ENERGY SECURITY OF UKRAINE IN TERMS OF RUSSIAN AGGRESSION

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Abstract. *Energy security is a key component of economic growth and sustainable development. Russian invasion of Ukraine in February 2022 and following energy crisis over Europe revealed significant dependence of European states, including Ukraine from Russian energy resources. Current strategy of the EU on total replacement of Russian energy supplies and accelerated implementation of renewables, being challenging now, lead to energy security of Europe in long term. Ukraine currently are meeting all burdens of the war, including thousands killed people and millions of refugees, ruined infrastructure and occupied territories. National energy security is one of many challenges for the country. Strong international support, national integrity and determination are key elements for both Ukrainian victory and postwar rebuilding of the country. Following the EU strategy, Ukraine needs urgent transformation of its energy sector in sustainable way, e.g., Ukraine has a huge potential in bioresources, including biogas / biomethane production being one of the largest producers of agricultural crops in the world.*

DOI: 10.24263/EDSD-2023-5-4

Introduction. Energy security is one of key components of economic growth and sustainable development. During last decades, the European Union made significant efforts for transition of its energy sector to sustainable renewables-based and climate-neutral trend. But Russian invasion of Ukraine in February 2022 and following energy crisis over Europe revealed dangerously significant dependence of most European states, including Ukraine, from Russian energy resources. Current strategy of the EU on total replacement of Russian energy supplies and accelerated implementation of renewables being challenging now lead to energy security of Europe in long term. Ukraine currently are meeting all burdens of the war, including thousands killed people and millions of refugees, ruined infrastructure and occupied territories. National energy security is one of many challenges for the country.

Energy security is the protection of national interests in the field of ensuring access to reliable, sustainable, affordable and modern sources of energy in a technically reliable, safe, economically efficient and ecologically acceptable way in normal conditions and in a special or emergency state (CMU, 2021b). This is a definition of energy security from Ukrainian government's Strategy of Energy Security before the Russian war in Ukraine. Obviously, the sustainability and environmental issues are important parts of long-term national enerhy security strategy. But we should agree, that in times of energy, social, and political crises the demands for sustainable development may go beyond the paradigm of the ideology of securitization (Żuk and Żuk, 2022). Thus, the sustainability may be

compromised, at least in short term, by urgent demands for the nations in available energy resources. And today's urgent needs for most European countries to replace Russian gas and oil by more reliable alternatives force the nations search other options, including, e.g., returning to coal, which is obviously not the environmentally friendly choice. On the other hand, current energy crisis over the Europe due to Russian invasion of Ukraine may accelerate the transition of the EU to renewables, and change the situation in long term. For example, significant part of recent REPowerEU strategy of the European Commission to cope the EU dependence on Russian gas involves renewables (EC, 2022). And the first reactions of the German government to the possible energy crisis caused by the Russian war in Ukraine indicate that this war is accelerating the deadline for achieving full renewable energy supplies from 2050 to 2035 (Żuk and Żuk, 2022).

Ukraine is becoming an integral part of European Union community, which means Ukraine may and should be a part of energy sector of the EU, sharing all challenges and approaches of the EU for its energy security. On the other hand, Ukraine has to work hard to solve its energy problems and collaborate with other European countries to solve the energy problems of Europe in general.

In this article, we analyze the energy security for Ukraine in terms of the Russian war against Ukraine, and effective strategies, which may be applied.

Energy security of the European Union

The European Union is a global leader in the sustainable development and in climate change fighting. In terms of this strategy, among other priorities, the EU was determined to reach 20% renewables in total energy mix of the Union in 2020 (EC, 2010). The goal was achieved as in 2020 renewable energy represented 22.1% of energy consumed in the EU (Eurostat, 2022). Further climate / energy goals of the EU were set in the European Green Deal (EC, 2019) and in Fit for 55 Communication (EC, 2021), including, e.g., 40% of renewables in the EU energy mix in 2030. While renewables were a priority for the EU during many years in terms of global warming, restriction of dependence of the Union on Russian energy supplies also implied.

Meanwhile for Europe Russian gas was cheaper than from other sources (it was one of Putin's geopolitical tricks), and European countries, particularly Germany only increased their dependence on Russia's energy supplies during last years. This resulted in more than half share of Russian gas in natural gas imports in many EU member states (Korteweg, 2018).

But open Russian aggression against Ukraine became a real game changer for most European leaders and for the European community. Just in a few days after the beginning of the war, the European Commission issued the communication on energy security of the EU member states REPowerEU, increasing the level of demands (EC, 2022). The communication has a clear purpose to solve the problem of energy dependence of the EU on Russia as soon as possible.

The communication proposes a detailed list of actions, which could decrease the EU demands in Russian gas by two third to the end of the 2022 and totally refuse Russian gas imports by 2030. It is the most radical plan in energy security of the EU that needs many efforts and coordinated activities of the EU member states and their partners. According to the document, by the end of 2022 the EU is able to replace over 100 bcm of Russian gas, following the LNG diversification (50 bcm replacement); increasing wind and solar deployment and green hydrogen production (20 bcm); energy saving (14 bcm); and other steps (EC, 2022).

Biogas and especially biomethane production is also important step to energy security of the EU. For example, Germany had 9,706 biogas plants operating as of 2018. That is the highest number

of biogas plants in any country in the world, excluding small scale community plants prevalent in China.

The Hydrogen Strategy for a Climate Neutral Europe was adopted in the EU in 2020 (EC, 2020) to ensure the realization of the ambitions of the European Green Deal (EC, 2019). And while technologies, infrastructure and economic issues are still discussed, the important role of (green) hydrogen in energy transition is generally accepted (Kovač et al., 2021; Parra et al., 2019; Yue et al., 2021)

Current energy crisis over the Europe should spur European states to accelerate investment in renewables and energy efficiency and we totally agree with the assessment (Poitiers et al., 2022) that even if these measures do not completely replace Russian gas in nearest future, in long-term perspective it will have strategic effect on energy security of the European Union (Yakymenko et al., 2022).

Energy security of Ukraine

Before the Russian war against Ukraine, energy production of Ukraine was provided mostly by fossil fuels and nuclear power. In 2020, Ukraine had the following structure of primary energy consumption: natural gas – 27.5%, coal – 26.4%, nuclear energy – 23.1%, oil – 16.4%, renewables – 6.6% (UkrStat, 2021). There has being a significant dependence on natural gas, coal and nuclear energy, and extremely low share of renewables in energy sector of Ukraine.

During last years Ukraine produced about 20 billion cubic meters (bcm) of **natural gas** annually[1]. It covered about two thirds of the national demands in natural gas. The rest of gas supplies, about 8-10 bcm, was imported in the country from some EU member states (Slovakia, Hungary, and Poland). But it was mostly Russian gas by origin. Ukraine also has been 85% dependent on the imports of petroleum products. And the share of oil products produced in Russia or from Russian raw materials in the structure of Ukrainian imports exceeded 80%. Ukraine also has been significantly dependent on nuclear fuel from Russia, which covered more than 50% of needs of Ukrainian nuclear power plants in 2021 (CMU, 2021b).

Thus, Ukraine shares the challenges of most European countries in its dependence on Russian energy resources. The Russian aggression aggravated energy security in Ukraine. The matter is that the Dnieper-Donetsk region of Ukraine accounts for approximately 90% of national gas production (IEA, 2020). Now this region is severely affected by the war. According to national experts, about 70% of gas production facilities in the country currently may be destroyed or out of operation.

Moreover, permanent terroristic attacks of Russian aggressors on Ukrainian energy infrastructure during winter season of 2022/2023 had devastating effects of energy sector of Ukraine. Recent assessment of the United Nations Development Programme (UNDP) and the World Bank of the results of Russian missiles attacks on energy infrastructure of Ukraine confirmed countrywide damages exceeding $10 billion, with Ukraine's capacity to produce electricity reduced by 61% (Cilliers, 2023).

Among the infrastructural advantages of Ukraine in energy sector, there is a potent gas transportation system, which during decades served as the main transport route for Russian gas to Europe. The other important part of energy infrastructure of Ukraine is the largest in Europe underground natural gas storage facilities (more than 30 bcm), which comprise 21% of total European

[1] https://expro.com.ua/novini/vidobutok-gazu-v-ukran-znizivsya-na-2-do-198-mlrd-kub-m

facilities[2]. While the gas transportation system from Russia to Europe will apparently lose its significance, gas storage facilities may play important role in energy security of both Ukraine and the EU.

On the other hand, before the war, Ukrainian economy was one of the most energy inefficient in Europe. For example, energy consumption per unit of national GDP in Ukraine was about 3 times higher than average over the EU (BusinessViews, 2019). And the country should use postwar economic recovery for radical technological modernization of all branches of the economy to make it much more energy efficient. In turn, it should significantly reduce the national demands in energy resources, including natural gas demands.

Unfortunately, energy infrastructure of Ukraine is worn and outdated in general. Almost all power units of thermal power plants have exhausted their park resource, are technologically outdated. The power units of nuclear power plants formally should be decommissioned due to the end of their service life. The wear and tear of electrical networks is more than 50%, while the wear and tear of some electrical network objects reaches more than 70% (CMU, 2021b). All these facilities need to be rebuilt and/or modernized in nearest years in terms of national energy security.

Paying attention to the low level of **renewables** in energy mix in Ukraine, in 2021 Ukrainian government proposed National Action Plan for the Development of Renewable Energy until 2030 (CMU, 2021a). According to the plan, in 2030, Ukraine should produce 27% of energy consumed from renewables. This level is much lower than updated plans in the EU, and Ukraine does have the potential to reach more. It is worth to indicate, that in Ukraine about three quarters of renewables are bioresources (UkrStat, 2021). Being one of the largest producers of agricultural crops in the world, Ukraine has a huge potential in bioresources, first of all, in form of agricultural residues. Experts of Bioenergy Association of Ukraine (UABIO) calculated that Ukraine has a biomass potential for energy production in a total of 21.7 million tons of oil equivalent (toe) per year. The main components of the energy potential of biomass are by-products and waste of agriculture, agricultural residues - 9.4 million toe/year or 43% of the total potential, and energy plants - 7.5 million toe/year, 34%. The largest shares of the potential of agricultural residues fall on the straw of cereal grain crops (36%) and by-products/waste from the production of grain corn - 33% (Geletuha et al., 2022). According to the reasonable assessment of UABIO, these bioresources may compensate about 10 bcm of natural gas for Ukraine. Thus successful realization of this potential itself may compensate all national imports of natural gas.

Advanced national strategy was proposed by experts of other industrial company, Ukrainian Technological Company[3] (UTC). Being one of the major industrial companies in biogas technology in the country, UTC assesses potential of Ukraine in **biomethane production** in 10-15 bcm annually with new facilities installation in a scale of about one bcm of biomethane per year. The resources for biogas / biomethane production may be the same agricultural residues and other organic waste, including food waste. This approach is promising for Ukraine. First of all, Ukraine does have a significant amount of bioresources and organic waste. Next, this way Ukraine may use natural gas transportation system and natural gas storage facilities. Also, biogas production generate significant amount of useful side product, digestate, which may be used as organic fertilizer.

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[2] https://utg.ua/img/menu/company/docs/2021/buklet/%D0%91%D1%83%D0%BA%D0%BB%D0%B5%D1%82_%D0%A3%D0%A2%D0%93_ua_30112021.pdf

[3] https://utc.bio

In addition, organic waste treatment has additional benefits for the environment. Organic waste deposited in landfills, produce significant amount of biomethane into the atmosphere. Methane is a powerful greenhouse gas, 80 times stronger for greenhouse effect / global warming than carbon dioxide (UNEP, 2021). On the other side, being treated in the technological process of anaerobic digestion, organic waste will be transformed into valuable energy resource. It still produces carbon dioxide during burning, but the effects for the environment will be much less aggressive compared to uncontrolled decomposing of organic waste in landfills.

It is important, that during methane fermentation of organic waste, e.g., manure, a significant amount of ammonia may be extracted and used as an alternative energy resource (Zhadan et al., 2021). The potential of ammonia as a carbon-free fuel is discussed nowadays. For example, hydrogen as a fuel has an extremely low energy density, which means that its energy density on a volumetric basis remains distinctly substandard to most liquid fuels. Ammonia alternatively is 50% higher in energy density than compressed or liquefied hydrogen. One major advantage there is an existing infrastructure for transportation and distribution of ammonia worldwide (Chehade and Dincer, 2021).

Currently, Ukraine has only about 70 biogas plants with total capacity of 105 MW[4]. For comparison, Germany, the main biogas producer in Europe, had over 9,700 biogas plants with total capacity of 4.8 GW yet in 2018 (WBA, 2022). Meanwhile Ukraine has both significant bioresources for biogas production and sufficient amount of well-educated professionals in the fields of biotechnology and industrial ecology. Under the financial and technological support of European partners, Ukraine may fast reach significant progress in biogas / biomethane production at the national scale.

Important issue for Ukrainian energy sector is the challenge of **nuclear power.** Ukraine is the third European country after France and Slovakia with highest share of nuclear power in energy mix. In 2020, Ukraine generated about 55% of its electricity in 15 nuclear reactors. Moreover, in autumn and winter nuclear generation covers up to 70% of national electricity generation[5]. The challenge here is that most Ukrainian nuclear reactors exhausted its operation life (30 years). Meanwhile, Nuclear Energy Agency (NEA) experts concluded that if nuclear utilities implement enhanced ageing management programmes using readily available technical evidence, while performing the necessary repairs and replacements, long-term operation should not face any major, generic, technical barriers (OECD, 2021).

Nevertheless, Ukraine has a challenging history, having been affected by the biggest nuclear catastrophe in world history—the Chornobyl (Chernobyl) nuclear disaster. See, for example, (Sidorik and Yakymenko, 2013). So, we need both strict international technological control during the operation of nuclear reactors and science-based decisions on its further operation.

The war added new risks and challenges in the field both for Ukraine and for Europe, e.g., currently the largest Ukrainian nuclear power plant, the largest in Europe, with 6 nuclear reactors, Zaporizhzhia NPP, is under the control of Russian invaders.

Ukraine has good climate conditions for **wind and solar power** generation and a big reserves here. Today not only Ukraine has low level of renewables in national energy mix (about 6.6%), but most renewables (75%) are represented by bioresources, mostly solid biofuels (UkrStat, 2021). Meanwhile international experts assess the potential of wind power generation in Ukraine in stunning

[4] https://ecolog-ua.com/news/za-rik-ukrayina-zapustyla-68-biogazovyh-stanciy
[5] https://www.energoatom.com.ua

320 GW (IRENA, 2017), which technically may cover all national energy demands. Of course, this potential should be restored yet through the deoccupation of southern regions of the country. Because the most promising wind power regions are the southern and southeastern parts of Ukraine, where the average wind speed at the height of the rotor axis of modern wind power plants reaches 7 m/s and higher[6].

Solar generation also has good potential in Ukraine. Even though Ukraine is in the bottom of the list of countries according to its photovoltaic power potential, the country is ahead of many European states, including Germany, Austria, Czech Republic and Poland (WB, 2020).

The National Renewable Energy Action Plan of Ukraine for the period up to 2030 foresees a significant increase in the installed capacity of solar and wind power plants - up to 9,947 MW and 5,033 MW in 2030, respectively (CMU, 2021a). Compared to the indicators of 2020 (6,872 MW of solar generation and 1,314 MW of wind power plants, this is an increase of 1.5 times for solar and 3.8 times for wind power plants. Obviously, it is not enough ambitious plans compared to the best indicators in the EU member states and keeping in mind current challenges for Ukraine.

Due to the plans for the construction of 10 GW of electrolyzers for the production of **green hydrogen** on the territory of Ukraine, the country can become an integral part of the implementation of the ambitious goals of the European Green Deal (Prokopchuk, 2020). In addition to Ukraine's role as a producer of green hydrogen on the European market, the EU may be also interested in adapting the Ukrainian gas transportation system to supply a mixture of hydrogen and natural gas. As experts note, there is no infrastructure for hydrogen in Eastern Europe. Its creation will take ten or more years. The possibility of using existing gas pipelines for the transfer of hydrogen or hydrogen mixtures requires research and practical tests but are promising.

Discussion. Ukraine makes great efforts to follows strategies and policies of the European Union in all the fields of sustainable development. And the precise plan for implementation of the EU regulatory principles and norms in Ukrainian legislation was developed in terms of Association Agreement between the European Union and Ukraine (AA, 2014). The Agreement had a tremendous effect on effective transformation of Ukrainian legislation toward European Union high standards, see, for example (CMU, 2022). And during last years Ukraine achieved a significant progress in many directions related to the sustainable development (Shapovalov et al., 2022; I. Yakymenko et al., 2018). Russian invasion of Ukraine interrupted the normal life of the country and put millions of Ukrainians in front of the challenge to defend their country, their freedom and their lives. And while the democratic world, including the EU, demonstrate undeniable support of Ukraine, the military, economic and social aspects of this war in the center of Europe need more and more international attention and determination.

Meanwhile, Ukrainian government presented an ambitious plan for the postwar recovery of Ukraine at the conference in Lugano, Switzerland, yet in June 2022 (Vinokurov, 2022). The total amount of financing in the next ten years may amount to about $750 billion. In the field of energy security, it is expected to attract about $130 billion. Among the projects are the construction of hydroelectric power plants and hydroelectric storage power plants, power plants based on renewable energy sources with a capacity of 5-10 GW, completion of two power units of the Khmelnytsky NPP, modernization of other NPPs, and construction of infrastructure for the production of green hydrogen.

[6] https://uwea.com.ua/ua

It is supposed to attract another $150-250 billion to increase the energy efficiency of residential buildings, build new ones and repair damaged buildings.

The bottleneck of the plan is the sources of financing as the primary source should be Russian reparations and frozen assets of the aggressor country and its oligarchs. Obviously, such strategy needs strong international support and the development of effective legal mechanisms for its implementation.

In conclusion, unreasonable and unprovoked Russian invasion of Ukraine threatens European values and undermines European sustainable development in many ways, including European energy security. Significant dependence of most European countries, including Ukraine, on Russian energy resources is a tremendous risk, which European community should overcome as fast as possible. Ukraine being an integral part of European community and defending European democratic values and freedoms, meets huge challenges in all the fields of country's life, including energy security issues. While strong international support is critically important both for Ukrainian victory and for the postwar recovery of the country, Ukraine has its own significant potential in energy sector, e.g., developed infrastructure for gas transportation and storage, a huge potential in bioresources / biogas / biomethane production, and significant electricity production due to nuclear power generation. All these aspects may be used for long-term effective collaboration of Ukraine and the European Union member states in the field of energy security.

Acknowledgment. Supported by the Erasmus+ Projects Jean Monnet EU Centre for the Circular and Green Economy (620627-EPP-1-2020-1-UA-EPPJMO-CoE) and Jean Monnet Support to Associations (611278-EPP-1-2019-1-UA-EPPJMO-SUPPA).

The authors are grateful to the Armed Forces of Ukraine for the opportunity to perform this work.

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