“Key energy indicators for sustainable development goals in Ukraine”

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KEY ENERGY INDICATORS FOR SUSTAINABLE DEVELOPMENT GOALS IN UKRAINE

Abstract

Transforming the energy sector to provide universal access to reliable and modern energy services is an essential task for Ukraine, one of the Eastern Partnership countries with heavy energy dependence. It will help accelerate the achievement of the Sustainable Development Goals. The paper is devoted to studying Ukraine's readiness to generate sustainable energy compared to the EU and other Eastern Partnership countries and the development of an information base for monitoring the achievement of SDG7.

The data from the World Energy Council (WEC), the International Energy Agency (IEA), and the State Statistics Service of Ukraine are analyzed. Thus, the study proposed to expand the list of national monitoring indicators that more fully reflect the social, economic, and environmental results of SDG7 "Affordable and clean energy" in Ukraine. The development of an information monitoring base expands the opportunities to assess the availability, sustainability, and balance of national energy policy in green economic transformation. Furthermore, the indicators of energy intensity, carbon intensity, as well as access to sustainable energy for the population and business are emphasized. The findings are aimed to raise the level of awareness of government agencies and make balanced decisions to accelerate the achievement of SDG7 in Ukraine.

Keywords sustainable development management, SDG7, indicators, energy equity, environmental sustainability, energy intensity, carbon intensity, the Eastern Partnership, Ukraine

JEL Classification O10, Q01, Q40, Q58

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INTRODUCTION

In today's environment, the energy sector plays a vital role in developing most economies, overcoming existing problems, and intensifying efforts to accelerate the achievement of the Sustainable Development Goals (SDGs). In Ukraine, the situation in the energy sector has changed significantly in recent years. The regulatory framework has been significantly transformed to increase competition, and the liberalization of prices for gas and electricity has begun. Several important strategic documents aimed at transforming the energy sector have been adopted. Ukraine's ratification of the Paris Agreement on climate change has become a defining step towards the energy transition.

Given the Ukrainian energy sector situation, there is a need to analyze the readiness of Ukraine, as one of the Eastern Partnership countries, to generate sustainable and reliable energy in the context of gradual integration into the European energy sector.

It should be noted that the Sustainable Development Goals are becoming key guidelines in the development of program and forecast docu-

ments. That is why it is essential to develop a monitoring system, including data collection, and identify key indicators for collecting data. To improve energy policy development and accelerate the achievement of SDG7 "Affordable and Clean Energy," methodological approaches and the list of national monitoring indicators should somehow be aligned with those used in most European countries. In addition, they must be based on fundamental principles and internationally recognized methodological frameworks.

1. LITERATURE REVIEW

For the first time, the UN High-Level Dialogue on Energy defined a universal energy goal to be achieved in 2030: "Ensure access to affordable, reliable, sustainable and modern energy for all." (UN, 2021). To assess the ability of countries to produce sustainable energy, the World Energy Council (WEC) has developed a methodology for calculating the Energy Trilemma Index (ETI). The assessment is carried out in three main areas: energy security, energy equity, environmental sustainability, and additional area – country context (WEC, 2021).

Global energy issues and regional and international challenges, as well as the assessment of energy policies for sustainable development have been detailed in the book Global Energy Assessment: Toward a Sustainable Future (GEA Writing Team, 2012). The energy policy of the EU countries in the context of the energy transition has certain features, which are reflected by Welsch et al. (2017).

Tvaronavičienė and Ślusarczyk (2020) consider a wide range of issues related to the practical implementation of the energy transition at the level of national energy systems of European countries. Joint work is intensified to specify the National energy and climate plans (NECPs) of most European countries after the adoption of the "Fit for 55" program, which provides for a 55% reduction in CO2 emissions by 2030 (Council of the European Union, 2021).

The energy transition in the post-Soviet countries also has specific features reflected in the works of many authors, including Teleuyev et al. (2020), Resniova and Ponomarenko (2021), Baktymbet et al. (2020), Lyndiyk et al. (2020), and Salimov (2018).

Demski et al. (2017) discuss the need to prioritize accessibility as a goal of the energy transition. Policy measures to ensure the principle of "affordable energy for all" should not be limited to energy prices but should include additional considerations such as fair distribution and equality. Shyu (2021) explores the possibility of developing or implementing a right-to-energy policy to overcome energy poverty, energy inequality, and lack of energy democracy. According to Yu et al. (2022), reducing energy poverty in developing countries is a priority to achieve SDG7.

An essential challenge for Ukraine on the way to achieving the Sustainable Development Goals (SDG7) is to ensure reliable access to energy services to bridge the digital split and increase the level of digital financial inclusion (Naumenkova et al., 2019). Renn et al. (2020) summarized the experience of implementing the concept of inclusive management in the energy sector using Germany as an example.

Within the emerging European energy market, the issues of integration development have not gone unnoticed. The Central and South Eastern Europe Energy Connectivity (CESEC) was created to accelerate the integration of gas and electricity markets in Central and South-Eastern Europe. For CESEC member countries, the International Renewable Energy Agency (IRENA) has analyzed the development prospects and potential of the energy sector until 2030 (IRENA, 2020). Noteworthy is the study of energy development trends and methodological recommendations for forming a list of indicators carried out regularly by the International Energy Agency (IEA, 2020).

Ukraine's orientation towards achieving SDG7 is in the attention of the authorities and the Government of Ukraine, which is reflected in relevant documents (Cabinet of Ministers of Ukraine, 2017; OECD, 2020; UNICEF, 2020). In 2015, the Law of Ukraine on the Natural Gas Market (Verkhovna Rada of Ukraine, 2015) was adopted to increase competition and diversify energy sup-

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plies. Furthermore, on April 22, 2016, Ukraine signed the Paris Agreement (UN, 2015). The updated nationally determined contribution to the Paris Agreement set the goal of reducing greenhouse gas emissions by 2030 to 35% compared to 1990 and achieving carbon neutrality by 2060 at the latest (Verkhovna Rada of Ukraine, 2021). In addition, since 2016, Ukraine has been implementing the EU-funded energy program EU4Energy, which aims to support the Eastern Partnership countries' efforts to implement sustainable energy policies and develop the energy sector at the regional level. This program aims to reduce the negative impact of energy on the environment, further liberalizing energy markets in the region, strengthening energy security, and providing citizens of these countries with access to stable and reliable energy sources.

In 2017, the Energy Strategy of Ukraine (Cabinet of Ministers of Ukraine, 2017) was approved, focused on achieving SDG7, and containing three main stages:

- 2017–2020: Harmonization of Ukrainian natural gas and electricity markets with EU energy legislation, restructuring the coal industry, and increasing the share of renewable energy sources in the energy mix;
- 2021–2025: Modernization of the energy infrastructure and practical integration of Ukraine's energy complex into the European energy sector;
- 2026–2035: Pursuing a more holistic reform to promote sustainable development.

Of particular relevance are the issues of financing the energy transition. First, it should be noted that global investment in renewable energy and energy efficiency is set to triple by 2030 (UN, 2021). Therefore, gaining access to adequate and predictable finance is of particular importance in developing and implementing a sustainable energy policy, and access to finance and the provision of technology transfer are given priority (UN, 2021). However, Polzin and Sanders (2020) identify a qualitative mismatch between available sources and required investments for the European energy transition.

Ukraine lacks funds to develop the energy sector and accelerate the achievement of SDG7. It should be noted that the projected amount of funding for state support for energy efficiency for the next 5 years in various sectors of the economy is set at about USD 335 million, which is not enough to overcome these problems. The establishment of the Decarbonization Fund is also envisaged, which should be an additional source of annual funding for energy efficiency measures of more than USD 35 million. It is planned to replenish this fund by attracting contributions from the payment of the CO2 emission tax (SAEE, 2021). Given the limited financial capacity, it is becoming increasingly essential to activate the MTM credit channel (Mishchenko et al., 2021) to more actively involve banks and other financial institutions to financing energy projects and developing climate finance markets (Eceiza et al., 2020).

2. AIMS AND METHODS

The paper aims to investigate Ukraine's readiness to provide sustainable energy generation and expand the list of indicators used in Ukraine to monitor the implementation of SDG7 "Affordable and Clean Energy."

Considering the methodological basis of the study, the paper primarily proceeded from the fact that the information base and indicators for monitoring the achievement of SDG7 at the national level should be formed, taking into account the Energy Strategy of Ukraine and the direction of economic development.

Secondly, indicators for monitoring the achievement of SDG7 should be based on the same principles and methodological approaches, be adapted for use in official practice, and allow for international comparisons.

Thirdly, it is crucial to develop a list of indicators to reflect social, economic, and environmental indicators of SDG7. The expansion of the information base provides an opportunity to analyze long-term dynamics and form more informed decisions.

Ukraine's readiness to produce affordable, reliable, and sustainable energy was assessed following the

methodology for preparing reports on monitoring the achievement of the Sustainable Development Goals in Ukraine, the methodology for analyzing energy balance and calculating energy indicators for sustainable development in accordance with IAEA, IEA, and WEC. The analysis also used the WEC methodological approaches underlying the Energy Trilemma Index (ETI) (WEC, 2021).

Thus, it is vital to ensure methodological unity when developing indicators for monitoring the achievement of SDG7 and forecast energy balances. With this in mind, the study considered it appropriate to follow the International Atomic Energy Agency's methodology in developing sustainable energy policies and creating an expanded list of indicators for monitoring the energy transition (IAEA, 2005).

In the analysis process, economic and statistical methods were used introducing data from state statistical observations within the framework of the official statistical system. As a result, Ukraine's readiness to implement a sustainable energy policy compared to the EU and other Eastern Partnership countries was assessed based on IAEA energy statistics, the State Statistics Service of Ukraine, the World Energy Council (WEC), and the International Energy Agency (IEA).

3. RESULTS AND DISCUSSION

The focus on achieving SDG7 is directly linked to the success of the energy sector. The Energy Trilemma Index (ETI) is used by the World Energy Council (WEC) for a comprehensive assessment of a country's energy policy (WEC, 2021). This index's ranking is based on 31 indicators calculated by relevant categories. The ETI value for each country is calculated as a weighted average for each parameter. The highest score reaches 100. The country's highest balance grade is AAAa, the lowest – DDDd. The first letter characterizes energy security, the second is energy equity, the third is environmental sustainability, and the fourth is the country context.

According to the data obtained, the values of the Energy Trilemma Index for Ukraine and most of the Eastern Partnership countries are lower than the economically advanced countries (Figure 1).

It should be noted that the methodology for calculating this index has changed. Thus, the list of balance grades is supplemented by another one that considers the country context. In addition, sub-indicators are added. They characterize macroeconomic stability, management efficiency, political stability, the country's attractiveness for investors, intellectual property protection, innovation potential, etc. These sub-indicators have a significant impact on the overall score for countries with fragile economies. Unfortunately, among the Eastern Partnership countries, Ukraine received the lowest score (d) in this dimension (Figure 1).

It is advisable to pay attention to the debatable methodological approaches to calculating ETI. Thus, Song et al. (2017) suggested "a stochastic multicriteria acceptability analysis to present a holistic measurement of the country-specific energy performance." Suggestions for improving the methodology for calculating ETI are reflected by Asbahi et al. (2019). However, the study also drew attention to the conclusions of Šprajc et al. (2019) that ETI cannot be considered reliable due to some shortcomings, including certain political overtones. In addition, some methodological uncertainty suggests caution when making comparative analyses and substantiating conclusions on short-term time intervals.

Assessing the progress in achieving the SDG7 in Ukraine, it should be noted that electricity generation for the period 2015–2020 decreased from 157.7 to 148.9 billion kWh, which is a threatening trend. In addition, the instability of the economic and political situation after the collapse of the USSR increased internal and external risks. Inefficient public administration led to adverse changes in the energy sector, increasing the country's energy dependence. This led to the use of the indicator in Ukraine's monitoring reports on the achievement of the SDGs, which determines the maximum share of imported primary energy resources (except nuclear fuel) from one country (company) in total supply (imports), % (Figure 2).

It should be noted that Ukraine is a traditional transit country for primary energy sources and has significant hydrocarbon production. However, only 65% of total energy demand is covered by do-

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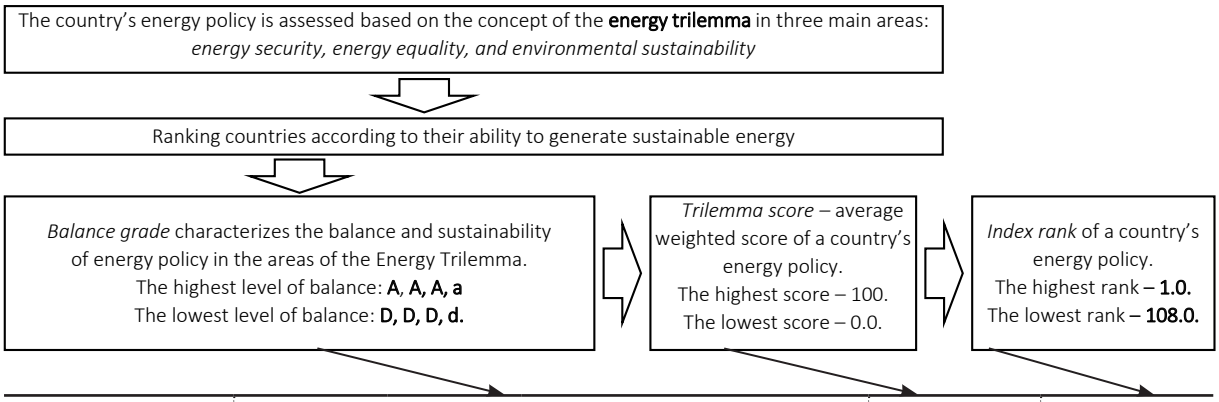
Source: Elaborated by the authors based on WEC (2021).



Country	Balance grade				Trilemma score	Index rank
	Energy security	Energy equity	Environmental sustainability	Context country		
EU countries with the highest level of energy policy balance: AAAa						
Sweden	A	A	A	a	84.2	1
Denmark	A	A	A	a	83.0	3
Finland	A	A	A	a	81.7	4
Austria	A	A	A	a	81.0	5
France	A	A	A	a	81.1	5
Germany	A	A	A	a	80.4	7
Other EU countries						
Luxembourg	C	A	A	a	76.9	10
Spain	A	B	A	a	76.9	10
Ireland	C	A	A	a	76.8	11
Belgium	B	A	A	a	76.3	12
Hungary	A	B	B	b	76.2	12
Lithuania	B	B	A	a	75.7	14
Portugal	B	B	A	a	75.6	14
Italy	A	B	A	b	75.4	15
Netherlands	B	A	B	a	75.3	16
Slovenia	A	B	A	a	74.9	17
Czech Republic	A	B	B	a	74.4	19
Estonia	A	B	B	a	73.9	20
Latvia	A	B	B	a	73.9	20
Malta	D	A	A	a	73.8	21
Romania	A	B	A	b	73.7	21
Slovakia	A	B	A	b	73.6	22
Croatia	A	B	A	b	73.4	23
Bulgaria	A	B	B	b	73,0	24
Poland	B	B	C	b	70.4	30
Greece	C	B	A	c	68.1	39
Cyprus	D	A	B	a	66.7	42
Eastern Partnership countries						
Azerbaijan	A	B	C	c	68.2	39
Ukraine	**A**	**C**	**B**	**d**	**66.5**	**43**
Georgia	C	C	B	b	66.2	44
Armenia	C	C	B	c	62.7	53
Moldova	D	C	D	c	56.5	68

Figure 1. Energy Trilemma Index of the EU and Eastern Partnership countries

Source: Elaborated based on the State Statistics Service of Ukraine (n.d.).

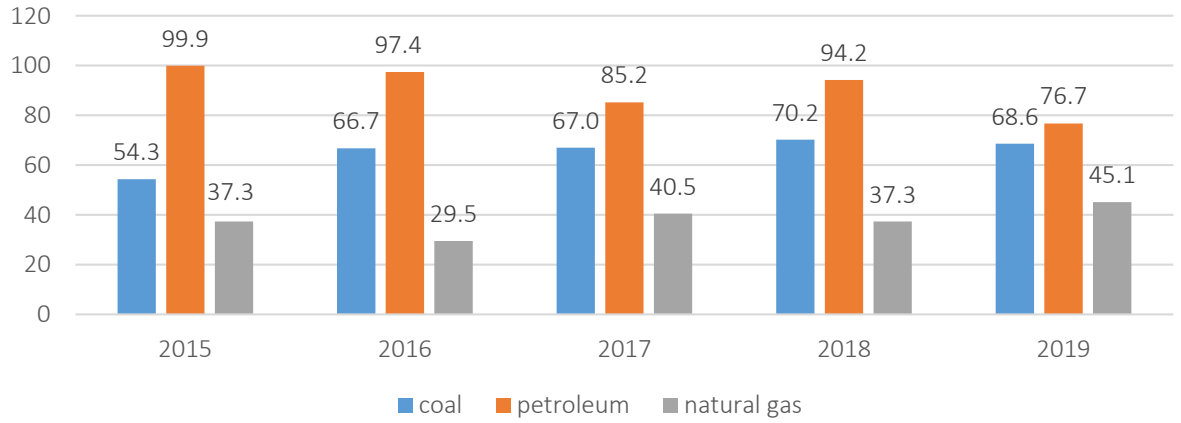


Figure 2. Maximum share of imported primary energy in Ukraine, %

mestic production (IEA, 2020). The total primary energy supply (TPES) has decreased by almost 45% over the past ten years (OECD, 2020).

A comparative analysis of the structure of power generation sources in the world, EU countries, and Ukraine shows that the share of low-carbon power generation sources in Ukraine in 2020 was 61.3%, exceeding the value of this indicator for EU countries by 56.7% (Table 1).

This is primarily because, in Ukraine, more than half of the electricity is produced at nuclear power plants (Figure 3). The task of actively using renewable energy sources requires a certain balance and sequence of actions, given the structure of the Ukrainian economy and the need for energy supply on a stable basis. With that in mind, it is advisable to pay attention to the structure of power generation sources in Ukraine (Figure 3).

Thus, in 2020, Ukrainian nuclear power plants generated almost 53.6% of electricity. In the EU, this share was 25.7% in 2020, in the world – 10.3% (according to the latest 2019 data). On the other hand, the share of renewable sources in the production of electricity in Ukraine for 1990–2020 increased from 1.4 to 7.2%. Thus, in transforming Ukraine's energy policy, given the achievement of SDG7, an important task is to maintain the safe operation of nuclear energy and effectively reform the coal industry, since the share of these industries in electricity generation is almost 85%.

An essential step in concretizing tasks for monitoring the achievement of SDG7 is to identify dominant sectors in terms of energy consumption, which allows more accurately determining the direction of actions for energy saving and energy efficiency.

Figure 4 shows that energy consumption in the world in 1990–2019 continued to grow in almost all sectors, but industry and transport remained a priority.

On the contrary, in the EU countries, energy consumption in the industry over the analyzed period decreased by 24.3%, but the volume of energy consumption in transport increased by 27.7%. On the

Table 1. Share of renewables, low-carbon sources, and fossil fuels in power generation, %

Source: Compiled according to IEA (2019).

Electricity generation by source	World		European Union-28		Ukraine	
	1990	2019*	1990	2020	1990	2020
Renewables	14.5	23.2	10.0	36.9	1.4	7.2
Low carbon sources	27.0	32.2	34.1	56.7	11.2	61.3
Coal	35.5	37.8	44.3	14.2	15.3	30.4
Oil	12.5	2.8	10.7	1.8	16.2	0.3
Gas	24.6	25.9	10.4	24.7	57.4	8.0

Note: * – latest data.

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Source: Elaborated by the authors according to IEA (2019).

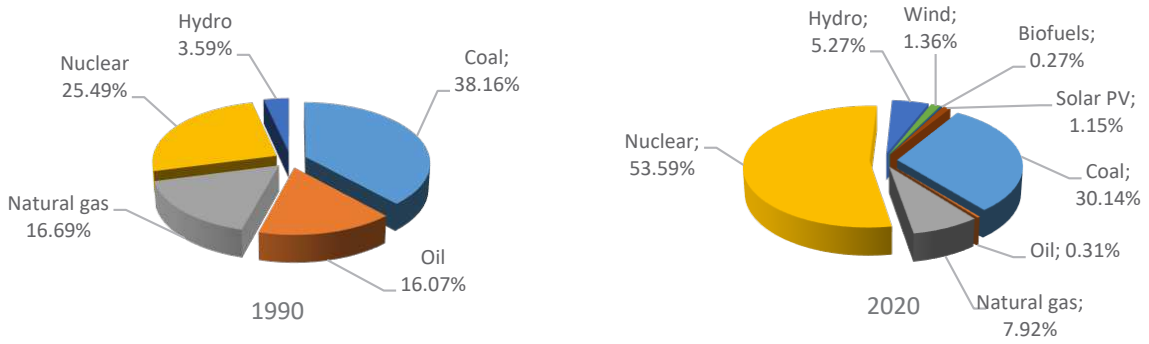
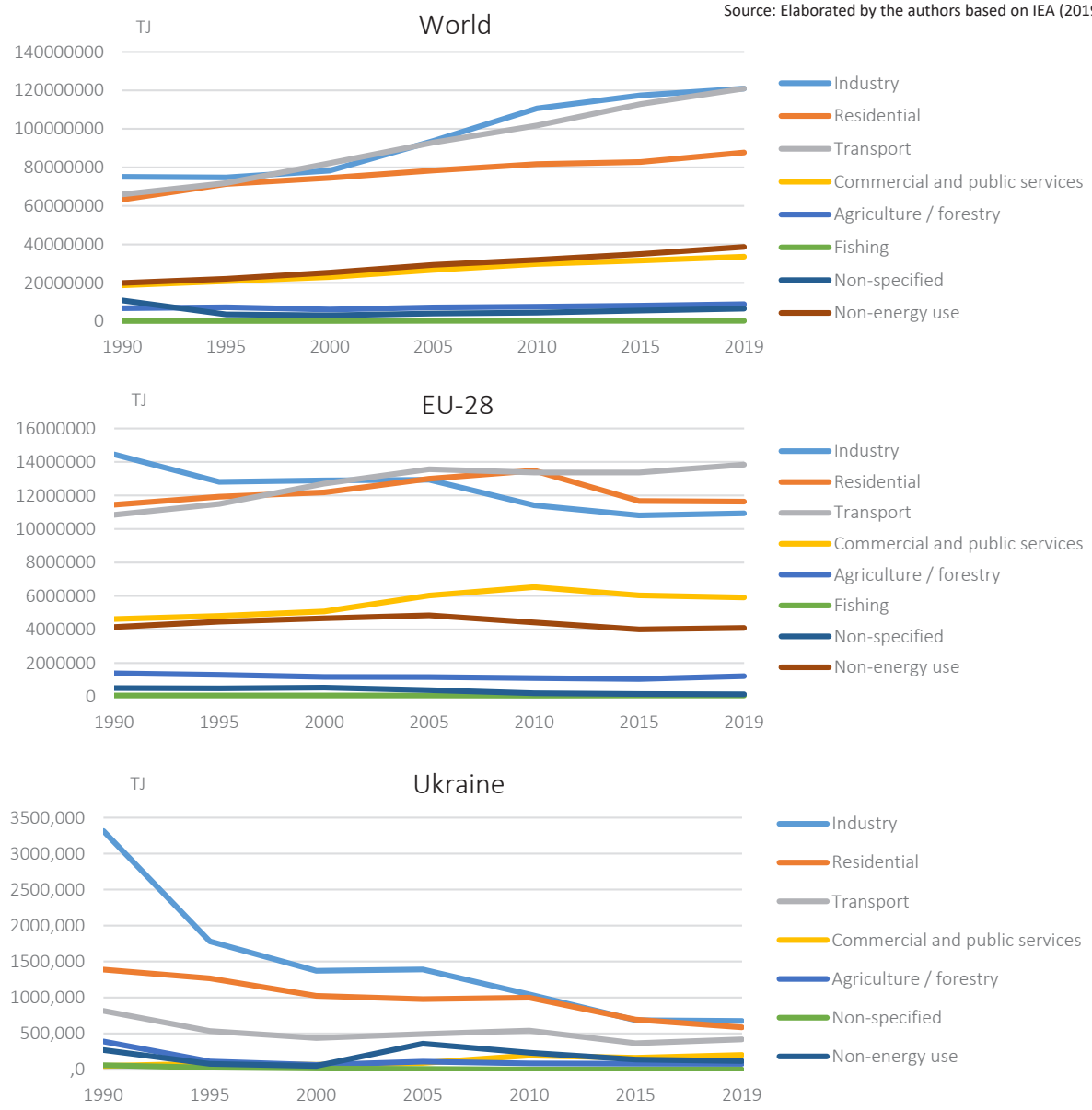


Figure 3. Power generation by source in Ukraine in 1990 and 2020, %

Source: Elaborated by the authors based on IEA (2019).



Note: 1TJ = 10^{12}J.

Figure 4. Total final energy consumption by sector in the world, European Union-2 8 and Ukraine in 1990–2019, TJ

Source: Elaborated by the authors based on IEA (2019).

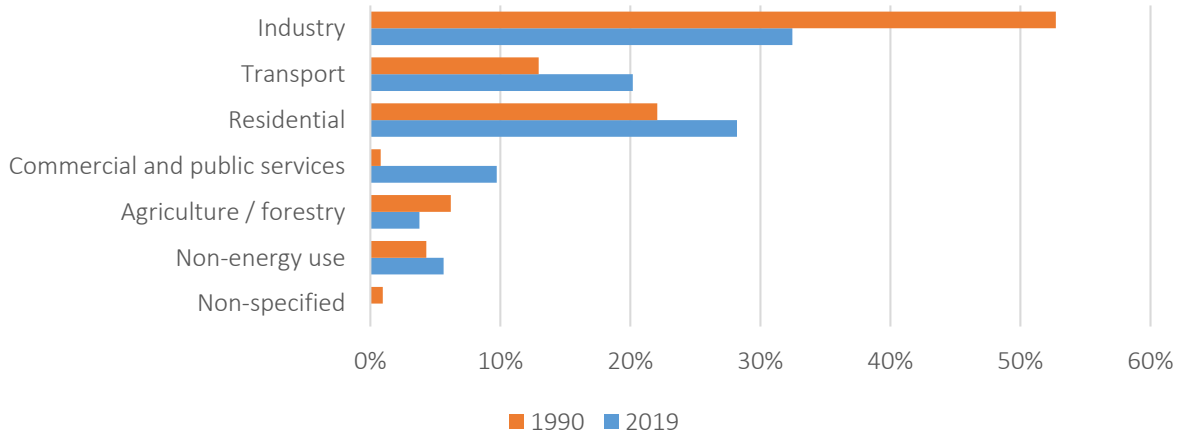


Figure 5. Share of total final energy consumption by sector in Ukraine in 1990–2019, %

other hand, in the EU housing sector, energy consumption decreased by 13.7% from 2010 to 2019.

The situation in Ukraine was characterized by a rapid and avalanche-like reduction in energy consumption – by 66.9% over 1990–2019. Energy consumption in industry decreased by 4.9 times, in transport – almost twice. These changes have a negative connotation and indicate the activation of deindustrialization processes. Therefore, for 1990–2019, the share of industry in total final energy consumption decreased from 52.7% to 32.5%, the share of industries such as transport and housing services increased. The share of agriculture and forestry in the structure of final energy consumption in the analyzed period ranged from 3.8% to 6.2%, which characterizes the raw material orientation of the development of these industries with a low level of product processing (Figure 5).

An important indicator of achieving SDG7 is energy intensity, calculated as the ratio of annual energy use by the country's economy (in different measurement units) to the values of macroeconomic indicators such as GDP or population. Thus, in 2019, the energy intensity of the world economy was estimated at 4.77 GJ/1000 USD (or 0.11 toe/1000 USD 2015 PPP), EU countries – 3.06 GJ/1000 USD, or 0.07 toe/1000 USD 2015 PPP (Figure 6).

For the period 1990–2019 in Ukraine, the value of the GDP energy intensity indicator (Total energy supply (TES) by GDP (PPP)) almost halved: from 14.27 to 7.68 GJ/1000 USD 2015 PPP, or in tons of oil equivalent: from 0.34 to 0.18 toe/1000 USD 2015 PPP (Figure 6). For comparison, this value is 2.5 times higher than the value of the same indicator for the EU and 1.6 for the global economy. It should be noted that the Energy Strategy of

Source: Elaborated by the authors based on IEA (2019).

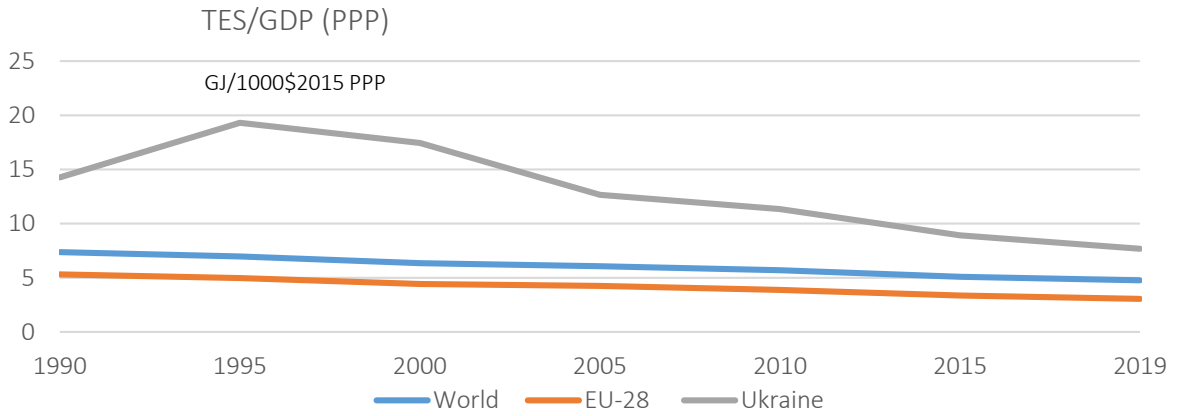


Figure 6. Total energy supply by GDP (PPP) (1990–2019)

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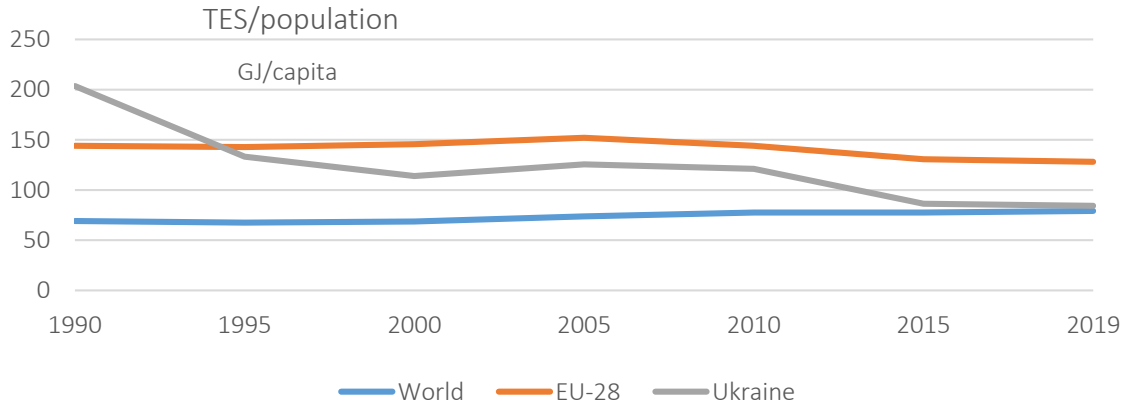

Figure 7. Total energy supply (TES) per capita (1990–2019)

Ukraine until 2035 (ESU-35) provides for a reduction in the GDP energy intensity to 0.13 toe/1000 USD 2015 PPP.

Energy intensity per capita in Ukraine for the period 1990–2019 also decreased from 203.48 to 84.15 GJ/capita, or from 4.86 to 2.01 toe/capita, despite the intensification of migration processes and the decline in the country's population, reflecting the growing negative changes in the structure of the economy. For the EU countries, the value of this indicator in 2019 was 128.12 GJ/capita (or 3.06 toe/capita) (Figure 7).

On the one hand, the high level of energy intensity of GDP is due to the economy's structure with a high share of resource-intensive and energy-intensive industries such as metallurgy, chemicals, and mining. At the same time, low energy efficiency in the energy conversion and power supply sectors and high specific energy costs for households' heating and hot water supply are the reason for low energy efficiency compared to other countries.

The main factors determining the low level of energy efficiency in Ukraine are:

- a high share of energy-intensive low-tech sectors of the economy;
- growth in energy consumption without a significant increase in the share of gross value added in the output of products and services;
- violation of the market balance between various types of energy resources and energy sources;
- unsatisfactory technical condition of Ukraine's energy sector, depreciation of most of the generating assets and power supply networks;
- lack of incentives in fiscal and monetary regulation in the implementation of long-term targeted investment projects and programs in the energy sector.

Given the integration of the Ukrainian energy market with the EU energy market, the implementation of energy efficiency programs is an essential direction in Ukraine's energy policy, as evidenced by the National Energy Efficiency Action Plan (NEEAP) through 2030. According to this plan, by 2030, primary energy consumption is expected to decrease by 22.3% and final consumption by 17.1% relative to the baseline scenario for developing the economy and the energy system (Business-as-usual). It was determined that the primary and final energy consumption in Ukraine should not exceed 91.5 million and 50.5 million tons of oil equivalent (toe) (Government Portal, 2021).

To achieve this goal, a number of sectoral and intersectoral measures to improve energy efficiency are envisaged.

The deterioration of the situation in the real sector of the Ukrainian economy, the growth of macro risks, and limited financial opportunities hinder the introduction of energy-efficient technologies in the real sector.

Source: Elaborated by the authors based on IEA (2019).

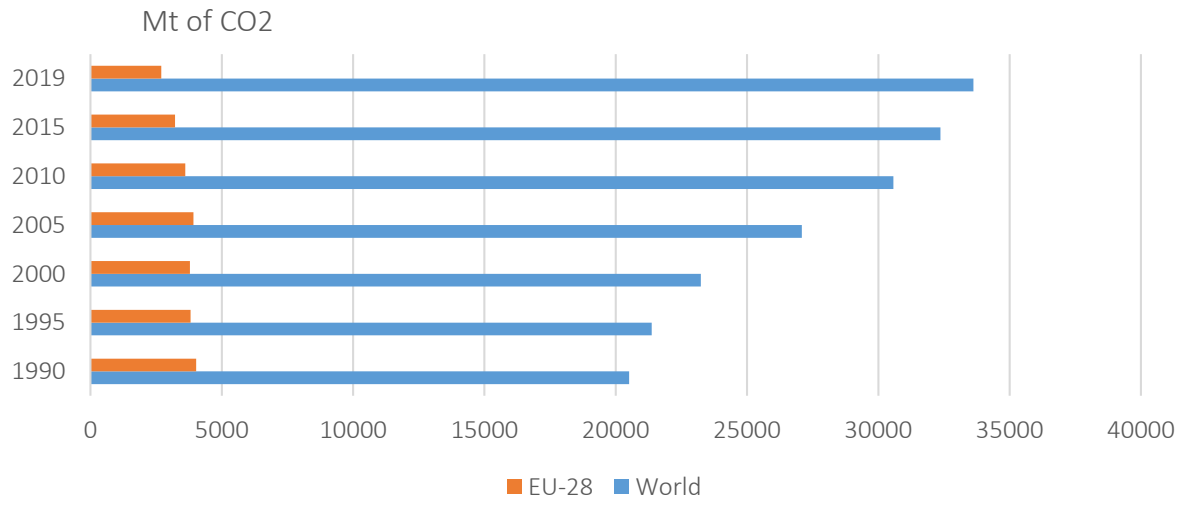

Figure 8. Total CO2 emissions, 1990–2020

In this context, the focus is on the differences between "energy efficiency" and "energy saving."

Thus, energy saving is seen as limiting or reducing energy consumption based on changes in the lifestyle and behavior of consumers. Sometimes a reduction in energy consumption can be achieved through limited access to modern energy sources. The forms of such coercive restrictions are the introduction of rolling blackouts, the establishment of exorbitant tariffs, and the absence and underdevelopment of energy infrastructure. That is why energy efficiency targets should be in line with other current SDG7 targets, such as universal access to stable and affordable energy sources, prudent energy pricing, and tariff policies.

Unlike energy saving, energy efficiency manifests itself in limiting or reducing energy consumption by using more efficient appliances, technologies, and systems. However, energy efficiency measures should be implemented primarily in sectors where value is added. Given this, the list of SDG7 energy indicators from the Energy Intensities group should include indicators that characterize energy consumption per unit of value added.

In the context of the transition to carbon-free energy systems, monitoring of CO2 emissions requires special attention. Therefore, on July 1, 2021, the second phase of the EU4Energy program was launched – Promoting the Clean Energy Transition in the Eastern Partnership Countries. It will last until June 30, 2025, and is designed for six countries of the EU's Eastern Partnership, including Ukraine, Armenia, Azerbaijan, Belarus, Georgia, and Moldova.

This program aims to reduce the negative impact of energy on the environment, further liberalizing energy markets in the region, strengthening energy security, and providing citizens of these countries with access to stable and reliable energy sources.

It should be noted that, despite the declared determination of the world to decarbonize the economy, the situation, unfortunately, does not add optimism. The total CO2 emissions in the world over the past thirty years have increased more than 1.64 times: from 20,511.13 to 33,621.53 million tons of CO2 (Figure 8). In this regard, the example of the EU countries is noteworthy, where the total CO2 emissions for the period 1990–2020 decreased by 33%.

Among the Eastern Partnership countries, Ukraine leads in total CO2 emissions – more than 162.4 million tons (Mt) as of 2020. However, the use of absolute indicators in the process of monitoring actions to accelerate the achievement of SDG7 is not correct since it is necessary to take into account economic characteristics, climatic conditions, country size, population, economic structure, etc.

For a comparative analysis of the results of decarbonization, it is advisable to pay attention to the

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Source: Compiled based on IEA (2019).

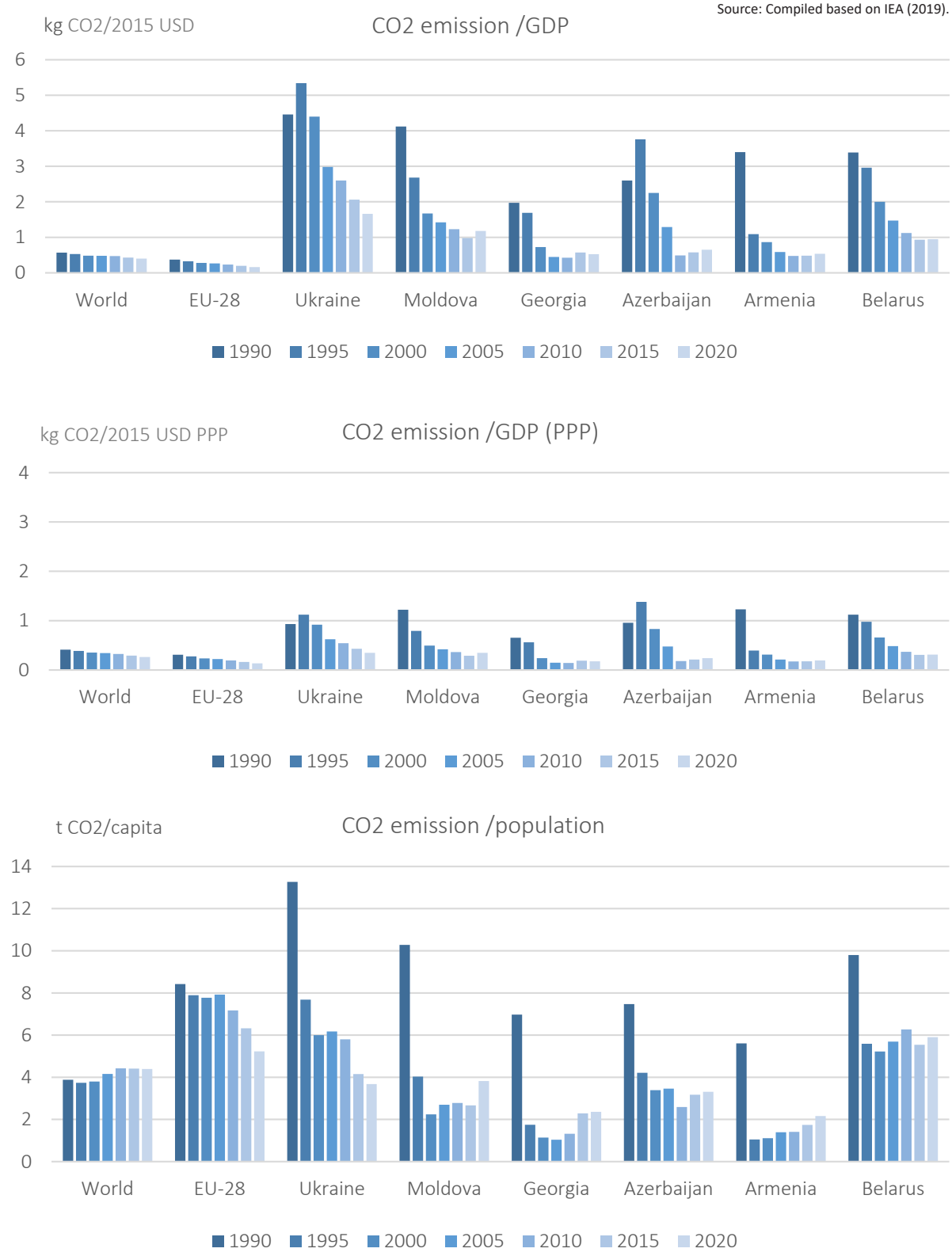
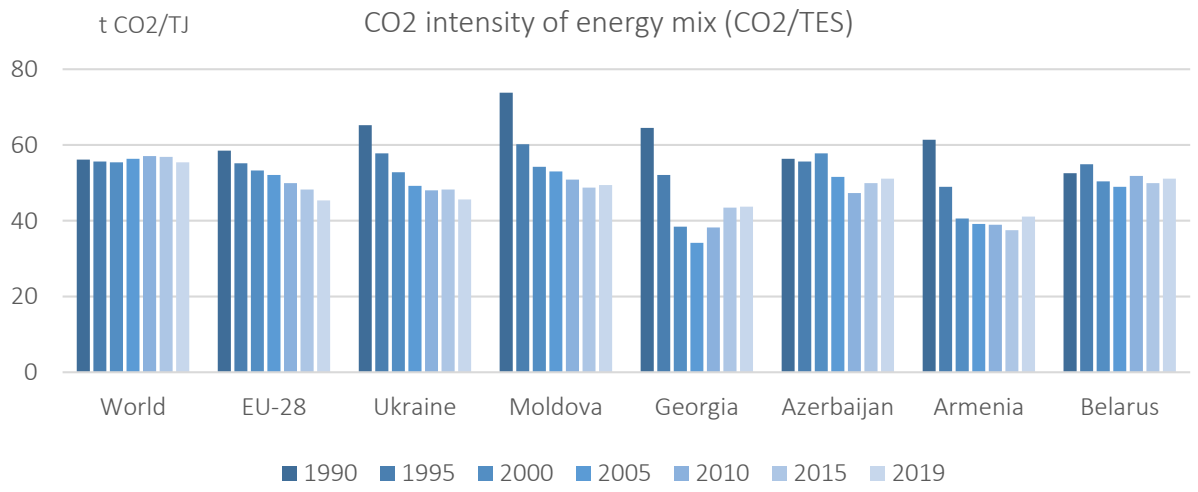


Figure 9. Carbon intensity in the world, European Union, and the countries of the EU's Eastern Partnership, 1990–2020

values of CO2 emission intensity (carbon intensity). A significant reduction in CO2 emissions in the Eastern Partnership countries occurred after the collapse of the USSR, the aggravation of the crisis after the break of economic ties, and changes in the economy's structure (Figure 9).



Note: CO2 emissions from fuel combustion only, tCO2/TJ (1TJ = 1012J); TES – Total Energy Supply.

Figure 10. CO2 intensity of energy mix (CO2/TES), 1990–2019

However, some features of these indicators should be noted. Thus, using the indicator of CO2 emissions per unit of GDP, taking into account purchasing power parity (CO2 emissions per unit of GDP (PPP)) leads to a significant decrease in the results. For example, in 2020 in Ukraine, CO2 emissions per unit of GDP without adjustment and with adjustment of purchasing power parity values differed by 4.8 times: 1.66 kg CO2/USD versus 0.35 kg CO2/USD PPP. Thus, there is a significant distortion of results for countries with unstable currencies. Therefore, there are questions about choosing a date for PPP (different years are used) and the currency (dollar, euro).

Another indicator of the intensity of CO2 emissions per capita (CO2 emission/population) is not without certain drawbacks. Given the intensification of migration processes, the lack of accurate population data, or the presence of territorial conflicts, the use of this indicator has certain limitations.

Among monitoring indicators, the indicator of CO2 emissions per unit of energy (CO2 intensity of energy mix (CO2/TES)) deserves attention as it does not contain a cost component and more accurately reflects environmental friendliness and manufacturability of the country's energy balance (Figure 10). Furthermore, when calculating this indicator, data on the supply of all fuel types, including solid biofuels, are taken into account.

Equally important is the analysis of emissions from final energy consumption. It allows determining which industries and end uses are the most environmentally damaging and are the main contributors to CO2 emissions. Changes in the sectoral structure of CO2 emissions for 1990–2019 in the global economy, the EU countries, and Ukraine are analyzed (Table 2).

Thus, in 2019, the most significant volumes of CO2 emissions globally (41.8%) are due to power and heat production. In Ukraine, the share of CO2 emissions from heat and power generation in 2019 amounted to 47.1%. From 1990 to 2019, the share of industrial enterprises in total CO2 emissions in Ukraine decreased from 28.3% to 20.59%. Noteworthy is the significant increase in CO2 emissions from transport in the EU – up to 32% in 2019. In Ukraine, the share of transport in total CO2 emissions increased from 8% to almost 16% for 1990–2019. Given this negative trend, it is advisable to impose restrictions on the operation in Ukraine of old cars from the EU countries.

Renewable energy transition programs are critical to transforming the energy sector to accelerate the achievement of SDGs. In the EU countries, the volume of electricity generation based on renewable energy sources is increasing, which requires certain coordination actions for the Eastern Partnership countries within the emerging single energy market.

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Table 2. CO2 emissions by sector, %

Source: Calculated based on IEA (2019).

Sector	World		EU-28		Ukraine	
	1990	2019	1990	2019	1990	2019
Electricity and heat producers	37.16	41.84	38.17	30.77	48.33	47.06
Other energy industries	4.73	5.04	4.40	5.48	3.48	1.76
Industry	19.28	18.60	18.56	13.20	28.30	20.59
Transport	22.48	24.45	18.84	31.14	7.98	15.88
Residential	8.93	5.86	12.33	12.20	7.55	10.00
Commercial and public services	3.73	2.45	4.97	4.74	0.44	2.35
Agriculture	1.94	1.21	1.99	2.07	3.19	2.35
Fishing	0.09	0.06	0.10	0.13	0.00	0.00
Final consumption not elsewhere specified	1.66	0.48	0.65	0.27	0.73	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

It should be noted that the national SDG7 system consists of national development targets. Thus, according to the monitoring report for 2020, the following main tasks for achieving SDG7 were identified:

- "7.1. Expand the infrastructure and modernize networks for reliable and sustainable energy supply by introducing innovative technologies.
- 7.2. Ensure diversification of the supply of primary energy resources.
- 7.3. Increase the share of renewable energy in the national energy balance, particularly by introducing additional capacities at facilities that produce energy from renewable sources.
- 7.4. Increase the energy efficiency of the economy" (UNICEF, 2020).

It should be noted that the focus of the tasks and the list of indicators for monitoring the achievement of SDG7 in Ukraine are pretty limited. This primarily concerns monitoring tasks related to energy availability, energy efficiency, and environmental impact. Given the tense situation in the Ukrainian energy sector, the study proposes to expand the list of national monitoring indicators that more fully reflect the social, economic, and environmental aspects in line with the focus on SDG7 (Table 3).

When compiling annual monitoring reports, the methodological approaches and the list of indicators should be comparable to those used in most European countries.

Based on the results of the study, the following conclusions were made, and some recommendations for policy-makers were proposed. First, in Ukraine, the assessment of SDG7 progress is based on a limited list of objectives and only seven indicators, which does not allow a comprehensive assessment of the economic, social, and environmental consequences of energy policy implementation. Therefore, the study proposes to adjust the priority of tasks and significantly expand the list of SDG7 monitoring indicators.

Second, it is highly recommended to implement indicators to monitor access to stable and reliable energy sources for both the population and real sector enterprises (business). Furthermore, it is expedient to develop threshold values for energy availability indicators to protect the most socially vulnerable groups.

Third, to assess the results aimed at improving energy efficiency, it is proposed to use indicators that characterize energy consumption per unit of value added in various sectors of the economy of Ukraine. And finally, CO_2/TES (CO_2 intensity of energy mix) is a more accurate indicator for monitoring decarbonization results in countries with fragile economies. This indicator does not contain a cost component and more accurately reflects the environmental component of the SDG7 achievement.

The development of monitoring requires appropriate coordination of work related to metadata development, determination of the bodies responsible for the calculation, clarification of deadlines for data submission to the State Statistics Service of Ukraine.

Table 3. Main indicators that are used and can be used in Ukraine to monitor the achievement of SDG7 "Affordable and Clean Energy"

Source: Developed by the authors based on the IEA recommendations and the State Statistics Service of Ukraine (n.d.).

Dimension	The list of monitoring indicators for SDG7		Target/fact (2020)
Social dimension	Equity	**Affordability:** share of annual household income spent on electricity (and separately – for poorest 20% of the population)	Not used in Ukraine
		Disparities: household energy use for each income group (quintiles)	
		Access to "modern" energy: household "modern" energy use for each income group	
Economic dimension	Energy production	**Generation of power (7.1.1)**, total (including power generating companies of TPP, CHPP, HPS, HAPP, NPP, Block stations, alternative energy sources (WPP, SPP, Biomass), billions KWh	163.8/148.9
		Reserves-to-production ratio: proven recoverable reserves/total energy production	Not used in Ukraine
		Resources-to-production ratio: total estimated resources/total energy production	
	Supply efficiency	Efficiency of energy conversion and distribution: electric power distribution losses, % (7.1.2) heat losses in heat networks, % (7.1.3)	11.0/10.13 - /20.4
	Energy use	Energy use per capita: total primary energy supply (TPES)/total population; total final consumption (TFC)/total population; electricity use/total population	Not used in Ukraine
		Energy use per unit of GDP: primary energy consumption/GDP; kg oe/USD PPP2011 **(7.4.1)**	0.167
	Energy intensities	**Industrial sector:** energy use in industrial sector/value added	Not used in Ukraine
		Agricultural sector: energy use in agricultural sector/value added	
		Service (commercial) sector: energy use in service sector/value added	
		Transport: energy use in passenger travel and freight sectors /passenger-km travel and tonne-km freight	
	Energy diversification	**Fuel** shares in energy and electricity, %	Not used in Ukraine
		Non-carbon energy share in energy and electricity, %	
		Renewable energy share in total final energy consumption, % **(7.3.1)**	11.0/9.2
	Energy prices	End-use energy prices by fuel; and by sector End-use energy prices by sector (with and without tax/subsidy)	not used in Ukraine
	Energy security	**Energy dependency:** maximum share of imported primary energy (excluding nuclear fuel) from one country(company) in the total supply (imports), %; **(7.2.1)** share of one supplier of the nuclear fuel market, % **(7.2.2)**	15.0 < 70.0/53.8
		Net energy import dependency: energy imports/total primary energy supply	Not used in Ukraine
		Strategic Fuel Stocks: stocks of critical fuel (e.g., oil, gas)/critical fuel consumption	
Environmental dimension	Climate change	**GHG emissions:** GHG emissions from energy production and use per capita; GHG emissions from energy production and use per unit of GDP. Carbon Intensity: CO2 intensity of energy mix (CO2/TES); CO2 emissions per unit of GDP (PPP); CO2 emissions per unit of GDP; CO2 emission/population	Not used in Ukraine
	Forest	**Rate of deforestation attributed to energy use:** forest area at two different times/ biomass utilization	Not used in Ukraine
	Solid waste management	Ratio of solid waste adequately disposed to total generated solid waste, %	Not used in Ukraine

Data collection for monitoring the achievement of SDG7 based on the use of the proposed extended list of indicators remains a controversial issue. Unfortunately, there may be questions about the reliability of the measurement, given the existing information base in Ukraine.

In addition, in the emerging integrated energy sector, the gradual institutional integration of Ukraine into the European Network of Transmission System Operators for Gas (ENTSO-G) and the European Network of Transmission System Operators for Electricity (ENTSO-E), tasks in specific areas should also be harmonized.

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CONCLUSION

Given the challenging situation that has arisen in the Ukrainian energy sector, the issue of achieving SDG7 "Affordable and Clean Energy" is of paramount importance. Therefore, the tasks of forming an appropriate institutional architecture, coordination mechanisms, and building a monitoring system are being updated. Given this, prioritizing actions and expanding indicators for monitoring the achievement of SDG7 to accelerate the energy transition and reform the energy sector deserves special attention.

The methodology for monitoring actions to achieve SDG7 is based on principles and approaches that are largely comparable to the WEA methodology, which is the basis for building the World Energy Trilemma Index. However, there are some differences, including those on the list of indicators. Note that when compiling national monitoring reports, the list of targets and indicators for achieving SDG7 may differ, complicating a comparative analysis of the progress made by different countries and may affect the soundness of the results.

Ukraine remains one of the least energy-efficient countries that needs to expand the list of indicators for monitoring energy use per unit of value added in various sectors of the Ukrainian economy. It emphasizes the inadmissibility of forcibly restricting access to modern energy and recommends expanding the list of indicators and targets that characterize energy availability, especially for the most vulnerable groups. The study compares carbon intensity indicators in the EU, the Eastern Partnership countries, and Ukraine. Finally, it formulates recommendations for using these indicators in countries with fragile economies.

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Visualization: Svitlana Mishchenko.
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