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RENEWABLE ENERGY SOURCES IN PENAL INSTITUTIONS AS A COMPONENT OF UKRAINE'S ENERGY SECURITY

The results of the conducted study prove that the transition to using renewable energy sources and energy efficiency technologies will ensure Ukraine's energy independence and, as a result, a high level of energy security. It is shown that the presence of an autonomous network at the local level provides a number of advantages, ensures independence from the general energy supply system and contributes to increasing energy efficiency indicators.

The economic and security expediency and necessity of implementing renewable energy sources in penal institutions are substantiated. This will provide an opportunity to ensure proper conditions of detention of persons in prisons, their medical care and personnel involved in this work in the context of energy threats caused by Russia's armed aggression against Ukraine, as well as to improve the state of energy security and energy efficiency of penal institutions, creating conditions for their energy autonomy.

Keywords: *energy security, national security, war, martial law, critical infrastructure facilities, threats, penal institutions, convicts (prisoners), proper conditions of detention, personnel, renewable energy sources, energy efficiency, energy system, energy autonomy.*

Statement of the problem. One of the main directions of the state policy on the national security of Ukraine in the economic sphere is to ensure energy security based on sustainable functioning and development of the fuel and energy complex, in particular, consistent and active implementation of energy saving policy and diversification of energy saving sources [1].

It should be noted that the lack of electricity is not only a lack of light in the building, it is a complete shutdown of life activities, which leads to catastrophic consequences. In the absence of electricity, pumping stations stop working, the population is unable to get water to meet their basic needs, and the sewage system and filtration and pumping stations stop working, which also leads to environmental pollution and contributes to an environmental disaster. In winter, this means a lack of heat supply, as all boiler houses have an electric control system, transport heat through heating mains using electric pumps, and are dependent on the water supply to feed the systems. In general, everything from household appliances to mobile phones and internet towers stops working without electricity.

Under such conditions, it is extremely difficult

to ensure the fulfilment of the main task of implementing the state policy in the field of execution of criminal sentences, which is entrusted to the State Criminal Executive Service of Ukraine [2], because according to the Article 4 of the European penitentiary (prison) rules "the detention of prisoners in conditions that violate their human rights cannot be justified by a lack of resources" [3].

That is why the transition to renewable energy sources and the use of energy efficiency technologies will help ensure Ukraine's energy independence and, as a result, a high level of energy security.

Military (combat) actions have also become an incentive for green transformation at the local level. In the current situation, when the country is facing a catastrophic energy shortage and the population is living in conditions of constant power cuts, government officials and local communities at all levels are looking for investments to implement solar power plants. The presence of an autonomous network at the local level offers a number of advantages, providing independence from the general energy supply system and contributing to energy efficiency.

The article raises the issue of the prospects for the

introduction of renewable energy sources in penal institutions to further ensure proper conditions of detention of persons in prisons and personnel involved in this work, and improve energy security and energy efficiency of penal institutions.

Analysis of recent research and publications.

The issue of energy security and renewable energy has been studied in several articles by Ukrainian and foreign scholars. However, it became particularly relevant during the war and the martial law.

The issue of energy security in time of war is complex, as it is influenced by various factors. For example, foreign researcher L. Triola [4] emphasizes the significant security threats posed by the USA energy practices and offers potential solutions such as renewable energy and electric vehicles.

Ukrainian scholar A. O. Sycheva [5] analyses the impact of the russian-ukrainian war on global energy markets as a trigger for rethinking the overall context of energy security, the interrelation between energy resources and the military dimension, namely the militarization of energy as a cause of hostilities.

In her research, S. Peters [6] argues that interstate wars over resources and armed conflicts will pose a new threat to global security. Therefore, in her opinion, there are only two sustainable strategies to prevent conflicts: first, reducing dependence on fossil fuels by developing alternative and renewable energy, and second, pursuing a global policy based on a more equitable and controlled distribution of energy.

Studying the role of renewable energy in the stock market reaction, Professor S. Liao [7] notes that European firms with a higher share of pre-purchased or produced renewable energy sources experience a smaller drop in shareholder returns.

Russia's invasion of Ukraine has been driving up energy prices and creating a shortage of fossil fuel supplies (gas and oil), prompting European countries to reconsider their dependence on russian energy imports and highlighting the need to look for alternatives and increase domestic renewable energy supplies.

The rapid rise in energy prices is a kind of totalizer for the implementation of the International Energy Agency's roadmap "Net Zero by 2050" [8] to reduce greenhouse gas emissions and transition the economy to clean energy to achieve the goals of the Paris Agreement [9].

The purpose of the article is to study the possibilities and prospects for the introduction of decentralized energy production and its accumulation from renewable sources on the example of penal institutions.

Summary of the main material. The term "energy security" itself emerged during the oil crises of 1973–1974, when the imposition of an embargo by members of the Organization of Petroleum Producers and Exporters on oil supplies to individual countries became a threat to their economic security [10, p. 302].

Traditionally, energy security is understood as the ability of the state, represented by its governing bodies, to provide end consumers with energy in the required amount and of the proper quality under normal conditions, as well as during the action of destabilizing factors (emergencies) of an internal or external nature within the guaranteed coverage of the minimum amount of the most important needs of the country, its individual districts, cities, towns, villages or facilities in fuel and energy resources.

A specific dimension of energy security that has been adopted as a standard in Western countries is the creation of a three-month strategic reserve of oil and oil products.

However, the global community has long appeared a vision that the availability of traditional fossil fuel reserves (oil, gas, coal) cannot fully ensure the country's energy security, so the search for new sources of energy supply is a priority.

Ensuring an uninterrupted and stable power supply is becoming a major challenge for the global community, and it is the reliability of power supply systems, local autonomy of facilities and the presence of backup energy storage sources that will become the basis for energy security in many countries if not already, then shortly.

Focusing on the purpose of the study, it should be noted that energy security and renewable energy sources are relevant in all countries of the world. The availability of scientific literature, practical research, lectures and media publications discussing economic feasibility and future financial prospects are intertwined with ambitious challenges to immediately and massively implement all efficient energy technologies to achieve zero carbon dioxide emissions.

Therefore, for objectivity, it is appropriate to consider two aspects in this article.

Firstly, the terrible consequences of the ongoing war on the territory of Ukraine indicate the need to create alternative (reserve or emergency) energy sources for the needs of enterprises, institutions, small businesses, military camps or units, penal institutions, individual households, etc.

Secondly, as Ukraine is on its way to membership in the European Union (EU), its energy sector should become an integral part of the

European energy sector, with the same strategic goals being implemented on its territory as in the European Community, and offer "green" and "clean" electricity to European partners.

For reference. When talking about renewable energy sources, the terms "clean" and "green" energy are commonly used. They are often used interchangeably, although they do have different meanings. Renewable energy focuses on sources that are naturally renewed over a short period of time, such as sunlight, wind or water flow. Clean energy emphasizes the absence of emissions, while green energy emphasizes the absence of negative environmental impact. Green energy includes renewable sources with minimal or no greenhouse gas emissions. Nuclear energy is considered clean, but not renewable, as its source, uranium, is a fossil fuel. Hydropower uses water as a renewable source, but large dams generate methane emissions due to the decomposition of plant material in the reservoirs. Therefore, nuclear and hydropower do not meet the stricter requirements to be considered green energy [11].

Ensuring an uninterrupted and stable electricity supply is an extremely important issue for Ukraine, as our country has faced many challenges to its energy independence due to numerous missile attacks by the aggressor country.

The Russian army, which has been conducting massive attacks on Ukraine's energy sector with missiles and drones for three years now, has given impetus to the country's transition to clean energy.

In such circumstances, it is important for European countries to move away from Russia's energy influence. While they are trying to find alternative sources of energy imports and increase the share of unconventional energy sources in the energy balance of the EU and other European countries, Russia, for its part, is trying to maximize its energy resources to pursue its own geopolitical interests.

In particular, after the embargo on Russian oil and oil products and a significant reduction in Russian gas exports to the EU market, the Kremlin is trying to increase oil and gas exports to alternative markets, primarily to China and India. In addition, it should be noted that the Crimean peninsula was annexed by Russia in 2014, and along with other factors, one of the reasons was the fact that Ukraine's Black Sea coast had important shale gas deposits.

The war, including over natural resources, continues, but according to the International Energy Agency, cited by The Guardian, Russia's invasion of Ukraine has helped to stimulate investment in clean energy. Fatih Birol, Executive Director of the

International Energy Agency, said: "Clean energy is growing fast – faster than many people realize. For the first time in history, the amount of investment in solar energy exceeds the amount of investment in oil production. This may be symbolic, but it is very important because it shows that the tide is turning" [12].

Considering the energy supply in the context of Ukraine's energy security, it should be noted that the current system has proved to be extremely vulnerable, so to ensure comprehensive energy security, it is appropriate to modernize the electricity systems, which will be part of the national energy systems of the state but will operate autonomously. In this regard, renewable energy sources are currently extremely relevant and require further implementation to ensure the country's energy security.

It is worth emphasizing that the most promising source of renewable energy for Ukraine is the development of various areas of solar energy. It is the high energy potential of solar radiation in Ukraine that is sufficient for widespread use for both electricity and heat generation equipment almost throughout the country [13, 14] and for electric cooling in summer. However, solar energy is seasonal. Thus, in the summer, generation is maximum and can generally be sufficient to meet basic needs, while in the winter, on the contrary, it is minimal, which can lead to a shortage. Therefore, it is irrational to rely solely on energy generated from solar radiation. Depending on the location of the facilities and the stable supply of electricity, storage stations (batteries) should also be provided, but wind energy should not be overlooked. The combined installation of renewable energy sources and storage stations will contribute to the full autonomy of facilities (buildings) regardless of the season, both during the day and at night.

Particular attention should be paid, first of all, to facilities that belong to critical infrastructure.

According to the Criteria for determining the institutions created to ensure the fulfilment of the tasks of the State Criminal Executive Service of Ukraine [15], all penal institutions are important for the national economy in a special period. The vulnerability of penal institutions also lies in the fact that the persons held in them are restricted in their independent movement, and the same applies to the staff who serve in these institutions.

The examples of the occupation of Crimea by Russia in 2014 clearly demonstrated the vulnerability of penal institutions. All the peninsula's institutions were seized by the military and subsequently transferred to the Russian federal

Penitentiary Service. The staff of these institutions became as much a hostage as the convicted (imprisoned) persons. A similar scenario developed in Donbas, and in 2022, during the full-scale invasion, it partially took place in the southern and eastern regions of Ukraine.

While in the situation described above, the restriction of the rights of prisoners and staff is related to the seizure of property, the winter of 2023 and the beginning of 2024 showed the energy vulnerability of both penal institutions in particular and all bodies and enterprises in general.

The lack of electricity in a penal institution leads to extremely negative consequences. First and foremost, it affects the safety of convicts (prisoners) and staff, as well as the proper supervision and protection. Other factors include the inability to provide adequate sanitary and communal living conditions, in particular the lack of water supply, which makes it impossible to meet the most basic hygiene needs, the inability to prepare food in a timely and proper manner, and the lack of heat in winter. The above factors are not exhaustive, there are also medical units and specialized hospitals in the penal institutions, and their activities are practically paralyzed due to the lack of electricity.

It is quite easy for the aggressor country to disable large energy-generating facilities, such as hydroelectric power plants and thermal power plants, and this fact has already been confirmed. At the same time, it is completely inappropriate to spend expensive Kalibr and Iskander missiles on small autonomous energy supply facilities that are not global in the energy system of the state.

In this regard, the energy autonomy of each penal institution, state and commercial organization, military unit or enterprise, and even a private household, which independently generates electricity for their own needs and, if there is a surplus, supplies it to the national energy system, makes it impossible for the aggressor to conduct an energy blockade of the state and contributes to the full energy security of the country.

Eventually, a network of thousands of autonomous wind and solar power plants can be deployed across the country, making it much more difficult for the Russian occupiers to destroy the energy system.

The availability of alternative and decentralized sources of electricity in penal institutions can serve as a basic example of autonomy in electricity supply and an integral element of energy security in general.

That is why, for the further and full development of the energy sector in the context of the electricity

crisis, there is a need for a rapid change in political strategies and implement the latest pilot projects at the national level.

At the same time, the electricity sector requires a very large amount of investment to rebuild destroyed or damaged facilities and ensure their transformation into new ones integrated with EU standards. Therefore, attracting private investors is one of the ways that could become a driving factor and be crucial in the implementation of such projects in the future.

Another extremely important factor at the international level is Ukraine's authorized decision to introduce a "green" energy policy.

"Green" energy is defined as renewable energy sources that are inexhaustible in nature. A separate property of such energy is its environmental impact. It is, but not related to the emission of gases that trap solar energy in the atmosphere. "Green" energy, such as solar and wind, produces neither carbon dioxide nor other gases that cause global warming. According to experts of the UN Intergovernmental Panel on Climate Change, to keep the temperature from rising above 2 °C, average carbon dioxide emissions need to be reduced by 40–60 % [16]. Therefore, the transition to "green" energy is usually at the top of the list of measures to stop the climate crisis.

During the London Conference on Ukraine's Recovery, the Energy Strategy of Ukraine until 2050 was presented. This document envisages the restoration of the energy sector using state-of-the-art technologies, increasing the resilience of the energy system, and strengthening the energy security of Ukraine and Europe [17].

At the same time, the National Economic Strategy for the period up to 2030 also outlines the decarbonization of the economy through energy efficiency, development of renewable energy sources and synchronization with "the European Green Deal" initiative as an important benchmark for economic development. The strategy also envisages an increase in the share of renewable energy sources to 25 % of the total energy system by 2030. In addition, the strategy points out the need to increase storage capacity, consider hydrogen production and achieve local generation regulation [18].

It should be noted that the Ministry of Energy and Environmental Protection of Ukraine presented a draft Concept of Ukraine's "Green" Energy Transition until 2050 before the war, which was driven by the transformation of approaches to energy development in the world and a special focus on fighting with climate change. One of the main indicators set out in this concept is to increase the

share of renewable energy sources to 70 % by 2050. At the same time, a significant amount of such production should be generated by rooftop solar power plants in households or commercial establishments [19].

In Ukraine, the demand for cooling in the warm season is growing every year. Abnormal warming leads to an increase in electricity consumption by households for domestic (household air conditioners and air ventilation systems) and industrial (refrigerators and freezers) purposes. The electricity shortage in the summer of 2024 forced the government to decide to save electricity in the premises of state-owned bodies, enterprises, institutions and organizations by stopping the use of air conditioners, and outdoor lighting of buildings and the surrounding area [20]. Therefore, the use of renewable energy sources is required not only for heating and hot water supply, but also for the operation of cooling systems for domestic and industrial purposes.

It is on the example of penal institutions that it is proposed to test the use of renewable energy sources (in summer – for cooling, in winter – for heating), since in places of detention of convicts on a small territory with a relatively high population density there are such facilities as dormitories (buildings) for prisoners, administrative buildings (offices) for staff, production areas and workshops, medical units and hospitals, storage facilities, vegetable storages and freezers, artesian wells, water towers, transformer substations, sewage and pumping stations, sewage treatment plants, boiler houses, etc. If solar power plants are installed on the roofs of these buildings, they can provide full or partial autonomy of the institution in uninterrupted power supply.

The vision outlined above coincides with the main provisions of the European Green Deal – Europe's roadmap [21] to become the first climate-neutral continent by 2050 and implement measures to reduce greenhouse gas emissions, invest in "green" technologies and protect the environment. It should be noted that the European Green Deal is not so much about climate policy as it is about the "green" concept of economic modernization and economic growth to ensure human life in harmony with the planet and its resources [21].

According to research, buildings are the largest energy consumer in Europe, so renovating homes and buildings will save energy, protect against extreme heat and cold, and help overcome energy poverty.

The energy efficiency of buildings in Ukraine is about three times lower than in Western Europe,

therefore, the issue of improving them for greater energy efficiency is relevant.

The necessary improvements can be achieved through a number of individual measures, such as installing insulation, replacing old windows or doors, modernization heating systems or installing solar panels.

At the same time, the European Union is setting new strategic goals to improve the energy efficiency of buildings, according to which, starting in 2020, all new buildings in the EU should be "near-zero energy buildings", i.e., they should have high energy efficiency and very low energy needs, which are covered mainly by renewable energy sources on-site and nearby [22].

In 2021, the European Commission's Joint Research Centre published a report, which, among other things, noted that the requirement for nearly zero-energy buildings would improve the energy efficiency of new buildings in the EU by 70 % compared to 2006, and its implementation requires accelerating the pace of investor participation in energy efficiency projects through national long-term renovation strategies and financial mechanisms [23].

In April 2024, the European Parliament adopted the new Energy Performance of Buildings Directive [24], which increases the energy efficiency requirements for new buildings. The directive requires all new residential and non-residential buildings to be "not nearly zero-emission buildings" but "zero-emission buildings" from January 1, 2028, for buildings owned by public authorities and from January 1, 2030 for all other new buildings, with specific exemptions. According to the revised directive, a zero-emission building has no local carbon emissions from fossil fuels and is very energy efficient [24]. Thus, the new rules will align the energy efficiency of buildings with the EU's goal of climate neutrality by 2050 and the principle of energy efficiency [25].

From the above, we can see that the EU is working purposefully to achieve the strategic goals set out in the European Climate Law [26].

For Ukraine, the implementation of the Energy Performance of Buildings Directive (from "near-zero-emission buildings" to "zero-emission buildings") [24], even under martial law, is a priority that should be considered not only as a fulfilment of commitments to fight with climate change but also as a component of the country's energy security as a whole.

At present, only the segment of home solar power plants continues to develop actively, driven by the

consumer's desire to ensure the most stable energy supply. Even before the war, there were more than 45,000 home solar power plants in Ukraine with an installed capacity of more than 1.2 GW.

In general, households continue to install solar power plants despite the problems with payments for electricity generated under "the green tariff", as people want to ensure a stable electricity supply. Commercial organizations are also actively installing solar power plants. Businesses are investing in electricity generation to meet their own needs. There is also certain dynamics in the growth of renewable energy sources, especially rooftop solar power plants installed by local governments on social sector buildings (hospitals, clinics, schools, kindergartens, retirement homes, etc.).

However, budgetary bodies, which are non-profit and entirely dependent on state funding, are developing slowly in this area, do not produce their own energy and remain dependent on electricity supplies from the general grid. In general, it would be rational for the state to provide its own bodies with an uninterrupted power supply, but this requires significant financial injections, and in a time of war and budget deficit, it is extremely difficult to do so. One solution could be to consider attracting foreign investments (credits, loans, grants, etc.) by the state to build renewable energy sources.

Another way is to create favourable conditions for attracting private investment. The question is: how can this be implemented with the most productive result and minimize abuse?

First, the state should speed up and simplify the procedures for approving new energy projects as much as possible.

Secondly, the basis should be a guarantee for the investor in terms of duration, since projects for the implementation of renewable energy sources to ensure payback and profit in the future are calculated for a significant period (the optimal period is 10 years or more), and state institutions are dependent on funding within the budget year.

Thirdly, it is a guarantee to the investor to buy back electricity at a set price or to offer alternative mechanisms.

Using the example of a penal institution (although it can be any state body), we will consider a possible algorithm for the introduction of renewable energy sources through private capital.

First, the penal institution, through the State Property Fund, leases for a long-term (at least 10 years) the roof area of the buildings on which the solar panels will be installed, as well as the possibility of using the existing electrical capacities

and transformers. The next step is to agree with the investor, where the institution will act as a "guaranteed buyer". In this case, counterclaims against the investor should be appropriate.

1. *Guaranteed price.* As this is a public sector, the optimal tariff for households for electricity is the one set by the state regulator, the National Commission for State Regulation of Energy and Public Utilities, and revised in case of changes by the regulator.

2. *The guaranteed number of kW of electricity that the investor will provide to the institution.* This factor is necessary for both the institution and the investor. The institution includes the need for funding in its budget request as a "guaranteed buyer", and in case the investor is technically unable to meet the full need, it can purchase the difference from another supplier. The investor also has a guarantee that the number of kW agreed upon by the parties will be purchased. If the investor generates more electricity than the amount stipulated in the agreement, he will be able to dispose of it.

3. *Renovation and maintenance of leased space.* Penal institutions have a fairly large number of buildings that are potentially attractive for renewable energy installation projects. A significant number of them were built and commissioned in the 1960s and 1980s. Of course, over this period of time, most buildings, including roofs, are not in the best condition and require routine and major repairs. In case of construction of solar power plants, there will be an additional load on the roofs, and there are risks that some of the structures may collapse, so it will be appropriate to restore (repair) the roofs. Of course, this will create an additional financial burden for the investor, but it can be compensated for by extending the cooperation agreement and the lease term to 15 or 20 years.

Conclusions

Summarizing the above, it can be concluded that the task of the state is to create the necessary conditions, market rules and incentives for private investment. By ensuring this and developing long-term strategies that will promote cost-effective transformation in the public sector and the development of renewable energy sources, the state will ultimately ensure the implementation of the Zero Emission Building Energy Efficiency Directive, meet the goals set by the European Climate Act, and most importantly, create a local electricity supply system that will be the foundation for ensuring the country's energy security and one of the main elements of national security.

The results of the study provide grounds to substantiate the economic and security feasibility and necessity of introducing renewable energy sources in penal institutions.

This will make it possible to ensure appropriate conditions for persons in places of detention, medical care and personnel involved in this work in the context of energy threats caused by Russia's armed aggression against Ukraine, as well as to improve energy security and energy efficiency of penal institutions, creating conditions for their energy autonomy.

The prospect of further research is to evaluate the efficiency of specific types of renewable energy sources in penal institutions.

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ВІДНОВЛЮВАНІ ДЖЕРЕЛА ЕНЕРГІЇ В УСТАНОВАХ ВИКОНАННЯ ПОКАРАНЬ ЯК СКЛАДОВА ЕНЕРГЕТИЧНОЇ БЕЗПЕКИ УКРАЇНИ

Згідно з результатами проведеного дослідження встановлено, що перехід до використання відновлюваних джерел енергії та технологій енергоефективності дасть змогу забезпечити енергетичну незалежність України і як наслідок – високий рівень енергетичної безпеки. Показано, що наявність автономної мережі на локальному рівні надає низку переваг, забезпечує незалежність від загальної системи енергетичного постачання та сприяє підвищенню показників енергоефективності.

Обґрунтовано економічну та безпекову доцільність і необхідність упровадження в установах виконання покарань відновлюваних джерел енергії. Це дасть можливість забезпечити належні умови утримання осіб, які перебувають у місцях позбавлення волі, їх медичного забезпечення та персоналу, який задіяний до цієї роботи, в умовах енергетичних загроз, спричинених збройною агресією росії

проти України, а також полішити стан енергетичної безпеки й енергоефективності установ виконання покарань, створивши умови для їхньої енергетичної автономії.

Ключові слова: *енергетична безпека, національна безпека, війна, воєнний стан, об'єкти критичної інфраструктури, загрози, установи виконання покарань, засуджені (ув'язнені), належні умови утримання, персонал, відновлювані джерела енергії, енергоефективність, енергетична система, енергетична автономія.*

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