

Consistency of trends in the economic and energy development of Ukraine: assessment and analysis

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Abstract. Reforming Ukraine's energy sector is targeted at the implementation of European legislation into national practice. However, the lack of a vision of the country's energy model, coordinated with trends and priorities of its economic development, is creating a number of problems with its energy supply. The aim of the presented study is to assess the consistency of trends in the economic and energy development of Ukraine. To achieve the goal, a methodological approach to assessing the consistency of trends and structural changes in the economy and energy sector was developed. It was proposed to carry out the assessment based on the analysis of the resource / commodity and production / consumption chains of the electric power industry, and the conditions of the electric power market. It was proved that the trends and structural changes in the economy of Ukraine were not accompanied by corresponding changes in the energy sector of the country. Such inconsistency conditioned: a low level of utilization of installed power generation capacities and, consequently, a high level of unused power generation reserves; a high level of power generation reserves that determined a significant level of non-productive costs and, consequently, a high total cost of power production.

1 Introduction

Energy is a major factor in the development of the world economy, since it is an important factor in the production of almost all goods and services in today's globalized economy. Energy development contributes to economic growth creating new jobs and the value associated with energy extraction, conversion, and distribution. In addition, stable and low energy prices help stimulate the growth rate of any economy [1]. The development of a country's energy sector in general is inextricably linked to the development of the economy.

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The most important branch of the energy sector is the electric power industry. It differs from other branches by its ability to transmit energy over significant distances. It is an infrastructure industry which is directly connected with all sectors of the economy that depend on electricity supply. The ability of the electric power industry to constantly maintain the level of electricity production that meets the current needs of the economy and to generate additional capacities to increase these needs is a key factor in the development of industry and services [2].

One of the problems significantly hindering the economic development of Ukraine is low energy efficiency in public production at a high degree of external energy dependence. A high energy intensity of production is one of the factors determining a low competitiveness of Ukrainian products on the internal and international markets. However, despite the fact that the overcoming of these problems is recognized at the state level as a priority task, significant positive changes in the fuel and energy sector of the country have not been achieved yet. Reforming Ukraine's energy sector is aimed at the implementation of European legislation into national practice. However, the lack of a vision of the country's energy model, coordinated with the trends and priorities of its economic development, will create a number of problems with its energy supply, in particular: irrational structure of primary energy sources, excessive energy conversion capacity, high power losses during the delivery to consumers, etc.

The presence of problems in this area in Ukraine is largely determined by the imperfection of managerial decisions on the implementation of structural and technological changes in the fuel and energy complex of the country, which are not coordinated with the benchmarks of its economic development. Consequently, assessing the consistency of trends and structural changes in the Ukrainian economy and energy sector should be the starting point for the formation of the state policy for the development of the national energy sector.

Scientists pay considerable attention to problems of development of the energy sector as a whole and power industry in particular. In their research, they analyse a large number of issues in the development of this sphere: sustainable development of energy markets ([3-6]), infrastructure of competitive electricity markets ([7-10]), pricing policy and price fluctuations in electricity markets ([11-14] etc.), energy policy in world countries ([15-17]), and many others. Some publications ([18]) raise individual aspects of the problem of consistency of economic and energy development trends of countries, but this problem requires more comprehensive substantive research for different countries across the world, and, in particular, Ukraine, since in case of developing countries the inconsistency of these trends complicates the already difficult situation of their economic growth in the absence of necessary resources (financial in particular) and technologies, increasing the gap with developed countries.

This justifies the need for a further study of these issues and development of a science-based methodological approach aimed at providing a balanced assessment of the dependence of structural changes in the energy sector on structural changes in the economy. The use of this methodological approach, along with assessing the consistency of economic and energy development trends in the country, will allow to identify patterns of change between the type composition of the power generation fleet and energy efficiency of economic activities, energy supply schedules, and sectoral structure of the economy, etc., and thus ensure the validity and effectiveness of management decisions on forming a strategic vision and planning activities for the development of economic and energy spheres.

2 Methodology and data

The purpose of this study is to assess and analyse the consistency of economic and energy development trends in Ukraine.

Based on a number of previous studies, we have developed a methodological approach to assessing the consistency of trends and structural changes in Ukraine’s economy and energy sector, which is presented in Figure 1.

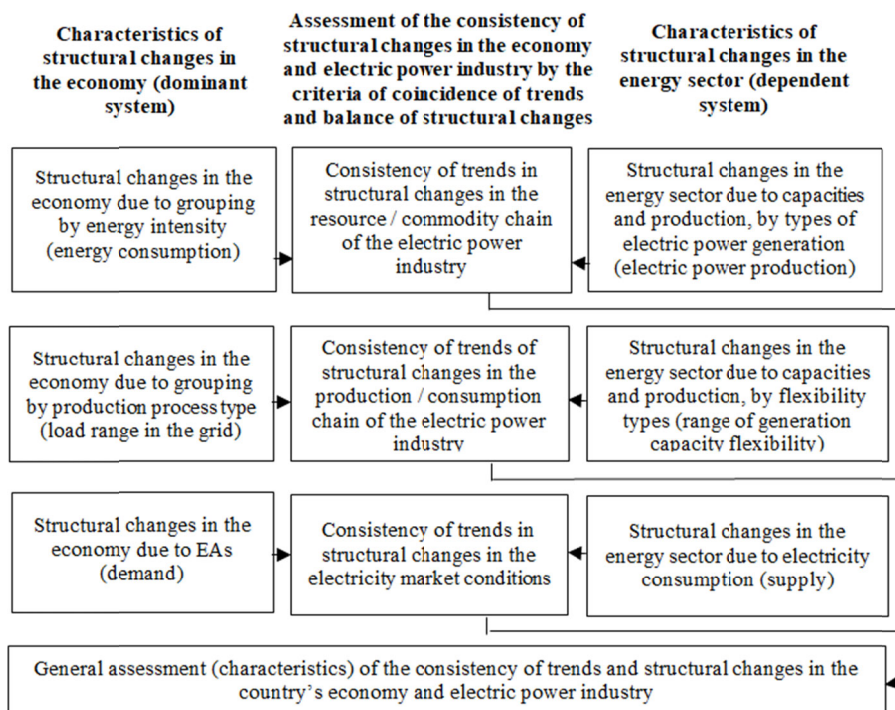


Fig. 1. Methodological approach to assessing the consistency of trends and structural changes in the economy and electric power industry of Ukraine.

According to the methodological approach (Figure 1), the overall assessment of the consistency of trends and structural changes in the economy and electric power industry is based on the analysis of the resource / commodity and production / consumption chains of the electric power industry and the conditions in the electric power market. Assessment of the consistency of trends and structural changes in the resource / commodity chain of the electric power industry is based on the analysis of consistency of the processes that took place in the economy, regarding energy intensity of economic activities (EAs), and the electric power industry (capacities, production), regarding types of electricity generation in 2010-2020.

The statistical basis for the calculations was the data of the State Statistics Service of Ukraine [19] and PJSC NEC Ukrenergo [20] for 2010-2020 (further updates of the data were discontinued in 2022 due to cyber security issues in the energy sector caused by Russian aggression). Theoretical aspects of calculating structural changes in the economy as a whole and the energy sector in particular have been covered in detail in previous works by the authors.

3 Results

Experts of the United Nations Industrial Development Organization (UNIDO) note that, despite the variety of definitions of the concept “structural change”, in the general sense it refers to long-term and persistent shifts in the sectoral composition of economic systems [21]. The study of structural changes in the economy is primarily associated with the analysis of the intensity and speed of transformation processes, uneven distribution and structural imbalances in the economy.

The magnitude and direction of the structural change of the *i*th group in terms of level of energy intensity of EAs in Ukraine’s economy for the Δ -th period ($I_i^{\Delta t}$) was determined as follows:

$$I_i^{\Delta t} = \frac{d_i^{t2} - d_i^{t1}}{d_i^{t1}}, \tag{1}$$

where d_i^{t1} i d_i^{t2} are the share of the *i*th EA group in terms of energy intensity in the country’s economy in the base (t1) and reporting (t2) periods, respectively.

Table 1 provides general characteristics of the direction of trends in the development of Ukraine’s economy (by level of EA energy intensity) and the electric power industry (by generation type) in 2010-2020.

Table 1. General characteristics of the direction of trends in the development of Ukraine’s economy and electric power industry, 2010-2020.

Generation source	Share, %				Average absolute increase / decrease, %	
	d_{2010}	Rank	d_{2020}	Rank	For 2010 – 2020	Rank
Energy intensity level						
High energy intensive	26.75	2	21.98	2	-0.38	3
Average energy intensive	14.08	3	13.81	3	-0.03	2
Low energy intensive	59.17	1	64.21	1	0.41	1
Capacities (by generation types)						
NPP	25.27	2	26.89	2	0.18	3
TPP	64.47	1	54.66	1	-1.09	4
HPP	10.07	3	12.30	3	0.25	2
RES	0.19	4	6.15	4	0.66	1
Production (by generation types)						
NPP	47.20	1	55.20	1	0.89	1
TPP	45.77	2	36.57	2	-1.02	4
HPP	6.98	3	5.46	3	-0.17	3
RES	0.05	4	2.77	4	0.30	2

Note: NPP – nuclear power plant, TPP – thermal power plant, HPP – hydropower plant, RES – renewable energy sources

Table 1 demonstrates that in 2010-2020 there was a decrease in the share of EAs with high and average energy intensity and an increase in the share of low energy intensive EAs, at an increase in the share of electricity generation by nuclear and renewables and a decrease in the share of electricity generation by hydro and thermal power plants.

Figure 2 shows the behaviour of integral coefficients of structural changes in Ukraine’s economy, regarding EA energy intensity, and electric power industry, regarding types of electric power generation (capacities, production).

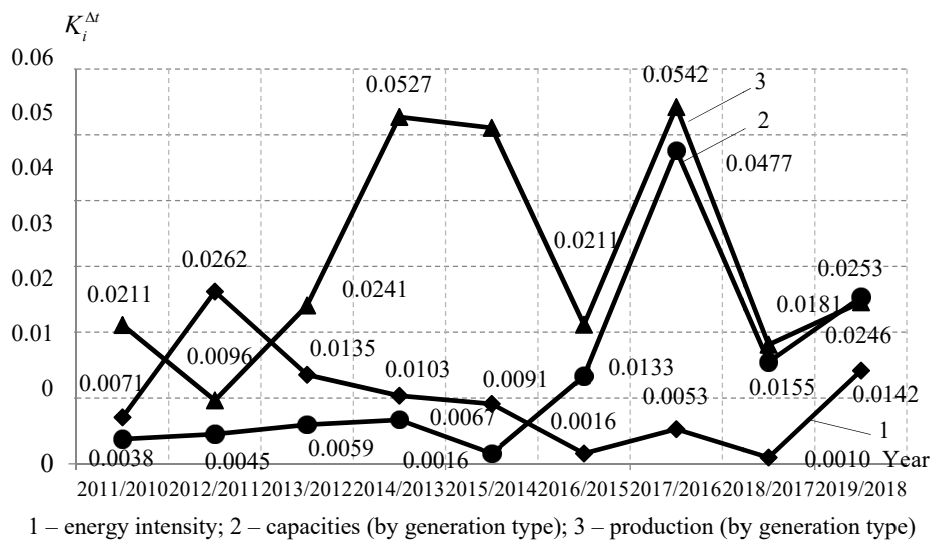


Fig. 2. Behavior of composite indices of structural changes in Ukraine’s economy and electric power industry due to EA energy intensity

As can be seen from Figure 2, in the period under study, the structural changes in the economy due to levels of EA energy intensity were characterized by relatively stable trends and tended to decrease, with a slight increase in 2018-2019. Structural changes in the electric power industry, both in the capacities and production, due to types of power generation, were characterized by unstable trends in 2010-2020.

It is proposed to investigate the existence of relationship (consistency) between structural changes in the economy and the electric power industry (capacities, production, consumption) using a linear correlation coefficient and its qualitative interpretation according to a special Chaddock scale [22] (Table 2).

Table 2. Evaluation of the closeness of the relationship between two variables based on the linear correlation coefficient [22].

Correlation coefficient value	0.1 – 0.3	0.3 – 0.5	0.5 – 0.7	0.7 – 0.9	0.9 – 0.99
Closeness of relationship	weak	moderate	significant	strong	very strong

As can be seen from Table 2, the presence of consistency (by direction) in the structural changes of the economy and electric power industry can be considered at the absolute value of the linear correlation coefficient greater than 0.5.

According to the values of the correlation coefficient, given in Table 3, and the qualitative characteristics, presented in Table 2, the relationship between structural changes in the economy, regarding EA energy intensity, and in the capacities and production of electric power, regarding types of electric power generation, can be characterized as follows: economy – electric power industry capacities (-0.2911) – weak and negative (inconsistency); economy – electric power production (-0.2751) – weak negative (inconsistency); electric power industry capacities – electric power production (0.3233) – moderate positive (inconsistency).

Table 3. Calculation of linear correlation coefficients for composite indices of structural changes in Ukraine's economy and electric power industry, 2010-2020.

Indicators		Economy			Electric power industry				
		Energy intensity	Type of production process	Economic activities	Capacities (flexibility type)	Production (flexibility type)	Capacities (generation type)	Production (generation type)	Final consumption
Economy	Energy intensity	1.0000	0.8951	0.9233	-0.2958	-0.3000	-0.2911	-0.2751	0.4688
	Type of production process	0.8951	1.0000	0.6866	-0.1952	-0.5849	-0.2024	-0.5642	0.2882
	Economic activities	0.9233	0.6866	1.0000	-0.4007	-0.0397	-0.3961	-0.0108	0.5829
Electric power industry	Capacities (flexibility type)	-0.2958	-0.1952	-0.4007	1.0000	0.2585	0.9986	0.3026	-0.2827
	Production (flexibility type)	-0.3000	-0.5849	-0.0397	0.2585	1.0000	0.2790	0.9877	0.3158
	Capacities (generation type)	-0.2911	-0.2024	-0.3961	0.9986	0.2790	1.0000	0.3233	-0.2865
	Production (generation type)	-0.2751	-0.5642	-0.0108	0.3026	0.9877	0.3233	1.0000	0.2806
	Final consumption	0.4688	0.2882	0.5829	-0.2827	0.3158	-0.2865	0.2806	1.0000

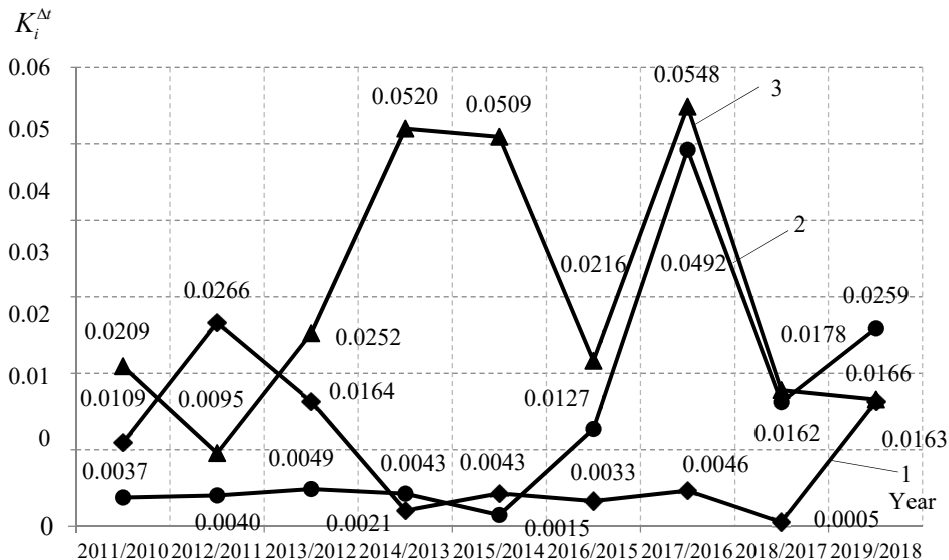
The assessment of the consistency of trends and structural changes in the production / consumption chain of the electric power industry is based on the analysis of consistency of the processes taking place in the economy, regarding types of the EA production process, and the electric power industry (capacities, production), regarding electric power generation (by flexibility type), in 2010-2020.

Table 4 shows general characteristics of the direction of economic development trends (by type of EA production process) and electric power industry (by type of electric power generation flexibility) in Ukraine in 2010-2020.

Table 4. General characteristics of trends in the development of Ukraine's economy and electric power industry in 2010-2020.

Characteristics	Share, %				Average absolute increase / decrease, %	
	d ₂₀₁₀	Rank	d ₂₀₂₀	Rank	For 2010 – 2020	Rank
Type of production process						
Continuous	32.26	2	27.17	2	-0.55	2
Discrete	67.84	1	72.83	1	0.55	1
Capacities (flexibility type)						
Non-flexible	25.27	2	26.89	2	0.18	2
Semi-flexible	64.47	1	54.66	1	-1.09	3
Flexible	10.26	3	18.45	3	0.91	1
Production (flexibility type)						
Non-flexible	47.20	1	55.20	1	0.89	1
Semi-flexible	45.77	2	36.57	2	-1.02	3
Flexible	7.04	3	8.23	3	0.13	2

Figure 3 shows the behaviour of the integral coefficients of structural changes in the economy, regarding types of the EA production process, and electric power industry (capacities, production), regarding electric power generation (by flexibility type) in Ukraine.



1 – production process type; 2 – capacities (by flexibility type); 3 – production (by flexibility type)

Fig. 3. Behavior of composite indices of structural changes in Ukraine’s economy and electric power industry due to types of EA production process

As seen from Figure 3, the structural changes in the economy due to the type of EA production process were characterized by relatively stable trends and tended to decline, with a slight increase in 2018-2019.

Structural changes in the electric power industry, both in the capacities and production, due to electric power generation (by flexibility type) in the period under study were characterized by unstable trends.

According to the values of the correlation coefficient, shown in Table 3, and the qualitative characteristics, presented in Table 2, the relationship between the structural changes in the economy, in terms of type of EA production process, and in the capacities and production of the electric power industry, in terms of power generation, by flexibility type, can be characterized as follows: economy – electric power industry capacities (-0.1952) – weak negative (inconsistency); economy – electric power production (-0.5849) – significant negative (consistency); electric power industry capacities – electric power production (0.2585) – weak positive (inconsistency).

The assessment of consistency of trends and structural changes in the power market conditions is based on the analysis of consistency of the processes taking place in the economy, regarding changes in the structure of EAs, and in the final electricity consumption, by consumer groups, in 2010-2020.

Table 5 provides general characteristics of the direction of trends in Ukraine’s economic development (by changes in the structure of EAs) and final electricity consumption (by consumer groups) in 2010-2020.

Table 5. General characteristics of the trends in the development of Ukraine’s economy and electric power industry in 2010-2020.

Economic activity / final consumption	Share, %				Average absolute increase / decrease, %	
	d ₂₀₁₀	Rank	d ₂₀₁₉	Rank	For 2010 – 2020	Rank
Economic activity						
Agriculture, forestry and fishing	8.17	4	10.35	2	0.242	3
Mining of coal and lignite	1.81	19	1.13	22	-0.075	26
Extraction of crude petroleum and natural gas	0.73	27	1.53	20	0.090	6
Mining of metal ores; other mining and quarrying; mining support service activities	2.39	16	2.51	15	0.012	14
Manufacture of food products, beverages and tobacco products	8.27	3	7.91	3	-0.040	22
Manufacture of textiles, wearing apparel, leather and related products	0.75	26	0.53	29	-0.024	19
Manufacture of wood and of products of wood and cork except furniture; manufacture of paper and paper products; publishing activities	1.76	20	2.12	18	0.040	9
Manufacture of coke and coke products	1.20	22	0.61	27	-0.065	24
Manufacture of refined petroleum products	2.13	17	0.61	28	-0.169	28
Manufacture of chemicals and chemical products	2.87	13	2.52	14	-0.039	21
Manufacture of other non-metallic mineral products	1.34	21	1.67	19	0.037	12
Manufacture of basic metals and manufacture of fabricated metal products	9.36	2	5.92	6	-0.382	31
Mechanical engineering	5.49	6	2.93	12	-0.285	30
Other manufacturing	0.85	24	1.31	21	0.051	8
Electricity, gas, steam and air conditioning supply	4.07	8	4.83	7	0.084	7
Water supply; sewerage, waste management and remediation activities	0.65	28	0.64	26	-0.001	15
Construction	4.14	7	6.82	5	0.298	1
Wholesale and retail trade; repair of motor vehicles and motorcycles	12.29	1	12.63	1	0.038	10
Transportation and storage	6.95	5	6.87	4	-0.009	17
Postal activities and telecommunications	1.82	18	1.00	23	-0.091	27
Accommodation and food service activities	0.95	23	0.84	24	-0.011	18
Financial and insurance activities	3.99	9	2.19	17	-0.200	29
Real estate activities	3.82	10	4.06	10	0.027	13
Renting and leasing of machinery and equipment; renting and	2.72	14	4.51	8	0.199	4

leasing of personal and household goods; legal and accounting activities, engineering, business services						
Computer programming, consultancy and related activities	0.61	29	3.04	11	0.270	2
Scientific research and development	0.47	30	0.41	31	-0.007	16
Public administration and defence; compulsory social security	3.05	12	4.22	9	0.130	5
Education	3.51	11	2.90	13	-0.069	25
Human health and social work activities	2.69	15	2.21	16	-0.054	23
Arts, sports, entertainment and recreation	0.78	25	0.47	30	-0.034	20
Other service activities	0.38	31	0.72	25	0.038	11
Final consumption						
Economy (except the utilities sector)	57.9	1	51.9	1	-0.66	4
Utilities sector	12.4	3	12.5	3	0.01	3
Population	25.5	2	29.3	2	0.42	1
Other household consumers	4.2	4	6.2	4	0.22	2

Table 5 shows that, in the studied period, the fastest growth of shares was observed in the following EAs: “Construction”, “Computer programming, consultancy and related activities”, “Agriculture, forestry and fishing”, “Renting and leasing of machinery and equipment” and “Public administration and defence; compulsory social security”, while the fastest decrease of shares was recorded in “Manufacture of basic metals; Manufacture of fabricated metal products”, “Manufacture of machinery and equipment”, “Financial and insurance activities”, “Manufacture of refined petroleum products” and Postal activities and telecommunications. In the period under study, in the final consumption, there was a growth in the shares of consumer groups “Population”, “Other household consumers” and “Utilities sector”, and a decline in the share in the consumer group “Economy”.

Figure 4 shows the behavior of the composite indices of structural changes in the economy, regarding changes in the structure of EAs, and in the final electricity consumption, by consumer groups, in 2010-2020.

As can be seen from Figure 4, the structural changes in the economy due to changes in the share of EAs and in the final electric power consumption (by consumer groups) were characterized by similar relatively volatile trends and tended to decrease, with a slight increase in 2018-2019.

According to the values of the correlation coefficient, given in Table 3, and qualitative characteristics, presented in Table 2, the relationship between structural changes in the economy, regarding changes in the structure of EAs, and in the final consumption of electricity, by consumer groups, can be characterized as follows: economy – final consumption of electricity (0.5829) – significant positive (consistency).

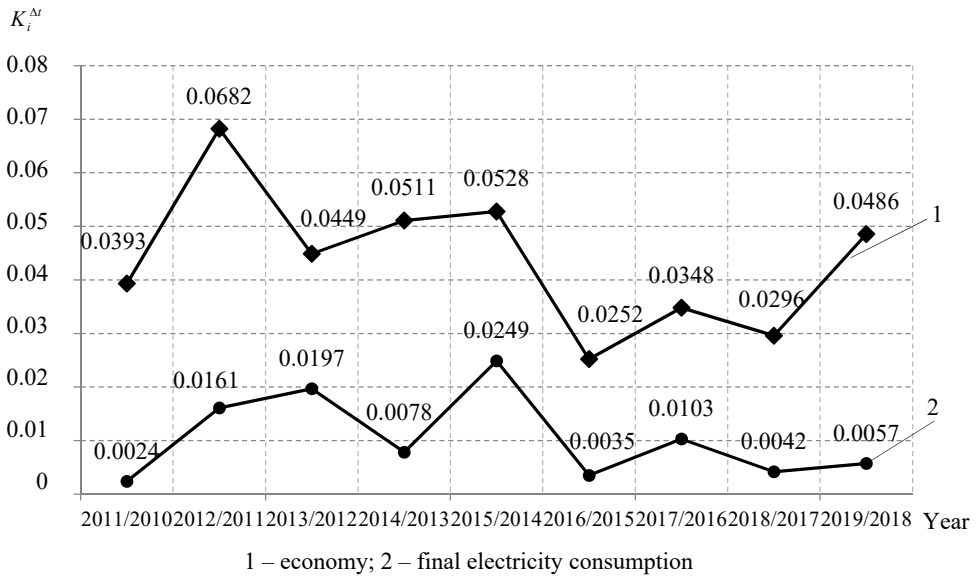


Fig. 4. Behavior of composite indices of structural changes in Ukraine’s economy and final electricity consumption.

Table 6 provides a general assessment (characteristics) of the consistency of trends and structural changes in the economy and electric power industry of the country in 2010-2020.

Table 6. General assessment (characteristics) of the consistency of trends and structural changes in Ukraine’s economy and electric power industry, 2010-2020.

Features of the economic and energy systems			Direction of trend changes in the economy		Electric power industry												
					Baseload power structure				Flexible generation structure				Final electricity consumption				
					installed capacities		electric power generation		installed capacities		electric power generation						
					trend	change	trend	change	trend	change	trend	change	trend	change			
Direction of trend changes in the energy sector					NSC		DC			NSC		DC			DC		
Economy	Energy intensity level of EAs	trend	DC	INC		C		INC		C		C					
		change			INC		INC										
	Structure of consumption by type (mode of energy consumption) of the EA production process	trend	DC	INC		C		INC		INC		C		C			
		change							INC		C						
Structure of the economy by EAs	trend	DC	INC		C		INC		C		C		C				
	change														C		

Note: INC – inconsistency, C – consistency, NSC – no significant changes, DC – decrease

4 Discussions

Nowadays, it is difficult to overestimate the importance of energy saving and energy efficiency since all global economic development is closely connected with the processes of energy consumption. The urgent need to reduce energy consumption and improve energy efficiency is conditioned by a number of factors, from the depletion of natural energy reserves and climate change due to the pressure of the energy sector and products of energy combustion on the environment to the desire of countries to ensure their own energy independence, including by cutting energy consumption.

At the same time, reforming countries' energy sector and introducing innovative technologies and solutions faces a number of problems that can significantly hinder these processes and affect their economies in particular. This is especially acute for emergent nations which have certain problems related to socio-economic development, limited financial resources, outdated material base and technologies.

For example, the case of Ukraine shows that the country's energy sector is characterized by stable trends towards the reduction in energy consumption in industrial and household economic activities, as well as in production of primary fuel and energy resources, and decrease in energy conversion volumes. However, this is mainly due to the reduction in the scale of energy-intensive industries and the economy in particular, which is a negative factor and does not allow talking about positive changes. Moreover, the magnitude of this reduction cannot provide a significant decrease in the almost fivefold gap between the level of energy efficiency of the global and Ukrainian economies. Thus, reforming the energy sector of Ukraine should undoubtedly be guided by modern trends and innovative technologies for energy conservation and energy efficiency. At the same time, the implementation of reforms should neither harm the national economy nor increase the lagging behind developed countries but consider the needs and opportunities of industry and economy in particular to achieve positive results. This issue, due to its insufficient study and high relevance, requires further research and discussion among scientists and practitioners.

5 Conclusions

Based on the analysis of the consistency of trends and structural changes in the economy and electric power industry of Ukraine, the following conclusions can be drawn. In Ukraine, there is a contradiction between national and global trends, both in the economic and energy development, which is manifested in a decrease in the volume of national GDP, power production and consumption against the background of its global growth.

To assess the consistency of trends in the economic and energy development of Ukraine, we propose a methodological approach, the scientific value of which is in the development of theoretical and methodological bases for determining the relationships between structural changes in the economy and energy sector of the country as well as defining the role of production factors in this phenomenon.

Structural changes in the country's economy, namely, the reduction of production volumes in industries with high energy intensity and continuous production cycle, led to a decrease in electricity consumption in economic activities, and hence a decline in its production. The decrease in the scale of the Ukrainian economy conditioned such negative phenomena in the country's energy sector as a decline in the intensity of using the installed capacity for power generation, transmission and distribution and increased the imbalance in modes of power production and consumption, which resulted in a growth in non-productive costs and, consequently, the prices (tariffs) for electricity.

Trends and non-significant structural changes in the generation capacity fleet are not consistent with similar changes in the electric power production and the country's economy. The above-mentioned inconsistency of trends and structural changes results in:

- low level of utilization of installed power generation capacities and, consequently, high level of unused power generation reserves;
- the high level of power generation reserves that determines a significant level of non-productive costs and, consequently, a high total cost of power production.

In general, it can be stated that trends and structural changes in the economy of Ukraine were not accompanied by corresponding changes in the energy sector of the country, and therefore these processes were inconsistent. The inconsistency of economic and energy development trends is determined by the lack of an adequate response in the systemic structure of the energy sector of Ukraine and, first of all, in the electric power complex.

The results of assessing the consistency of economic and energy development trends in Ukraine were proposed by the authors for the implementation and sent in the form of analytical reports to public authorities and local governments of the country. The methodological approach developed in the study can be applied for modelling the processes of harmonization of trends and structural changes in the energy sector and economy; modelling and forecasting scenarios of coordinated energy and economic development; justifying optimal management decisions when planning activities for the development of the country's economic and energy spheres.

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