UKRAINIAN ENERGY SYSTEM: THE MAIN CHARACTERISTICS AND FACTOR ANALYSIS

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Abstract
Ukrainian energy sector depends on the fossil fuels, as long as the indicator of energy intensity is one of the highest in the world. Despite the fact that Ukraine has a significant potential of energy resources, it is an energy-deficient country. The government policy is aimed on the support of renewable energy, providing certain instruments in order to increase investment in this sphere. Moreover, there are different programs stimulating the improvement of energy efficiency. This paper also represents a first attempt to analyze the factors influencing the final energy consumption of economic entities of Ukraine using the logarithmic mean Divisia index (LDMI) method. The conducted analysis shows that the reduction of final energy consumption is caused mainly by decrease of energy intensity indicator. This information can be useful for the enterprises' management and the government in order to take further actions in energy efficiency improvement and transition towards renewable energy sources.
Keywords: energy consumption, LMDI method, energy intensity, energy policy, Ukraine

1. INTRODUCTION

Energy plays an extremely important role in economic processes. In Ukraine today, the current state of economic development, the need for modernization and greening the production necessitates the formation of new models, tools and mechanisms in management of energy system. The necessity of reducing energy consumption is one of the most pressing issues for the country. In the context of a progressive environmental crisis, the products of energy-intensive enterprises cannot compete on the international market. Given the constant increase in demand for energy resources, limited traditional energy sources and, consequently, rising prices, the issue of reducing energy consumption is acute.

Reducing energy consumption can be achieved in various ways. Improvement of energy efficiency leads to use less energy for the same needs. But consumers can also be encourage to change the source of used energy to renewables. The availability of inexhaustible resource base and ecological purity are their defining advantages in terms of depletion of traditional energy sources and growing environmental pollution. The state policy in energy sector is being developed taking into account these considerations.

However, access to clean and reliable energy supply remaind quite limited. Achieving high rates of economic development in Ukraine in the future will require an increase in energy consumption. At the same time, Ukrainian economy is characterized at the moment by a high level of energy intensity, which is a negative factor of development in terms of limited energy potential. Therefore, an indispensable need is energy efficiency improvements, as well as expansion of the use of renewable energy sources in the practice of Ukrainian enterprises. In this case, government should provide adequate policy supporting actions of transition towards sustainable energy, along with the development of relevant legal framework at the state level, the implementation of specific actions in regulatory policy on energy issues, devising measures to attract state and private investment to implimentation of modern energy saving technologies. Moreover, analysis of the structure

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of final energy consumption and influencing factors can give the information whether such a policy was successful.

The aim of this paper is to consider the main features of Ukrainian energy system. This study is also focuses on identifying the key factors influencing the level of energy consumption by means of application of logarithmic mean Divisia index (LMDI) on a real-life case study based on data from Ukraine. The adoption of additive and multiplicative models enables to evaluate influence of the activity level (total volume of production) of economic entities, proportion of each economic activity in total production and energy intensity effect of economic sectors on the level of final energy consumption of economic entities in Ukraine. The identification and evaluation of these drivers will help researchers, managers and officials in decision-making for energy management and energy policies improvement in operational, tactical and strategic levels.

The remainder of this paper is organized as follows. Section 2 comprises a literature review in the related area. In Section 3, energy consumption in Ukraine is examined, namely, its dynamics and structure by sources. In addition, the indicator of energy intensity in Ukraine compared to EU countries is analyzed. In Section 4, energy policy in Ukraine, which includes renewable energy policies and energy efficiency policies, is discussed. In Section 5, research methodology of logarithmic mean Divisia index (LMDI) is considered for evaluation of factors, which have influence on the energy consumption level. Results of the conducted analysis are presented and discussed in Section 6. Section 7 summarizes all the findings and concludes the study.

2. LITERATURE REVIEW

Energy consumption varies significantly amongst the various economies. For this reason it is crucial to analyze the dynamics and influencing factors using quantitative mathematical models.

Olanrewaju and Jimoh (2014) grouped the energy models based on the following criteria: analysis of historical data (Index Decomposition Analysis – IDA); predicting future energy consumption (ANN model); optimization of energy use for adequate assessment of industrial energy potential (Data Envelopment Analysis – DEA) and hybrid models for energy potential.

The IDA method is based on the number theory and requires data at sectoral level. In addition, both multiplicative and additive decomposition forms are prevalent in the IDA method (Wang and Feng, 2018).

The Logarithmic Mean Divisia Index method (LMDI) is one of the most popular method for studying energy related issues. The method was proposed by Ang and Choi (1997), who modified the Divisia index decomposition method (Divisia, 1926) by replacing the arithmetic mean weight function by a logarithmic one. The researchers (Gandhi et al., 2017) emphasize following advantages of the method: the method satisfies factor-reversal and time reversal tests with no residual term; the relationship between the multiplicative and additive forms can be established easily; the method is easy to apply and the results are understandable. All the above make the LMDI method is suitable for this study.

Ang (2015) presented a guide for implementation of LMDI decomposition approach. The author discussed and compared eight LMDI models that gives strong foundation for the implementation of LMDI decomposition approach.

Today the LMDI method is being applied in numerous studies of energy consumption. However, it is worth mentioning that they are not limited to the energy sector.

Lima et al. (2016) used energy decomposition for cross-country comparisons. They analyzed trends of energy consumption and energy intensity throughout 1990-2012 in China, UK, India, Portugal, Brazil and Spain and used LMDI to identify the main driving forces underlying energy consumption. The obtained results could contribute to energy policy design in order to improve overall energy consumption.

Wang and Li (2016) complemented LMDI approach by IPAT method to carry out a comparative analysis of drivers for energy consumption in China and India. The IPAT method enabled to decompose changes in energy consumption into three factors, namely, technical effect, income effect and population effect, while LMDI technique was used to quantify the contributing rate of those three effects.

Kim (2017) conducted LMDI decomposition analysis of energy consumption in the Korean manufacturing sector for the period from 1991 to 2011 applying both the additive and multiplicative methods. The results showed that the largest contribution to the increase of energy consumption was made by the activity effect. During the economic crises the energy consumption pattern changed. The following sectors were analyzed: food and tobacco, textile and clothing, wood and wood products, pulp and publications, petroleum and chemical, non-metallic, primary metal and non-ferrous, fabricated metal, other manufacturing. The results showed that the improvement of energy intensity in energy intensive industries is different. In accordance with this the policy implications were provided.

Wang et al. (2017) carried out the analysis of energy consumption in Hunan Province (China) using a LMDI method and long-term energy alternatives planning (LEAP) system. The identified factors are the efficiency effect, the scale effect and structure effect. The results of LMDI model was extrapolated by LEAP-Hunan model. The various scenarios of total energy consumptions were designed, which can be used to analyze the impacts of various effects.

Achour and Belloumi (2016) determinate the main driving factors of changes in energy consumption in Tunisian transportation sector using the LMDI methods. The most significant factors (in order of their significance) are: the output effect, the population scale, the transportation structure effect, the transportation intensity effect, the energy intensity effect. The results may be applied in the development of sustainable transport policy

LMDI method was also used by Li, Wang and Chen (2019) to investigate the critical driving forces of water and energy consumption in China and to reveal the linkage between water use and energy consumption changes. The obtained results show the ability of the method to be applied to the different objects and may be basis for the future research interdisciplinary research.

Chen et al. (2019) decomposed solar energy consumption in the United States using the LMDI method. They identified four factors influencing changes in solar consumptions: the energy structure effect, energy intensity effect, economic activity effect and population effect. The analysis was expended by application of LSTM (long short – term memory) to predict changes in solar energy consumption. In addition, the comparison with the results of ARIMA (autoregressive integrated moving average) showed that the combination LMDI-LSTM has better feasibility and can be used not only for decomposition, but also for prediction, classification, identification, etc., that would be of significant value for business and policy makers.

Moutinho, Moreira and Silva (2015) identified the driving forces the have influence on the change in level of energy-related CO_2 emissions in Eastern, Western, Northern and Southern Europe for the two periods of time: before (1999-2004) and after (2005-2010) the Kyoto Protokol. The researchers decomposed the resulting factor into six effects: the carbon emission effect, the energy mix effect, the energy intensity effect, the average renewable capacity productivity effect, the change of renewable energy per capita and the change in population by each on EU country group. The results of the research showed that the CO2 emissions is directly correlated with the energy consumption while the variability of CO2 emissions can be explained by different country effect and levels of energy efficiency. The conducted study is not only economic, but also environmental. The best environmental performer is a group of countries, which has low energy intensity or which is a good performance in terms of energy intensity. This results could be used in order to develop the economic, energy and the environmental policies on the efficient use of resources, in particular energy efficiency and use of renewable sources.

Despite the fact of wide application of LMDI method in the energy studies all over the world, there is a lack of such studies in Ukraine. This paper is authors' attempt to fill this gap.

3. ENERGY CONSUMPTION IN UKRAINE

Having analyzed the state of Ukrainian energy sector during the period from 2008 to 2017, it is worth mentioning that unlike worldwide trends, energy consumption in Ukraine is shrinking (Fig. 1).

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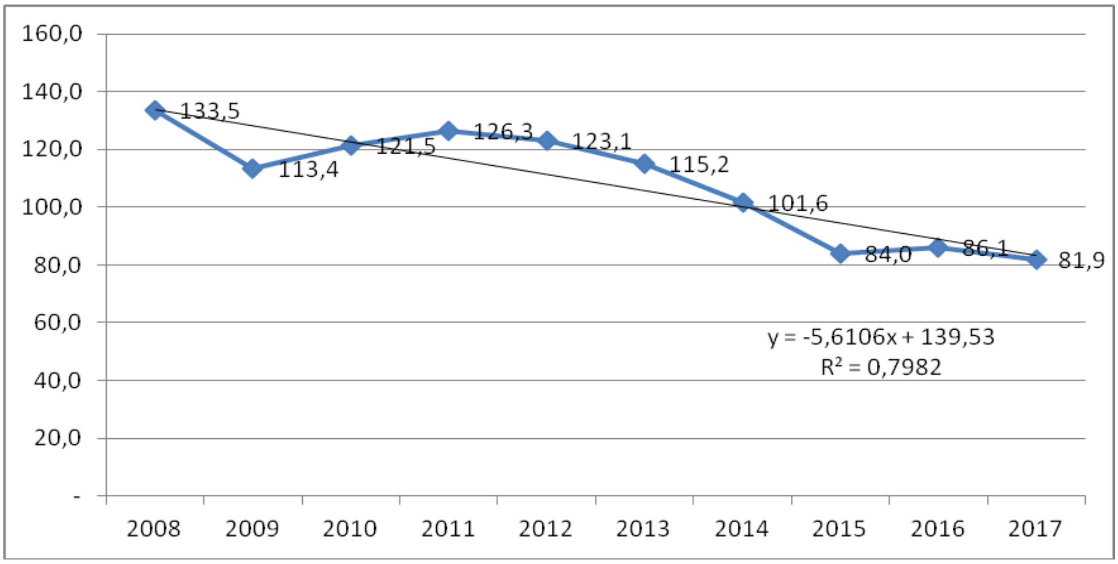

FIGURE 1 - PRIMARY ENERGY CONSUMPTION IN UKRAINE WITHIN THE PERIOD FROM 2008-2017, MTOE.
(DATA SOURCE: Statistical Review of World Energy, 2018).

As you can see from Figure 1, there was a slight increase in primary energy consumption only in 2010, 2011 and 2016 in comparison with previous years by 8.1 mtoe (7.1%), 4.8 mtoe (4.0%) and 2.0 mtoe (2.4%) respectively. For the other years, there was a reduction in the primary energy consumption. This indicator dropped by 51.6 mtoe or 38.7% in 2017 as compared with 2008. However, this was not the result of energy efficiency improvement.

Analysis of the structure of primary energy consumption in Ukraine in 2017 (Figure 2) highlights that natural gas and coal, which are fossil energy resources, make up the largest shares in total energy resources (31.27% and 30.03% respectively). Renewables represents the lowest share of total energy consumption (0.48%).

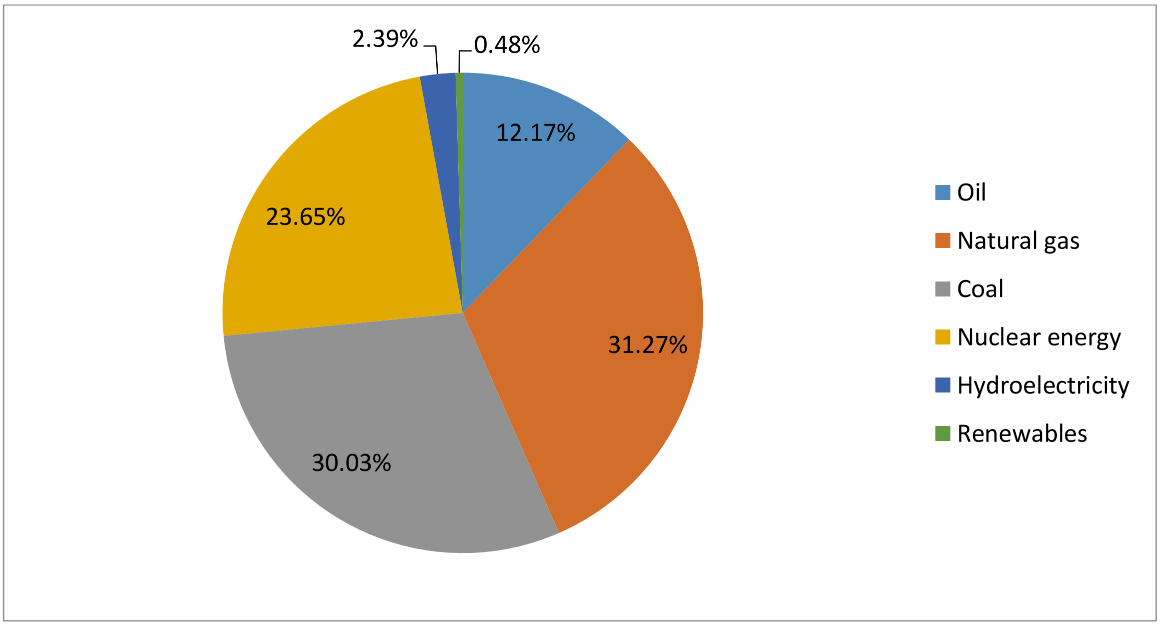

FIGURE 2 - PRIMARY ENERGY CONSUMPTION STRUCTURE BY SOURCES IN UKRAINE IN 2017, %.
(DATA SOURCE: Statistical Review of World Energy, 2018).

The main indicator, which reflects efficiency of energy using in national economy, is energy intensity. It can be calculated as units of energy per unit of GDP.

World energy intensity over the last decade (2008-2017) was analyzed. The dynamics of this indicator can be seen in Figure 3.

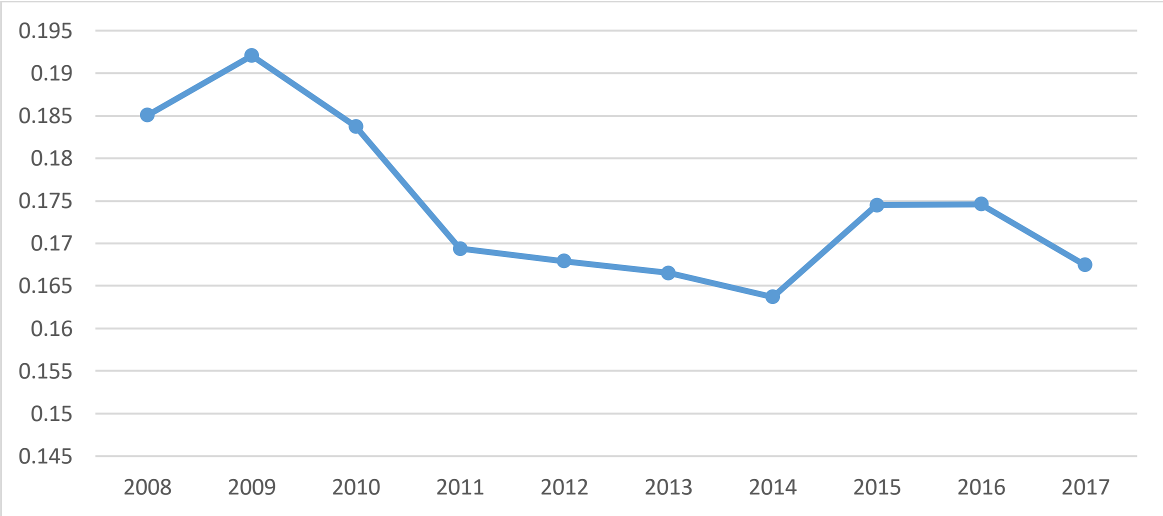

FIGURE 3 - WORLD ENERGY INTENSITY WITHIN THE PERIOD FROM 2008 TO 2017, KG OF OIL EQUIVALENT / USD.
(DATA SOURCE: Statistical Review of World Energy (2018) and GDP (current US$) - Ukraine, World (n.d.)).

As you can see from Figure 3, the average level of energy intensity in the world has been gradually declining over the past ten years, although this dynamic is uneven. There was an increase by 0.011 kg of oil equivalent/USD (6.7%) in 2015 in comparison with 2014. In 2017 this indicator fell to 0.167 kg of oil equivalent/$ (by 0.08 kg of oil equivalent/USD or 4.6%. Countries of the former USSR, South Africa, Taiwan and Iran have the highest level of energy intensity in the world. EU countries have the lowest level of this indicator.

Ukraine remains one of the countries, in which energy intensity is considerably higher than in EU countries (Figure 4).

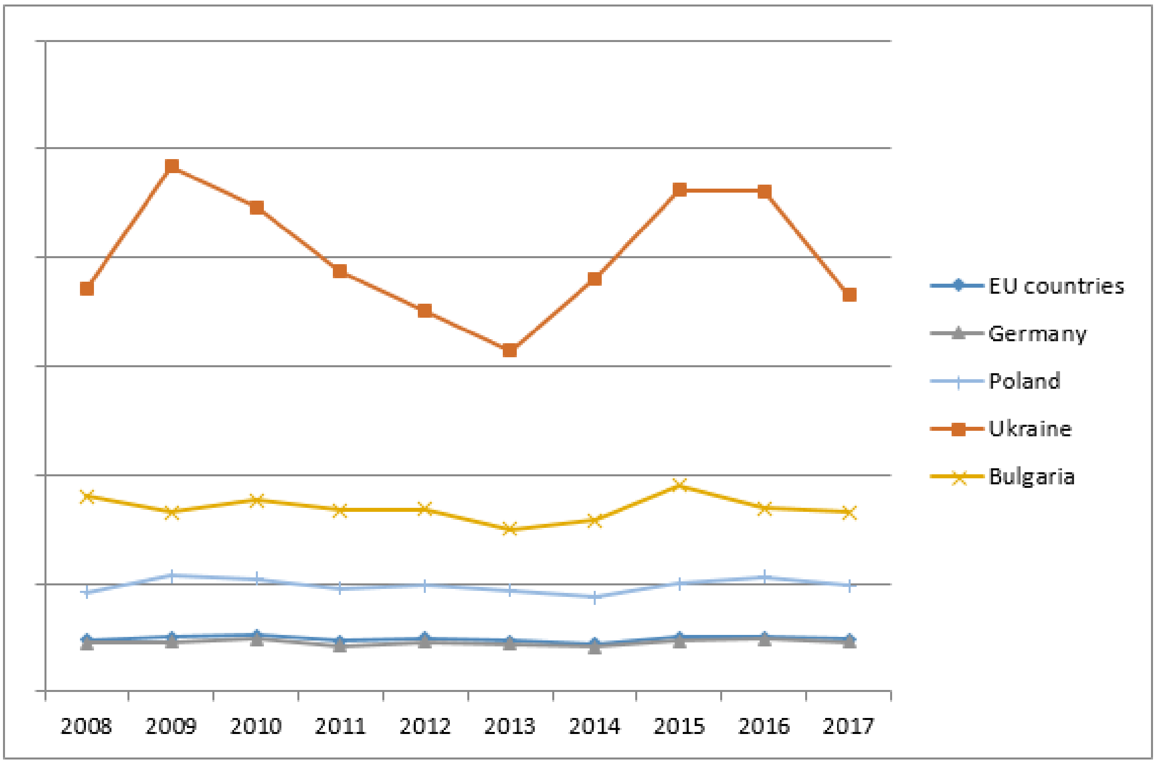

FIGURE 4 - ENERGY INTENSITY IN UKRAINE AND EU COUNTRIES WITHIN THE PERIOD FROM 2008 TO 2017, KG OF OIL EQUIVALENT / USD.
(DATA SOURCE: Statistical Review of World Energy (2018) and GDP (current US$) - Ukraine, World. (n.d.)).

Among the countries of the European Union, Bulgaria has the highest level of energy intensity. However, Ukraine has even worse situation as its energy intensity was more than twice the Bulgarian indicator.

Germany, for its part, is one of the leaders in energy intensity in the EU and in the world. Its energy intensity was 0.091 kg of oil equivalent/USD in 2017, that is by 87.5% less than in Ukraine, by 45.5% less than in the world and by 7.1% less than on average in the EU countries.

Therefore, the state of Ukrainian energy system and its low energy efficiency threaten Ukrainian energy, economic and national safety that is formed within the European Union, since energy resource endowment is insufficient.

This situation is compounded by a number of other challenges. Among other things, there is a lack of cohesion in Ukrainian legislative basis on issues related to energy efficiency. For example, so far more than 250 legal and regulatory instruments are operating, however, the number of successful projects in this area remains low. The main consumers of energy resources are industry and utilities and residential sector. Obsolete and ineffective equipment use in technological processes leads to energy loss, production cost increase and, therefore, reduces competitiveness of domestic products in the world market. With regards to housing facilities, there is a present need of thermo-modernization of buildings that would allow to reduce energy consumption for household needs.

Ukraine has quite enough energy resources. Natural gas exploitable reserves account for 452.8 billion cubic metres. There are 269 out of 402 deposits of hydrocarbons in the industrial exploitation. In all, 905.6 billion cubic metres of all reserves (68.9%) have been extracted. Thus, proven natural gas reserves are enough for 22 years, if progress is maintained (about 20.5 billion cubic metres annually) (UNIAN, 2018).

Despite the fact that Ukraine has significant reserves of oil, natural gas, coal and shale gas, it is an energy-deficient country. Moreover, most of the deposits are on their final stage of exploitation (Chychyna, 2015).This necessitates structural transformation of Ukrainian energy sector, implementation of energy efficient technologies and transition to renewable.

The main consumer of energy resources in Ukraine is industrial sector that used 71.2% of total consumed thermal energy (41927489 Gcal) and 75.2% (67365227 thousand kWh) of total consumed electricity in 2017.

At the same time, the problem of efficient use of resources concerns not only creation and implementation of energy saving technologies in industrial enterprises, but also non-profit organizations of public sector, among which educational establishments.

Today problems of Ukrainian energy sector can be solved by means of implementation of renewables, as Ukraine has at its disposal the significant potential of them. Enterprise energy sector could use such equipment as wind generators, solar collectors, heat pumps of different types, as well as boilers that operate on bio-fuel. Their application is interesting in relation to their economical effectiveness in operation and reducing the negative impacts on the environment.

However, the race of renewable implementation remains rather slow.

4. ENERGY POLICY IN UKRAINE

4.1. Renewable energy policies in Ukraine

Ukrainian government support the renewables implementation; however, actual growth rates of this sector are far behind planned indicators. One of the factors of such gap is lack of financing renewable projects.

Supply and demand on financial resources for renewable projects in Ukraine are unbalanced, as the investment in energy efficiency are risky enough and do not guarantee the return in short-term perspective. Moreover, the legislative framework for energy sector is imperfect and there is a lack of coordination between players of energy market, namely: state, local communities, investors, energy producers and consumers.

In general, the possible sources of financing the renewable projects are own funds of enterprises, debt capital, as well as different grants and subventions. However, the implementation of complex economic programs, among which expansion of renewable energy use, is not possible without the full government support, state regulation in combination with market mechanisms of financing.

The Ukrainian government has a direct impact on investment in this area by means of three main instruments:

1. “Feed-in tariffs” (“green tariffs’). This term is codified at the legislative level since 2009. “Feed-in tariffs” are applied to electricity, which is produced based on renewables. The State, represented by the state enterprise “Enerhorynok”, buy this electricity from enterprises and households. The tariffs will be applied up to December 31st, 2029 (Law of Ukraine on alternative sources of energy No 555-IV. (2003, February 20)).
2. Tax incentives. Article 197, paragraph 16, of the Tax Code of Ukraine provides exemption from taxation on the activities related to importation into Ukraine of the equipment, facilities, materials, which associated with production and using of alternative fuels and renewable energy (Tax Code of Ukraine, 2011).
3. Preferential regime of joining the electricity network for the objects of renewable energy. The initial steps are being made in order to simplify the procedures of joining and launch of these objects. However, the investors face the technical, time and financial risks.

All these instruments are rather effective at the stage of implementation of renewable energy in economic practice. However, at the current stage in order to accelerate development of this area it is necessary to apply the tender system, when the producers are granted the right to sell a certain quantity of electricity at the lowest price, proposed by them at the auction. This price should be lower than the existing under the current system of renewable energy stimulation.

As for non-governmental support of the renewable energy, in Ukraine today there are several financial programs in this area. According to the report “Development of renewable energy sources in Ukraine” these programs are:

1. programs of direct financing of renewables (USELF program and direct lending of EBRD, “Clean Production” program and NEFCO investment fund, Danish investment fund);
2. programs of renewables financing by engaging intermediaries (“Development of municipal infrastructure” program of European investment bank, programs of World Bank and International financial corporation, German-Ukrainian fund);
3. bank financing (Ukrhazbank, Ukreximbank, Oschadbank);
4. co-financing of renewable energy projects (Clean technologies fund, World ecological fund) (The development of renewable sources in Ukraine, 2017, March).

4.2. Energy efficiency policies in Ukraine

The transition towards the sustainable energy means development of energy efficiency actions, as well as renewables implementation. In Ukraine today the reforms related to the energy efficiency improvement are being conducted extremely slowly.

However, there have been done some measures in the sphere of the efficient usage of fuel and energy resources and energy saving by the government. Namely, the State Agency on energy efficiency and energy saving was established by the Cabinet of Ministers Resolution No. 676 dated 26 November 2014 (The project of the Concept of the Fund of Energy Efficiency, 2016).

Today the energy efficiency policy in Ukraine is focused on addressing the problems of inadequacy of financial needs of this area and available private and state investment that leads to the number of legislative initiatives for the creation of public-private partnerships, communities of end consumers and energy consumption accounts. The “Concept of the Program of modernization and development of Ukrainian heat supplying systems for the period from 2012 to 2022” was suggested but it was not approved.

After considering the structure of the final consumption in Ukrainian energy balance in 2017, it must be specified that the total volume of the end energy consumption is 50086 thousand ton of oil equivalent (Ktoe), while the main shares belong to the industrial sector – 30.2% (15103Ktoe), transport – 19.5% (9768 Ktoe) and others 45.3% (22701 Ktoe) including residential sector – 16435 Ktoe or 32.8% of the total end consumption and non-energetic consumption – 5.0% (2515 Ktoe).

As we can see, the situation in the residual sector is one of the worst. The Ministry of regional development, construction and housing and communal services estimates the energy losses in the residual sector during the heating period to be about 60% or 3 billion of USD. Nevertheless, the housing stock is one of the promising objects for energy efficiency actions. The potential of the reduction of natural gas consumption in Ukraine by means of thermomodernization is 11.4 billion of cubic meters, among them 7.3 billion by means of housing energy audit (The project of the Concept of the Fund of Energy Efficiency, 2016). The housing stock consists of 6.5 million individual and 240 thousand high block houses (The housing stock on January 1, 2016, n.d.). More than 80% of them were built before 1990es and do not meet the energy efficiency standards. According to the Ministry of regional development, construction and housing and communal services the cost requirements of the thermomodernization of individual houses are 28 billion of USD and high block houses are 17 billion USD (The project of the Concept of the Fund of Energy Efficiency, 2016). The finance sources of thermomodernization are external loans, budget (state and local) allocation, investment of the consumers of energy services. The European Bank of reconstruction and development has allocated 75 million Euro on these purposes (Ukraine will be given 75 million for energy efficiency, n.d.). The EU announced plans to invest 100 million Euro to the Fund of energy efficiency of Ukraine that was established by adoption of the law in 2017. However, this sum is insufficient. This also applies to finance from the budget. In the period from 2015 to 2017 the most of allocation to the energy efficiency were made as part of the program “Warm credits”. It provides the refund: 20% of the loan to buy a gas boilers, 30% of loans for individual to buy energy saving goods, 40% of the loan for the associations of co-owners of high block buildings and construction cooperatives on thermomodernization (On the amendment to the Resolutions of the Cabinet of Ministers of Ukraine No 243 on 01.03.2010 and No 1056 on 17.10.2011. (2015)). In 2015-2016 this program provided for more than 1 billion UAH, in 2017 – 400 million. In 2017 the law on the Fund of energy efficiency was adopted, but there is still a problem with its filling by the budget financing. The volume of the local programs of “warm credits” in 2015 was 14 million of UAH, in 2016 – 45 million UAH. Obviously, the budget financing of this sphere is also insufficient for prompt problem solving. Therefore, these loans are rather the indicator of government energy efficiency strategy.

5. MATERIALS AND METHODS

Looking at the dynamics of final energy consumption in Ukraine, the revealing its factors is of great interest for authors. This analysis can be conducted by means of the logarithmic mean Divisia index (LDMI) method. This method was developed in works of Ang, Zhang and Choi (1998), Ang and Liu (2001), Ang (2005), Ang (2015). This method is used today in many countries to identifying the factors, which have influence on the energy consumption level.

This study analyses the characteristics of final energy consumption of economic entities in Ukraine using data for the period from 2013 to 2017. This study does not include data of energy consumption of households and for non-energetic use, because these sectors does not create additional value for the national economy.

LDMI method can be applied to the additive and multiplicative decomposition analysis problem. Both cases are shown in this paper.

The aggregate indicator used in the model is final energy consumption of economic entities (E). The changes in this indicator is decomposed based on three elements. The first element is the activity level of economic entities or the total volume of production of economic entities ($Q = \sum_{i=1} Q_i$). The second element is the activity share ($S_i = \frac{Q_i}{Q}$), which describes the proportion of each economic activity in total production. The third element is energy intensity effect of sector i ($I_i = \frac{E_i}{Q_i}$). Eq.1 is the expression of final energy consumption of economic entities:

$$E = \sum_{i=1} E_i = \sum_{i=1} Q_i \cdot \frac{Q_i}{Q} \cdot \frac{E_i}{Q_i} = \sum_{i=1} QS_i I_i. \quad (1)$$

Eq. 2 shows the structural formula for the LMDI additive factor decomposition analysis. In this case the total change in energy consumption (ΔE_{tot}) is calculated by addition the individual effects – the activity effect (ΔE_{act}), structure effect (ΔE_{str}), and intensity effect (ΔE_{int}).

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$$

$$\Delta E_{act} = \sum_i \frac{E_i^T - E_i^0}{lnE_i^T - lnE_i^0} \ln\left(\frac{Q^T}{Q^0}\right) \quad (2)$$

$$\Delta E_{str} = \sum_i \frac{E_i^T - E_i^0}{lnE_i^T - lnE_i^0} \ln\left(\frac{S_i^T}{S_i^0}\right)$$

$$\Delta E_{int} = \sum_i \frac{E_i^T - E_i^0}{lnE_i^T - lnE_i^0} \ln\left(\frac{I_i^T}{I_i^0}\right)$$

In the multiplicative factor decomposition, the change in energy consumption from period 0 to T is calculated based on the activity effect (D_{act}), structure effect (D_{str}), and intensity effect (D_{int}). The total change in energy consumption (D_{tot}) can be calculated by multiplying the mentioned individual effects.

$$D_{tot} = \frac{E^T}{E^0} = D_{act} D_{str} D_{int}$$

$$D_{act} = \exp\left(\sum_i \frac{(E_i^T - E_i^0)/(lnE_i^T - lnE_i^0)}{(E^T - E^0)/(lnE^T - lnE^0)} \ln\left(\frac{Q^T}{Q^0}\right)\right) \quad (3)$$

$$D_{str} = \exp\left(\sum_i \frac{(E_i^T - E_i^0)/(lnE_i^T - lnE_i^0)}{(E^T - E^0)/(lnE^T - lnE^0)} \ln\left(\frac{S_i^T}{S_i^0}\right)\right)$$

$$D_{int} = \exp\left(\sum_i \frac{(E_i^T - E_i^0)/(lnE_i^T - lnE_i^0)}{(E^T - E^0)/(lnE^T - lnE^0)} \ln\left(\frac{I_i^T}{I_i^0}\right)\right)$$

The advantage of the LMDI method is that the results of additive and multiplicative decomposition are closely linked, as shown in Eq. 4:

$$\frac{\Delta E_{tot}}{lnD_{tot}} = \frac{\Delta E_{act}}{lnD_{act}} = \frac{\Delta E_{str}}{lnD_{str}} = \frac{\Delta E_{int}}{lnD_{int}} \quad (4)$$

As mentioned, the proposed research eliminated the influence of households and consumers of energy for non-energetic purposes on the indicator of final energy consumption of economic entities, since they do not create additional value and their share in total energy consumption is low. The data include consumption in such sectors of Ukrainian economy, as industry, transportation, agricultural and service sector. The activity level of each sector and the volumes of energy consumption were adopted from the State Statistics Service of Ukraine. The indicators of structure and intensity were calculated by authors over the period 2013-2017. As illustrated in Figure 5, energy consumption by the industrial sector plays a dominant role in total final energy consumption. For example, in 2017 industry consumed 15103.0 Ktoe or 30.15 % of total final energy consumption.

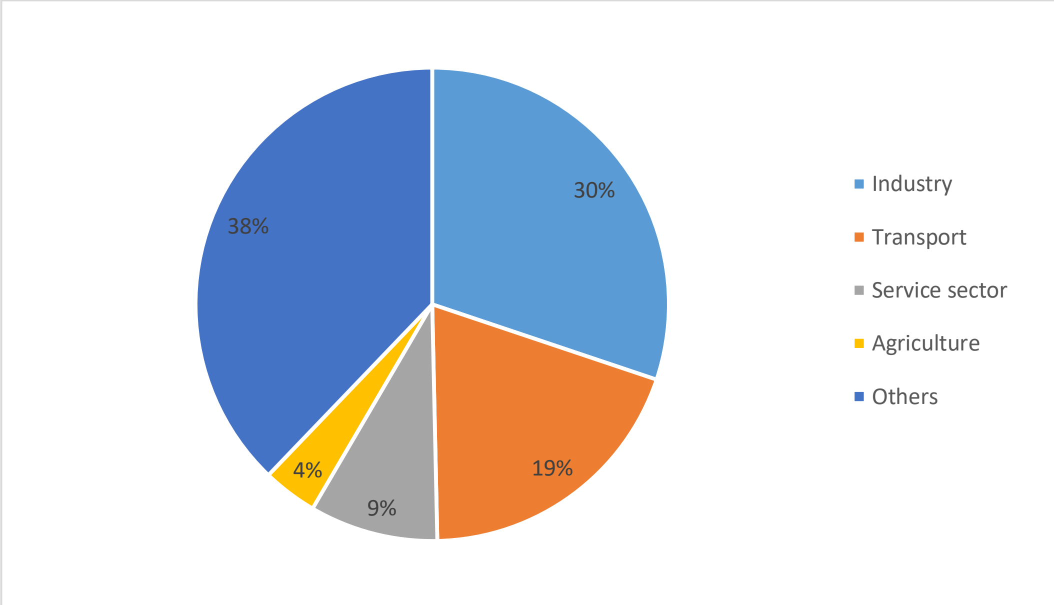

FIGURE 5 - STRUCTURE OF FINAL ENERGY CONSUMPTION OF ECONOMIC ENTITIES OF UKRAINE IN 2017.
(DATA SOURCE: State Statistics Service of Ukraine, n.d.).

Table 1 illustrates the changes in energy consumption, production level and energy intensity of Ukrainian economic entities for the period from 2013 to 2017, which are subdivided for main economic sectors.

TABLE 1 – THE CHANGE IN FINAL ENERGY CONSUMPTION OF ECONOMIC ENTITIES OF UKRAINE (2013-2017), %.

	Energy Consumption		Activity level		
	Annual Average Change Rate	Total Change Rate	Annual Average Change Rate	Total Change Rate	Energy Intensity
Industry	-8.83	-30.92	18.13	94.76	-64.53
Transport	-3.53	-13.40	20.29	109.37	-58.64
Service sector	-6.47	-23.48	20.94	113.91	-64.23
Agriculture	-4.43	-16.59	27.81	166.88	-68.75
Others	-9.64	-33.34	19.15	101.55	-66.93
Total	-7.88	-27.99	19.73	105.49	-64.96

The total energy consumption showed an average annual decline of 7.88 %, with total decline 27.99 % over the period from 2013-2017. During this period total production level increased on the average annually of 19.73 %, with total increase of 105.49 %. Energy intensity has decreased by 64.96 %.

6. RESULTS

Table 2 presents the results of an additive LMDI factor decomposition analysis for energy consumption in Ukrainian economy by rolling base year. It indicates that final energy consumption of economic entities of Ukraine in 2014 declined by 8097 thousand tons of oil equivalent (Ktoe) as compared to 2013. As for the decomposition, the final energy consumption increased by 6985.696 Ktoe due to the activity effect, increased by 435.728 Ktoe due to the structure effect and declined by 15518.424 Ktoe due to the intensity effect. In 2015 the resulting indicator declined by 10629.0 Ktoe as compared to 2014.

The structure effect reduced it by 1342.075 Ktoe, the intensity effect by 19284.346 Ktoe, whereas the activity effect increased final energy consumption by 9997.421 Ktoe. In 2016 the final energy consumption of economic entities increased by 818 Ktoe compared to 2015. The activity effect and the structure effect increased this indicator respectively by 10291.02 Ktoe and 158.891 Ktoe. However, the intensity effect had opposite impact on the resulting indicator. There was a reduction by 9631.91 Ktoe. In 2017 compared to 2016 the final energy consumption declined by 1563 Ktoe that was caused by the intensity effect (by 13705.632).

The activity effect and the structure effect increased the final energy consumption respectively by 11889.953 Ktoe and 252.679 Ktoe. In general, the total reduction in the final energy consumption of economic entities of Ukraine by 197471 Ktoe in 2017 compared to 2013 was due to the structure effect by 497 Ktoe, the intensity effect by 61640.375 Ktoe. However, the activity effect lead to an increase of the final energy consumption by 42667.285 Ktoe.

TABLE 2 – RESULTS OF THE ADDITIVE LOGARITHMIC MEAN DIVISIA INDEX (LMDI) FACTOR DECOMPOSITION ANALYSIS OF FINAL ENERGY CONSUMPTION OF ECONOMIC ENTITIES OF UKRAINE (ROLLING BASE YEAR), KTOE.

Period	Activity Effect	Structure Effect	Intensity Effect	Total Effect
2013-2014	6985.696	435.728	-15518.424	-8097.000
2014-2015	9997.421	-1342.075	-19284.346	-10629.000
2015-2016	10291.020	158.891	-9631.910	818.000
2016-2017	11889.953	252.679	-13705.632	-1563.000
2013-2017	42667.285	-497.909	-61640.375	-19471.000

Table 3 presents the results of a multiplicative LMDI factor decomposition analysis for energy consumption in Ukrainian economy by rolling base year. The results can be interpreted as follows. In 2017 the final energy consumption reduced by 27.99% as compared to 2013. As for the decomposition, it reduced by 0.84% due to the structure effect and by 64.64% due to the intensity effect. It increased by 105.37% due to the activity effect. The total effect is calculated by multiplying the values of the activity, structure and intensity effects.

TABLE 3 – RESULTS OF THE MULTIPLICATIVE LOGARITHMIC MEAN DIVISIA INDEX (LMDI) FACTOR DECOMPOSITION ANALYSIS OF FINAL ENERGY CONSUMPTION OF ECONOMIC ENTITIES OF UKRAINE (ROLLING BASE YEAR).

Period	Activity Effect	Structure effect	Intensity Effect	Total Effect
2013-2014	1.1127	1,0067	0,7888	0,8836
2014-2015	1.1955	0,9763	0,7086	0,8271
2015-2016	1.2224	1,0031	0,8286	1,0161
2016-2017	1.2633	1,0050	0,7638	0,9697
2013-2017	2.0537	0,9916	0,3536	0,7201

Therefore, during the period from 2013 to 2017 the final energy consumption of economic entities in Ukraine has been decreasing. However, in 2016 as compared to 2015 there was a slight increase of this indicator. The intensity effect played a major role in declining of the final energy consumption, whereas the activity effect played a significant role in increasing the final energy consumption. The structure effect had an opposing direction of impact on the final energy consumption each year.

According to the world trend of sustainable development, it is worth mentioning that the reduction of final energy consumption in Ukraine is positive. Moreover, as its reduction is caused mainly by decrease of energy intensity indicator. However, as was shown above the energy intensity of Ukrainian economy has one of the highest levels in Europe and in the world. That is why, in order to reduce the energy consumption, it is urgent to provide measures to improve energy efficiency and reduce the energy intensity in Ukraine.

7. CONCLUSIONS

This study provide a brief analysis of energy sector of Ukraine. Several key trends of the indicators of energy consumption and energy intensity are shown. The state policy in the area of renewable energy sources and energy efficiency is researched. The structure of final energy consumption of economic entities of Ukraine is studied. LMDI model is presented with its basic formulae. The results of an additive and multiplicative LMDI factor decomposition analysis for energy consumption in Ukrainian economy are presented. It will be useful for the enterprises' management and the government in order to take further actions in energy efficiency improvement and transition towards renewable energy sources.

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