Asesorías y Tutorías para la Investigación Científica en la Educación Puig-Salabarría S.C.
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RFC: ATI120618V12

Revista Dilemas Contemporáneos: Educación, Política y Valores.
http://www.dilemascontemporaneoseducacionpoliticayvalores.com/
Año: VII Número: 1 Artículo no.:142 Período: 1 de septiembre al 31 de diciembre, 2019.

TÍTULO: Pequeña formación de energía en el contexto de la mejora de la seguridad energética de los países de la Unión Europea.

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RESUMEN: La participación de la energía distribuida en el suministro total de energía de los países de la Unión Europea (en lo sucesivo, la UE) ha aumentado constantemente a lo largo del siglo XXI. Las tecnologías para la generación y distribución de energía y suministro de calor son cada vez más accesibles y rentables para el uso de pequeñas empresas y hogares. Esto proporciona una gama más amplia de oportunidades para garantizar la sostenibilidad de las redes de energía tanto de las regiones individuales como del estado en su conjunto. El objetivo del trabajo científico es analizar las posibilidades de implementar y desarrollar el concepto de pequeña energía para aumentar la seguridad e independencia de las redes energéticas del bloque de la UE.

PALABRAS CLAVES: Energía distribuida, seguridad energética de los países de la UE, redes energéticas independientes, descentralización de fuentes de energía, energías renovables.

TITLE: Small energy formation within the context of enhancing energy safety of the EU countries.

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ABSTRACT: The share of distributed energy in the total energy supply of the countries of the European Union (hereinafter referred to as the EU) has been steadily increasing throughout the 21st century. Technologies for generating and distribution of energy and heat supply are becoming more accessible and profitable for use by small enterprises and households. This provides a wider range of opportunities to ensure the sustainability of energy networks of both individual regions and the state as a whole. The purpose of scientific work is to analyze the possibilities of implementing and developing the concept of small energy to increase the security and independence of the energy networks of the EU block.

KEY WORDS: Distributed energy, energy security of the EU countries, independent energy networks, decentralization of energy sources, renewable energy.

INTRODUCTION.

The electric power sector of the countries of the European Union is currently undergoing significant changes. Traditional sources of energy are becoming less demanded, while renewable energy plays an increasingly important role in the fuel and energy complex (hereinafter - the fuel and energy complex) of developed European countries. These trends are caused not only by technological progress and technical capabilities, but also by environmental demand.

The current supranational bodies of the EU and states increase environmental requirements by stimulating the transition to environmentally neutral sources of energy and heat ("Terminological dictionary," n.d.). Also, environmental demand problems can serve as a driving force for further penetration of distributed energy generation technologies in Europe. Several EU countries are already showing a gradual and steady upward trend in the use of distributed energy sources.

For further analysis of the distributed energy system of the EU countries, we turn to the very concept of “small energy”. According to the international terminology dictionary, small or distributed energy is a direction related to obtaining energy sources independent of centralized heat and electricity networks. A characteristic feature of low-energy installations is the compact size of generation and distribution systems, including computer control technologies (including artificial intelligence and machine control algorithm modes) over the direction of energy transfer directly to the generating sector or in reverse mode to the central network (if there are appropriate technological solutions).

Considering the EU legislative framework in the field of fuel and energy production, in the definition of “distributed energy” an important aspect is the direct source of energy. In particular, for the EU countries, the main source of small energy systems is alternative energy such as water, wind, solar energy, land, and other similar types, however, there are systems based on natural gas and/or connected to large industrial complexes that receive energy from technological processes of product production.

According to the European Statistics Service (Eurostat), small-scale energy dissemination indicators relate to renewable energy. Distributed energy has been included in the EU statistical databases since 2004, and from this period onwards the report of the EU Energy Commission for the Council of the European Union on the work done as part of the technological development of the EU fuel and energy complex is published annually. The time period is not accidental, since it was in 2004 that the Council of the European Union approved new requirements for the environmental friendliness of the EU countries, including many aspects of the generation, distribution and conservation of heat and electricity, and the main regulatory acts and initiatives were enshrined in “Directive 2004/8/EC of the European Parliament and of the Council of February 11, 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC”. But since most small energy systems are based on renewable energy, let’s look at the indicators of renewable energy generation in the EU countries (“Directive,” 2004).

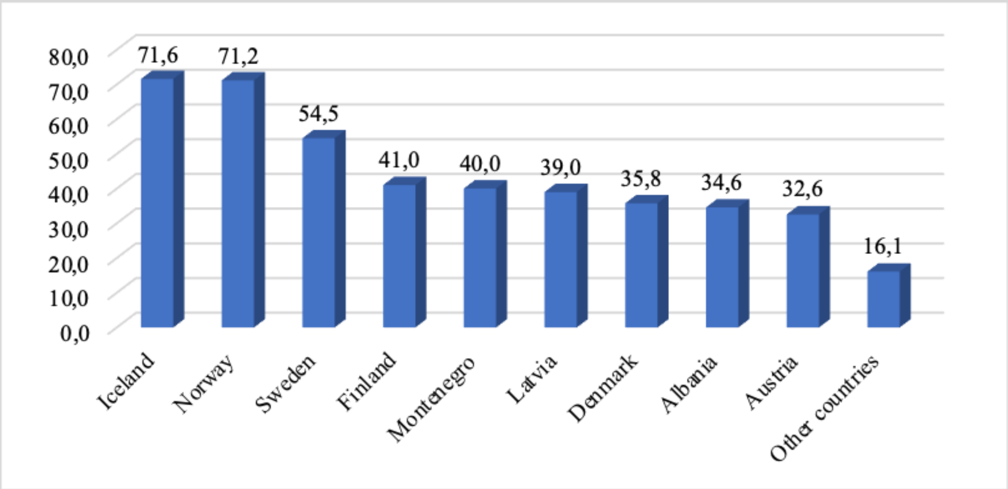

Figure 1. Top 10 countries of the European Union in the share of renewable energy in the total production of heat and electricity in 2017. **Source**: compiled by the authors according to Eurostat (n.d.).

Figure 1 shows the 10 leading countries by the share of renewable energy sources. Also, according to Eurostat, in the above countries, distributed energy installations occupy more than 15% of the total generated energy. Due to the different standards used in calculating and determining small energy, more accurate data cannot be distinguished, however, experts trace a direct relationship between the development of renewable energy sources and the introduction of distributed energy systems in the country.

Separately, we can mention autonomous energy complexes (hereinafter - AEC). AECs are also isolated from a single energy system but are used primarily in large enterprises or in buildings with high energy consumption. This system can be separately connected using adaptive intelligent systems and/or operate based on its power generation station. The creation of such micro-energy systems of industrial and commercial consumers also fits into the concept of small energy, however, according to the directive 2004/38/ of the European Union, it does not apply to distributed energy, and therefore, it is regulated by separate regulatory legal acts. Nevertheless, before the introduction of more compact energy systems and the massive introduction of renewable energy sources in the 21st century, autonomous energy systems were the only type of separate generation and distribution of heat and electricity (Directive, 2004).

Using renewable energy, improving energy efficiency and overall efficiency is only part of a distributed energy system. The main aspect is the locality and mobility of the movement of generated and stored heat and electricity in the network. Although more and more networks using distributed energy technologies are aimed at complete independence from external sources, they remain connected to the common network channel of the municipality and/or region. They can either supply the generated energy to the direct consumer and reverse sell the energy to the common network, and, if necessary, make purchases of energy from the central line in the presence of malfunctions and/or the formation of an internal deficit. The above possibilities form a system of measures to increase the energy security of all network participants and allow the rational distribution of the energy received between all consumers.

The subsystem of small energy can be considered the distribution of energy resources - these are electric generating units (usually in the range from several kW to 50 MW) located in the electrical distribution system at or near the end user, parallel to the power grid or autonomous units.

Small-energy technologies mainly consist of energy production and storage systems located at or near the point of use. Distributed energy includes several technologies, including fuel cells, microturbines, reciprocating engines, load reduction, and other energy management technologies. DER also includes power electronic interfaces, communication and control devices for efficient dispatching and operation of individual generating units, several system packages and aggregate power supplies (Capehart, 2016).

DEVELOPMENT.

Distributed energy is a fairly new direction in the development of the energy industry, and in many countries, there are differences in approaches to the formation of indicators for its accounting and legal documents.

Distributed energy is also not distinguished in open statistical data and may relate to small-generation structures; therefore, to analyze the market at the macro level, it is necessary to study the principles and approaches of various structures. It should be noted that small-scale energy systems operate mainly due to renewable energy sources connected directly to the house structure of the serviced building.

For a detailed consideration of the concept of small energy in the European Union, documents and decisions of the European Energy Commission, the Council of the European Union, and the development strategy of the top 10 EU countries for the largest share of renewable energy were selected and analyzed. The work also examines the process of interaction between the state and manufacturers of technological solutions for small energy and examines the potential effect of the massive introduction of distributed energy technologies in the short and long term (“Study,” n.d.).

The scientific base of the study is based on data from state statistics, analytics of energy companies and assessments of independent experts (Chernyaev, 2014a, 2014b, 2018, 2019).

It is customary to consider the economic effect of introducing small-scale energy technologies in the long term, since the initial costs of such systems are many times higher than the standard network connection, except for, particularly remote settlements. However, according to the European Distributed Energy Partnership (hereinafter - EDEP), from 2020 the average payback period will decrease from 5 years in the period 2015-2019. up to 3.5 years in the period 2020-2024.

This decrease largely depends on how the state and the region determine the level of benefits and establish legislative regulation when using all the capabilities of small energy systems, including exporting energy for implementation in the general energy network.

The technological factor can also play a significant role - according to the Eurelectric statistical resource, from 2010 to 2020, total investments in distributed energy in the EU will amount to 400 billion euros. The main goal of such investments is to make distributed energy network technologies available to individuals with different income levels and small enterprises everywhere. From 2020 to 2030, it is planned to promote preferential taxation at the legislative level during the installation and use of these systems in households, as contributing to the preservation of the local environment. By 2035, the share of all investments in the energy sector of the EU countries should fall on the development of small energy, and by 2050, reach 80% or more. In the global development strategy of the European Union, distributed energy is listed as one of the most effective tools for turning the European part of the continent into climate neutral, i.e. human life will not affect the processes of global warming. However, these forecasts are aimed at the long-term perspective, and in short-term forecasts, small-scale energy contributes to increasing the stability of the energy system, increasing the energy security of all its links (“Distributed,” n.d.).

The system of interaction between participants in the distributed energy market in the EU countries is built schematically (Figure 2): the state acts as a regulator of the implementation of standards through regional services, and also makes changes to the regulatory framework. But many experts note a weak interaction between the state and equipment manufacturing companies.

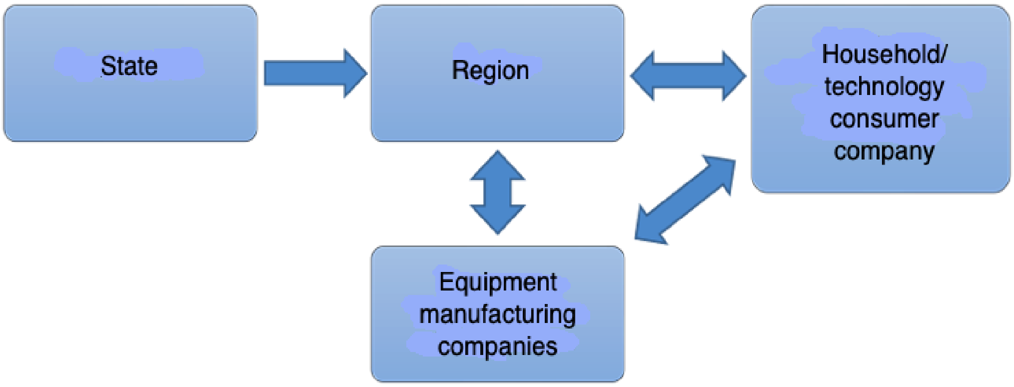

Figure 2. The interaction of the EU distributed energy market participants. **Source**: compiled by the authors according to the electronic resource ("Distributed Energy System," n.d.).

Strengthening the interaction of the state with producers could be facilitated by state orders for the introduction of small energy systems in the social sphere and industries controlled by the state (or supranational organization). Sweden was the only state to officially announce a tender for the purchase of equipment for building distributed energy systems at the state level. In 2016, as part of a strategy to increase energy conservation in small towns, the Swedish Government announced the creation of the country's first fully autonomous energy system in Simris. It is noted, that with the successful functioning of the system within a certain time frame, the technology supplier company "E.ON" will be able to fulfill orders for similar technological installations in other settlements throughout the country (Sweden's, 2017).

"Siemens" is the leader in the market for small energy equipment in Europe. Its representatives also note insufficient interaction at the state level. According to the annual report for 2018, the company can produce and supply 50% more ready-made solutions, using only current production capacities, which in the future will provide large regional and even state orders (Siemens, n.d.).

It is also worth highlighting all the advantages that small energy systems can provide to their users: high variability of use, systems used in industry, can provide commercial areas (from small buildings to large buildings), municipalities, etc. With the help of local distributed energy solutions, a number of the difficulties that are inherent in both the power system and households with a traditional connection to the power grid. The solution could be the targeted use of renewable energy, combined heat and power plants or the provision of energy storage solutions. Among the main advantages stand out:

- System Security. In the event of unforeseen and emergencies, the systems can independently from the external network maintain the minimum necessary level at any time of the year and in various weather and climate situations. Also, in the event of a malfunction, physical or another harmful effect on the power network, it is possible to isolate it from the external circuit and eliminate the malfunctions locally.
- Social protection. The introduction of distributed energy in social structures contributes to the protection of such institutions as medical facilities, law enforcement, data centers, fire safety, and others. As in the case of households and enterprises, these systems can maintain the minimum required level of heat and energy supply, and in the long run, ensure full energy independence.
- Supply Stability. The availability and reliability of the power supply without interruptions and voltage changes is another decisive factor. This is especially true for consumers who rely on a stable and stable power supply to protect their processes and operations. Systems can control the level and volume of energy supply, which increases the life of many functioning systems.
- Reducing the emission of carbon dioxide (CO_2). A growing number of companies and institutions are striving to exceed the minimum environmental requirements and use renewable energy sources, including closed-loop carbon-free grid (Khokhlov, Melnikov, Veselov, Kholkin, & Datsko, 2018).

As with any innovation, there are several contradictions and shortcomings. So, in densely populated urban areas, the creation of small power systems can be difficult. As of August 1, 2019, there is no fully autonomous urban settlement using low-energy technologies in 100% coverage. Despite the visible advantages of distributed energy, it has not yet become widespread in the energy system. The main barriers to entry into the small energy market can be identified:

- The imperfection of the legislative mechanism. Despite the fact that each EU country is trying to introduce additional regulations to regulate small energy issues, there is no single mechanism for the interaction of distributed energy systems with large energy grid companies that determine the order and form of technological connection to networks, relations with sales companies, which complicates the opportunity selling surplus electricity to the wholesale and retail markets.
- Barriers of an economic nature due to high specific capital investments, which necessitate the search for financial resources and increase investment risks.
- Lobbying the interests of large generating companies that are not interested in the emergence of competitors.
- Barriers of a technological nature associated with difficulties in voltage control, reactive power control, with a decrease in the efficiency of electrical protections, the complexity of the system operator, a decrease in the reliability and stability of the energy system (Capehart, 2016).

However, there are several examples of new areas that are fully constructed using distributed energy systems. A successful example is a dynamically developing district of Vienna (Austria) - Seestadt Aspern. All constructed buildings will use low-energy technologies due to their energy-generating plants and large renewable energy systems located within the urban environment, but even a new district, aimed at introducing such technologies, will be able to fully provide only the availability of heat.

Electricity will be provided autonomously by 60-70% after the completion of construction, the remainder will be purchased from the unified power network of the city of Vienna. At the first stages of the implementation of the system, a data center was founded, with the help of which the adaptation of network efficiency is carried out. The key aspect is not only improving the working mechanisms of the current system, but also the ability to share the acquired data with other settlements to improve the quality of energy-saving and energy efficiency. In the long run, experts agree that Smart-cities will be able to transfer experience in regulating operational processes and increase efficiency based on artificial intelligence with virtually no human use. Artificial intelligence will be able to compare information about consumption, possible threats, unforeseen precedents and at the software level update the system to the necessary realities ("Aspern Seestadt," 2015).

Such technologies are already partially used at present and are distributed by specialists in different categories. In the areas of "smart user" and "smart building", the main focus is on optimizing energy use and costs, as well as including the building as an active participant in the energy market. Various technologies are tested in different combinations in them, so the energy-saving adaptation program distinguishes different types of buildings and, accordingly, different levels of consumption in different time frames. The main technology for all types of buildings has been the dynamic generation of energy.

With a non-linear consumption schedule, it is necessary to change the volume of electricity production, including producing energy reserves if, during peak hours, consumption exceeds maximum energy production. This technology becomes relevant when using renewable energy sources. Wind and solar power plants can generate different amounts of energy depending on weather and climate conditions and time of day, therefore, if own generation is operating in suboptimal mode, the efficiency of work decreases and the cost of production of 1 kW·h of electricity increases, but if in households short-term additional purchases of energy will not have a significant financial expense, then at production facilities they can affect the cost of the product and lead to additional costs. For levelling such events, the small-scale energy system must have a system of intellectual adaptation ("Distributed energy," 2019).

In the Seestadt Aspern example considered, each type of building has not only its computing power connected to a single network, a data center but also various modules for temporary storage and energy generation, from which we can distinguish:

• Student housing: production (250 kW), energy storage (120 kW).

• Residential buildings: seven different heat pumps (800 kW), hybrid panels for a solar-thermal generation (75 kW) and photovoltaic system (110 kW), heat storage on the ground (40 MWh), hot water storage, energy storage (20 kW).

• Elementary school/kindergarten building: two heat pumps (510 kW), own production (29 kW), solar thermal generation (90 kW), hot water storage (70 kW).

In the field of intelligent networks, the focus is on automation and monitoring of the distribution network. So, even ordinary power systems require equipping with additional sensors and chips to maintain the functioning of a smart grid of distributed energy. For example, in the analyzed area 12 transformer stations were equipped with 23 transformers of various types of technologies with monitoring through 500 smart meters and 100 sensors in the distribution network ("Aspern Seestadt," 2015).

They are based on an intelligent system of information and communication technologies (ICT), which provides data storage and integration, as well as business analytics and combines both a traditional analysis structure and the detection of data from multicorrelation of several data sources. Maximum efficiency is achieved through mathematical and econometric analysis of possible flaws in system security and control of intra-system losses during generation, storage and transfer of energy and heat.

The widespread adoption of distributed energy is a debatable issue because of the reliability and cost-effectiveness of the technologies used. Despite the positive results of the operation of small energy systems, many EU countries prefer the development of traditional methods of energy generation and consolidation of centralized heat and energy supply systems. Cheap energy sources such as natural gas, delivered in a traditional and liquefied form to the EU member states, can serve as a counterweight. Some gas pipelines and their large branches run close to settlements. The construction of distributed energy systems, especially based on renewable energy sources, is unprofitable in this case, and the decision to switch to other methods of generating and using energy can be implemented only on a state initiative.

Natural gas is also included in environmentally friendly methods of energy generation in the EU and its conversion to central heat and power generating stations may be preferable. Also, the dependence on technology in the case of the distribution of distributed energy increases significantly: the life of individual sections of the system is small and requires regular updates, and smart technologies require separate data centers for storing and processing information, which also increases maintenance costs.

Among other things, such systems can be subjected to external influences and disseminate information about the energy use of individual households in the public domain. On the other hand, distributed energy systems are constantly improving and increasing demand encourages manufacturers to invest more resources in developing safer and more reliable technological solutions. However, even supporters of the introduction of small energy systems point to the impossibility of uniform and equal distribution on the territory of all EU member states. Experts note that the first ready-made solutions will arise in countries with a small population and high incomes, but, over time, cheaper technologies contribute to the introduction of the European Union throughout the sphere of influence (L'Abbate, Fulli, Starr, & Peteves, 2008).

CONCLUSIONS.

As conclusion, it is worth noting the directions of improving energy efficiency and energy security, which brings distributed energy. The basis has used the experience of Austria, Vienna. Also, in Table 1 the economic and functional benefits of using small energy systems are noted.

Table 1. Benefits of introducing distributed energy.

Name of factor	Additional description
Economic benefit	• Allows you to save on costs by reducing peak demand at the facility, as a result, the charge for demand is reduced. • Machine learning and artificial intelligence system provide greater predictability of energy costs (lower financial risk for companies) with renewable energy systems.
Multifunctional	• Provides better reliability and quality of power supply, especially where frequent power outages, power surges. • Facilitates improving the efficiency of equipment for distributed energy when used in combination with combined heat and power equipment for heating, cooling, and drainage. • Provides power for remote areas where traditional transmission and distribution lines are not suitable. Places such as cell towers, small remote cities, are located outside the electric grid and use small energy systems as their main source of energy. • It has combined thermal and energy capabilities. • Reduces overload of power lines. • Facilitates faster deployment of new systems than laying traditional networks on a large scale. • Provides auxiliary benefits, including voltage support and stability, reserves for unforeseen circumstances, and the possibility of starting in black mode (the ability of the generating unit to switch from a shutdown state to a working state and start power supply without using an electrical system).
Productivity/efficiency	• Some equipment of a small energy system provides high-quality power for "interruption-sensitive" installations and data storage. • Small energy systems are built primarily on a modular system, which allows you to add, combine, disband the links of a single energy chain. • In enterprises, backup power and / or the use of third-party power plants reduces downtime, allowing employees to resume work (that is, if it is not possible to produce their energy, the power supply system of the production can temporarily connect other power generating plants that are not used to their full capacity at this moment).
Security/safety	• Enhances the energy security of all network links. • Backup power for fast recovery.
Business continuity	• Provides cleaner, more efficient operation of power plants and reduces emissions. • Reduces network wear due to constant regulation of energy flows. • It has a higher energy conversion efficiency than a centralized system. • Allows more efficient load management.

Source: compiled by the authors according to the electronic resource (Brauner, 2017).

Particular attention should be paid to energy storage systems that are outside the scope of Table 1. At the present stage, it is possible to save only small energy reserves for a short time. The cost of such systems also does not correspond to the possible benefits, except for several social facilities and information storage centers. However, achievements in the production of new types of batteries in the long term can be designated as one of the advantages of distributed energy technologies and increase energy security and energy generation efficiency.

Analyzing the aggregate information on small energy in the EU, we can confidently say that these technologies are only at the initial stage of their implementation in everyday life. However, the swiftness of scientific and technological progress contributes to the leveling of barriers to the massive use of distributed energy and will be able to significantly increase aspects of human life. If the countries of the European Union continue to actively develop small energy, their success can be consolidated and used by other countries, where the problems of energy conservation and environmental friendliness are no less acute.

Acknowledgment.

The publication has been prepared with the support of the "RUDN University Program 5-100". The article has been prepared within the framework of initiative research work No.061605-0-000 titled "Enhancing Economic Efficiency of Distributed Energy as a Condition for Achieving Energy Independence of the Russian Regions", carried out on the basis of the National Economy Department, Faculty of Economics, RUDN.

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RECIBIDO: 10 de agosto del 2019. **APROBADO:** 25 de agosto del 2019