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COOPERATION BETWEEN UKRAINE AND SWEDEN IN THE FIELD OF ENERGY BASED ON THE SUSTAINABLE DEVELOPMENT CONCEPT

The article is devoted to the issue of further development of cooperation between Ukraine and Sweden in the field of energy and recycling. The authors study and emphasize the difference between the concepts of renewable energy and clean energy. It is noted that renewable energy is obtained from renewable energy sources, which include light, wind, hydropower, geothermal energy, and bioenergy. One of the distinctive feature clean energy is its production with zero carbon dioxide emissions.The disadvantages of nuclear power are characterized.The dynamics of the share of renewable energy in the total energy production of Ukraine and Sweden is analyzed. Based on the results of the comparative analysis, it is determined that in the energy sector of both Sweden and Ukraine, hydropower accounts for the largest share of renewable energy. At the same time, Ukraine's small hydro potential does not allow it to be the main to further increasing the share of renewable energy.It is established that one of the most promising areas of cooperation between Ukraine and Sweden is waste recycling. The analysis made it possible to identify the problem of growing waste generation and increasing the area of landfills in Ukraine, which in turn leads to methane emissions into the atmosphere and a rapid increase in the greenhouse effect. The author emphasizes the particular importance of organizing waste recycling based on Western European standards in the context of Ukraine's movement towards the EU. The full compliance of Sweden's waste management policy with the principles of sustainable development and the principles of the circular economy is determined. The practical experience of a Swedish company in recycling is characterized, which will allow Ukraine to annually convert waste into clean energy. The results of the analysis show that almost 50% of the energy received by Swedish households is provided by recycling. It is noted that the effective implementation of innovations by Swedish companies has allowed the country not only to solve the problem of recycling its own waste, but also to import it from neighboring countries: Norway, Finland, Denmark, and other European countries: Great Britain, Ireland.

Keywords: *energy, renewable energy, hydropower, hydro potential, waste management, clean energy*

Problem statement. In 1992, at the International Conference on Environment and Development in Rio de Janeiro, a document was adopted that determined the vector of the world's movement in the 21st century – Agenda 21. One of the ideas put forward in this document was the concept of sustainable development, the main goals of which were to meet the needs of humanity while preserving the ability of future generations to fully satisfy their needs, as well as to improve the quality of the environment and improve the economies of the world.

Since then, there has been a general trend towards reducing gas emissions into the atmosphere, including decarbonization, to reduce the greenhouse effect, reduce anthropogenic impact in the course of business activities, etc.

Interpreting the goals of the sustainable development concept to the energy sector, the main energy goal is the transition to the use of renewable energy sources, such as light, water, wind, the Earth's natural heat, etc. As of 2021, almost 70 % of Ukraine's electricity was clean, and the vast majority of energy produced was the result of low-carbon generation. However, there was a big problem with the fact that just over 55 % of the energy was generated by nuclear power plants. Among the main problems of nuclear power is the management of radioactive waste and spent nuclear fuel, which requires proper storage and safe disposal.

The trend indicates that interest in nuclear power is declining globally, being replaced by renewable energy sources. For instance, more than 98 % of the electricity generated in Sweden is clean, the share of renewable energy is growing and the share of nuclear power is decreasing. The involvement of Swedish experience in organizing the energy sector, as well as cooperation with Sweden, including scientific one, will help Ukraine move further in the field of electricity production, because "there is no limit to perfection".

Analysis of recent publications. Melekh L. and Nagirnyak O. highlighted in their article the problems of legal regulation of alternative energy in Ukraine, the peculiarities of environmental policy, as well as the prospects for the development of this sphere in Ukraine based on public-private partnership [1]. Zaharii V. K. and Kovalchuk T. H. studied the current state and prospects for the development of renewable energy in the world and Ukraine [2]. Bukharina L. M. and Tytarchuk D. I. conducted a review of the modern energy-saving policy at Ukrainian enterprises, as well as the problems' outline of effective use of energy resources in Ukraine [3]. The study of Ukraine's cooperation with Scandinavian countries, in particular Sweden, in the field of renewable energy, as well as a review of the practice of using waste as a source of energy, was carried out by Redko K. Yu. and Alenina D. O. [4].

Unresolved parts of the problem. While recognizing the contribution of scientists to the study of problems and prospects of energy development, the issue of Ukraine's cooperation with countries that have achieved high results in energy efficiency requires additional research.

The purpose of the article is to conduct a comparative analysis of the results of the implementation of renewable energy in Ukraine and Sweden in the context of the circular economy, and to identify areas of cooperation in the field under study.

Research methodology. The paper uses the method of economic analysis, statistical methods to analyze the dynamics of the share of renewable energy in total energy production in Ukraine and Sweden, the shares of renewable energy sources, and graphical methods to present the results of the analysis.

Research findings. Problems in conducting research can arise even before it begins. The most common problem is a lack of clarity on definitions. In energy research, the concepts of clean energy and renewable energy are often confused. As the name implies, renewable energy is derived from renewable energy sources, which include light, wind, hydropower, geothermal energy, and bioenergy. Clean energy is a broader term that fully encompasses renewable energy. In addition, clean energy is defined as energy produced with zero carbon dioxide emissions. It also includes decarbonization, nuclear power, etc.

The European Green Deal, which was presented in December 2019, focuses on developing the principle of climate neutrality by adhering to the principles of a circular economy. This type of economy involves the refusal to use primary raw materials in the production of goods and services. In the energy sector, the emphasis is on renewable energy, as, for example, nuclear power requires uranium ore, large amounts of water for cooling pools, and a place to dispose of nuclear waste with low radiation levels.

To develop a strategy for cooperation between Ukraine and Sweden in the energy sector, first of all, it is worth examining the share of renewable energy in the total energy production of these two countries (Figure 1).

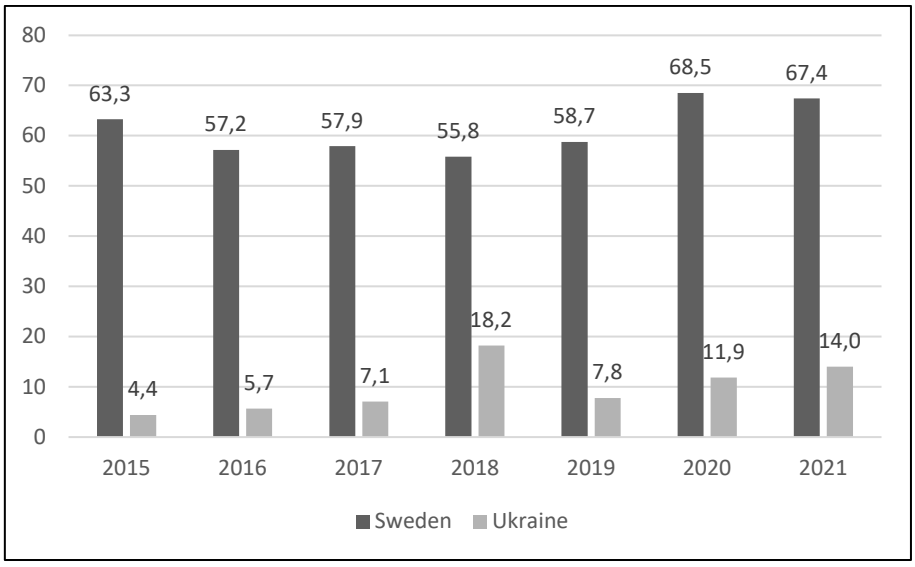


Figure 1. Share of renewable energy in total energy production in Ukraine and Sweden in 2015–2021, %

Source: compiled by the authors according to [5]

As can be seen from Figure 1, both Ukraine and Sweden show a general trend towards an increase in the share of renewable energy, although this growth is uneven and not linear. As already mentioned, more than half of all energy in Ukraine is produced at nuclear power plants, which is why a high rate of clean energy production of 69.4 % was achieved. For a clearer outline of the vector of Ukraine's energy development, it is worth considering the distribution of renewable energy production by sources (Figure 2).

Figure 2 shows that hydropower accounts for the largest share of renewable energy in the energy sector of both Sweden and Ukraine (63.84 % and 48.81 %, respectively). If we compare the most powerful hydroelectric power plants (HPP) in these countries, the Dnipro HPP has an actual capacity of 1569 MW, while the Swedish Harsprånget HPP has 977 MW and is the 4th largest in Scandinavia. However, it is worth noting that there are 47 hydropower plants with a capacity of more than 100 MW in Sweden and only 12 of them in Ukraine. Of course, there are projects to build new HPPs/PSPPs, such as the Kostiantynivska HPP on the Southern Bug River, but a significant expansion in the number of HPPs to increase the share of hydropower generated in the national market of Ukraine is impossible. The reason for this is the limited availability of inland waters, as in Ukraine they occupy 2 % of the total area, while in Sweden they cover 8.87 %. Moreover, Sweden has a greater potential for hydropower, as the entire northern and western parts of the country are covered by mountains and plateaus with powerful rivers (e.g., Umeålven, Luleålven, etc.).

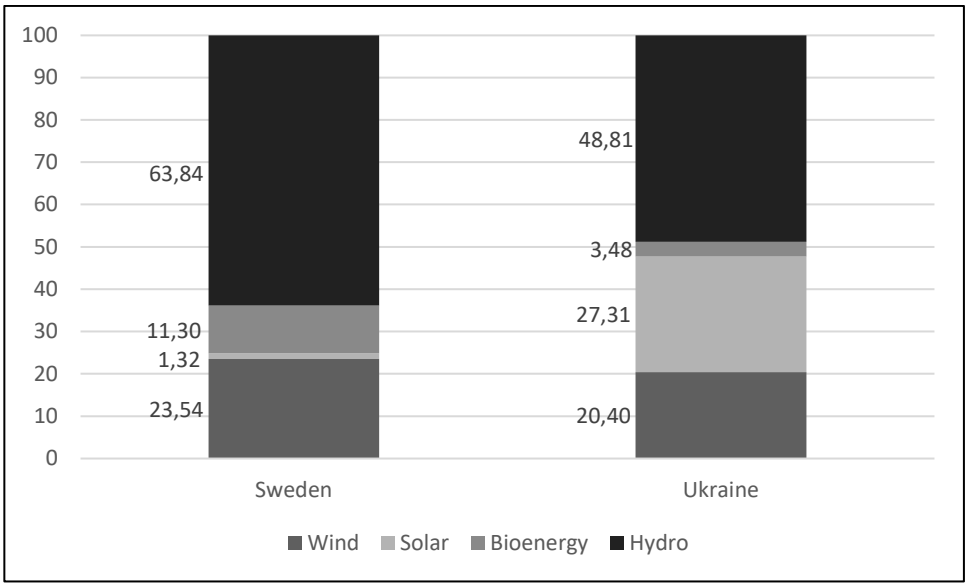


Figure 2. Distribution of renewable energy production in Ukraine and Sweden by sources as of 2021, %

Source: compiled by the authors according to [5]

As an interim conclusion about Swedish-Ukrainian cooperation in hydropower, we can say that it will not be effective enough due to Ukraine's insufficient hydro potential. It is also worth adding the fact that hydropower in Ukraine is considered a non-permanent renewable source, and the negative environmental consequences of further increasing its share will be greater than the benefits that the national economy will receive from the implementation of the hydropower plan [6, p. 30].

Particular attention should be paid to the project on energy production from waste incineration proposed by the State Agency on Energy Efficiency and Energy Saving of Ukraine in 2018. At that time, the head of the State Agency on Energy Efficiency and Energy Saving, Serhiy Savchuk, said: "By producing energy from garbage, Ukraine will be able to save up to 1 billion cubic meters of gas per year and solve the problem of landfills".

Indeed, Ukraine has a so-called “garbage problem”, as the population generates about 450 million tons of garbage, both industrial and household, every year. Of this, more than 93 % is taken to landfills, while only 4.5 % is recycled. The process of garbage decay in landfills is one of the main causes of methane emissions into the atmosphere, which leads to a rapid increase in the greenhouse effect. Given that Ukraine is applying to join the EU, compliance with waste management regulations should not be neglected. The waste recycling rate set in the European Union is 50 % of its total volume. Ukraine needs to radically change its waste management policy, focusing on Western European standards.

Considering Sweden’s waste management policy, we can note its full compliance with the principles of sustainable development and the circular economy. At this point, it is worth considering the distribution of waste by treatment method in Sweden (Figure 3).

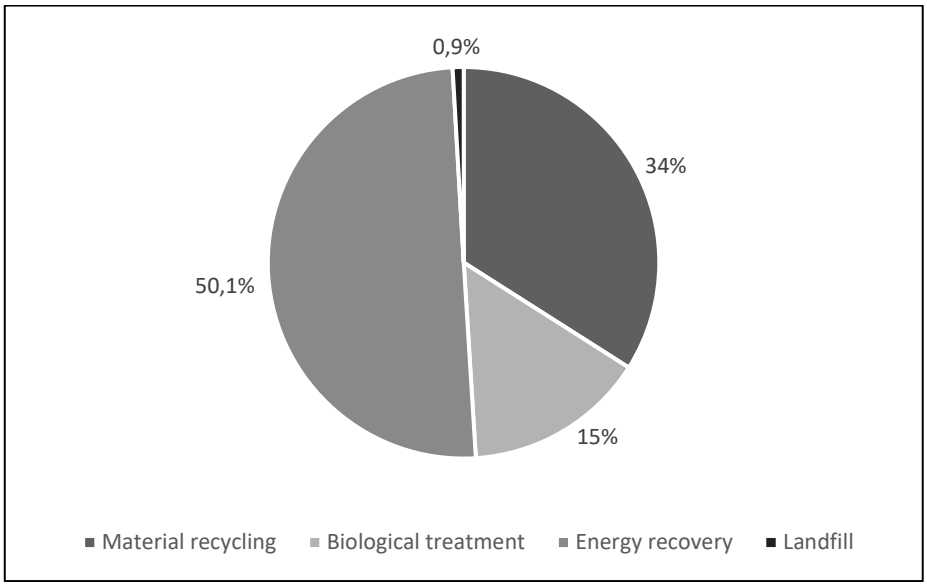


Figure 3. Distribution of waste by treatment method in Sweden as of 2021, %

Source: compiled by the authors according to [7]

As can be seen in Figure 3, in 2021, Sweden recycled 99.1 % of all waste, of which more than 50 % became a source of energy for more than a million families. Avfall Sverige (English: Swedish Waste Management) is a Swedish company association that deals with waste management and processing and serves about 95 % of the population of Sweden. De facto, this company is a kind of supervisory authority in the waste management sector that defines the basic principles and guidelines of the sector, protects the interests of its clients, conducts research, and collects informative and statistical material. To understand how the Swedes manage to burn garbage and simultaneously produce the lion’s share of energy and not pollute the environment, we need to consider the technological component of one of the companies in this sector.

Sysav (English: South Scania Waste Company) is a company in Malmö that processes and recycles waste into energy. If we look at the process of producing energy from waste, we can note the relative simplicity of the technology. After sorting the waste, it is sent to a boiler and burned. The plant’s capacity at this stage is approximately 55 tons of incinerated waste per hour. During the incineration process, carbon monoxide is released, the

temperature of which reaches 850°C; it heats the water in the boiler, which turns into steam at a temperature of about 400°C. This steam is fed into a turbine under a pressure of 4 MPa, which activates a generator that produces energy. The spent carbon monoxide is completely purified in several stages and released to the surface through a pipe [8]. To summarize the facts about the productivity of this enterprise, Sysav processes about 630 thousand tons of waste per year and generates more than 250 thousand MWh of electricity. To generate the same amount of energy, the equivalent would be 167 million cubic meters of natural gas. Thus, 35 waste incineration plants in Sweden produce almost 17 TWh of electricity, and at a tariff of $0.47 per 1 kWh, the profitability of this project is almost $8 billion. It should be added that all these innovative developments have led to a shortage of domestic garbage, so Sweden imports it from neighboring countries: Norway, Finland, Denmark – and other European countries: Great Britain, and Ireland. Although the word "import" implies the "purchase" of garbage, actually, exporting countries pay Sweden to remove garbage from their territory because waste recycling is much more expensive for these countries than exporting with a tariff. Therefore, in addition to raw materials for energy, Sweden receives $100 million in revenue from this.

The use of Swedish experience in "waste-to-energy" technology will allow converting the above 450 million tons of Ukrainian waste per year into 178.6 TWh of clean electricity. According to the Ministry of Energy, in 2021, total electricity consumption in Ukraine amounted to 154.8 TWh. As you can see, Ukraine has a very high potential in the field of waste management. Of course, it is inappropriate to convert all domestic waste into energy. However, even if we take into account the EU recommendation regarding 50 % of recycled waste, the total revenue from the implementation of such an energy-based approach to waste management at a tariff of UAH 1.44 per 1 kWh will amount to UAH 128.6 billion.

Conclusions. Based on the comparative analysis of the state of renewable energy, it is possible to note the high efficiency of the energy sector of the Swedish economy. Analyzing the experience of Swedish companies and developing the gradual introduction of similar measures will allow Ukraine to both solve environmental problems caused by the increase in the area of landfills and have an additional source of energy.

Prospects for further research. Further research will focus on developing a strategy for cooperation between Ukraine and Sweden in the energy sector.

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КОМПАРАТИВНИЙ АНАЛІЗ РЕЗУЛЬТАТІВ ВПРОВАДЖЕННЯ ВІДНОВЛЮВАЛЬНОЇ ЕНЕРГЕТИКИ УКРАЇНИ ТА ШВЕЦІЇ В УМОВАХ ЦИРКУЛЯРНОЇ ЕКОНОМІКИ

Статтю присвячено питання подальшого розвитку співпраці України та Швецію у сфері енергетики та ресайклінгу. Авторами досліджено і підкреслено різницю понять відновлювальна енергія і чиста енергія. Відзначено, що відновлювана енергія отримується з відновлюваних джерел енергії, до яких відносяться світло-, вітро-, гідроенергетика, геотермальна енергетика, біоенергетика. В свою чергу, відмінністю чистої енергії є її виробництво з нульовою емісією вуглекислого газу. Охарактеризовано недоліки атомної енергетики. Розглянуто динаміку частки відновлюваної енергії у загальному виробництві енергії України та Швеції. За результатами порівняльного аналізу визначено, що у енергетичній сфері як Швеції, так і України найбільшу частку відновлюваної енергетики займає гідроенергія. При цьому, замалий гідро потенціал України не дозволяє зробити її основною у подальшому збільшенні частки відновлювальної енергетики. Встановлено, що один з найбільш перспективних напрямів співпраці України і Швеції є сфера переробки сміття. Проведений аналіз дозволив ідентифікувати проблему зростання генерації обсягів сміття і збільшення площі сміттєзвалищ в Україні, що в свою чергу призводить до викидів метану в атмосферу та стрімкого посилення парникового ефекту. Підкреслено особливу важливість питань організації переробки відходів орієнтованих на західноєвропейські стандарти в умовах руху України до ЄС. Визначено повну відповідність політику Швеції щодо організації переробки відходів принципам сталого розвитку й засадам циркулярної економіки. Результати аналізу доводять, що майже 50% енергії, що отримують шведські домогосподарства, забезпечуються переробкою сміття. Охарактеризовано практичний досвід шведських компаній щодо переробки, який дозволить Україні щорічно конвертувати сміття у чисту електроенергію. Відзначено, що ефективне впровадження шведськими компаніями інновацій дозволило країні не тільки вирішити проблему переробки власного сміття, а імпортує його у країн-сусідів: Норвегії, Фінляндії, Данії, та інших країн Європи: Велика Британія, Ірландія.

Ключові слова: енергетика, відновлювана енергія, гідроенергетика, гідропотенціал, управління відходами, чиста енергія