors change that have an impact on the final consumption of FER in the economy of Ukraine

Period	Capital investments and current expenditures for environmental protection, UAH billion	People's income, UAH billion	Capital investments, total, UAH billion
2007	9,69	623,29	222,68
2008	12,18	845,64	272,07
2009	11,07	894,29	192,88
2010	13,13	1101,18	189,06
2011	18,49	1266,75	259,93
2012	20,51	1457,86	293,69
2013	20,38	1548,73	267,73
2014*	21,93	1516,77	219,42
2015*	24,59	1772,02	273,12
2016*	32,49	2051,33	359,22
2017*	31,49	2652,08	448,46
2018*	34,39	3248,73	578,73
2019*	43,74	3699,35	623,98

Note * Excluding the temporarily occupied territory of the Autonomous Republic of Crimea, Sevastopol and part of the temporarily occupied territories of Donetsk and Luhansk regions.
Source Compiled according to data [25].

$$Y = 659799,2 \cdot X_1^{-0,293} \cdot X_2^{0,074} \cdot X_3^{-0,06} \tag{4}$$

The results of the calculations are presented in Figs. 2 and 3.

The obtained results allow to conclude about Ukraine's sustainable energy development model formation. For multifactor power regression (2) Multiple correlation coefficient is 0.89, which indicates a close relationship of Y with factors X1, X2,

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		Y_t	X_1	X_2	X_3	Y_r	$(Y_t-Y_r)^2$	$(Y_t-Y_s)^2$	a_0	a_1	a_2	a_3		*Forecast quality*
2	2007	85956	623,29	9,69	222,68	85698,21	66456,72	442455044,38	659799,20	-0,293	0,074	-0,060		0,0595
3	2008	83282	845,64	12,18	272,07	78760,87	20440648,25	337112197,30						0,0633
4	2009	67555	894,29	11,07	192,88	77919,63	107425579,72	6935929,99						0,0962
5	2010	74003	1101,18	13,13	189,06	72566,32	2064038,64	82475737,99						0,0802
6	2011	75852	1266,75	18,49	259,93	68237,29	57983823,07	119478352,69						0,0763
7	2012	73107	1457,86	20,51	293,69	65078,41	64458326,97	67004299,22		$Y = a_0 \cdot X_1^{a_1} \cdot X_2^{a_2} \cdot X_3^{a_3}$				0,0822
8	2013	69558	1548,73	20,38	267,73	63960,14	31336067,19	21498202,22						0,0908
9	2014*	61459	1516,77	21,93	219,42	64072,03	6827942,93	11988107,22						0,1163
10	2015*	50830	1772,02	24,59	273,12	60797,91	99359165,45	198567120,38		$R=$	*0,89*			0,1700
11	2016*	51648	2051,33	32,49	359,22	57283,90	31763314,81	176182739,15		F_{pozp}	*20,95*			0,1647
12	2017*	49911	2652,08	31,49	448,46	53226,70	10993887,67	225311646,30		F_{madx}	*4,26*			0,1763
13	2018*	51458	3248,73	34,39	578,73	49889,08	2461507,34	181262725,30						0,1659
14	2019*	49359	3699,35	43,74	623,98	47340,95	4072515,09	242187814,92						0,1803
15	2020*		3700	44	624	**47321,50**	**439253273,84**	**211245991 7,08**						**0,1171**
16														**88,29%**

Fig. 2 The results of the final fuel and energy resources consumption modeling on the basis of multifactor power dependence

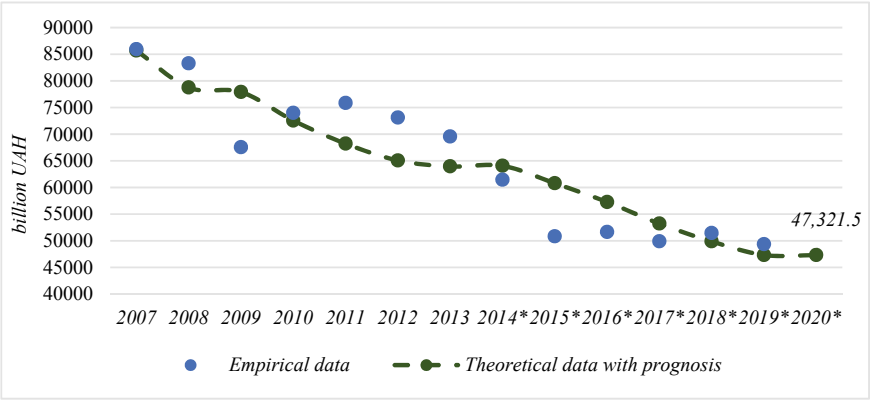

Fig. 3 Graphic representation of the final fuel and energy resources consumption forecasting results on the basis of multifactor power dependence

X3, as well as the proximity of the selected mathematical model to the selected data. According to Fisher's criterion F (4,26) = 20,395, which significantly exceeds the critical tabular value and indicates the importance of the relationship. Thus, the constructed model has a fairly high quality forecast (88.3%).

Positive coefficients values of independent variables of the constructed sustainable energy development model indicate an increase in final consumption of fuel and energy resources with increasing influence factors, negative on the contrary, a decrease. The conducted calculations made it possible to forecast the final consumption of fuel and energy resources on the basis of multifactor dependence and to determine the main dependencies in the Ukraine's sustainable energy development model formation.

2 Conclusions

The effect of natural and economic laws of sustainable energy development model formation is closely related to many different key (permanent) and random factors, which indicates its objective propensity to the equilibrium loss risk. The slow "green" energy transition may lead to a deepening of crisis processes in the economic development of Ukraine and increase the negative social and economic consequences for citizens. Ukraine's transition to a climatically neutral economy requires the state to attract investments of up to 5% of GDP annually. Households play a huge role in these processes. Households demand for energy equipment, heating, vehicles and their investments into energy efficiency also affect the formation of the country's economy technological structure, the development of renewable energy, the use of "smart" energy management systems etc.

Thus, Ukraine's transition to the sustainable energy development model requires the improvement of regulatory policies and economic incentives mechanisms, environmental supervision and monitoring, improvement of overall methodological approaches to regulating the polluting enterprises activities. Further study of sustainable energy development model formation requires a systematic study of the relationship of economic, environmental and social indicators, identification of existing laws, conducting the necessary assessments and conclusions. This will create an objective basis for improving the management system at the macro and micro levels to ensure energy security and the transition to energy efficient and energy saving use and consumption of energy resources with innovative technologies implementation.

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