РОЗДІЛ 1

Економіка природокористування і еколого-економічні проблеми

Economic and Environmental Aspects of Smart Grid Technologies Implementation in Ukraine*, **

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Interruptions in electricity supply may have a series of failures that can affect banking, telecommunications, traffic, and safety sectors. Due to the two-way interactive abilities, Smart Grid allows consumers to automatically redirect on failure, or shut down of the equipment. Smart Grid technologies are the costly ones; however, due to the mitigation of possible problems, they are economically sound. Smart grids can't operate without smart meters, which may easily transmit real-time power consumption data to energy data centers, helping the consumer to make effective decisions about how much energy to use and at what time of day. Smart Grid meters do allow the consumer to track and reduce energy consumption bills during peak hours and increase the corresponding consumption during minimum hours. At a higher level of management (e.g., on the level of separate region or country), the Smart Grid distribution system operators have the opportunity to increase the reliability of power supply primarily by detecting or preventing emergencies. Ukraine's energy system is currently outdated and cannot withstand current loads. High levels of wear of the main and auxiliary equipment of the power system and uneven load distribution in the network often lead to emergencies and power outages. The Smart Grid achievements and energy sustainability are also related to energy trilemma, which consists of key core dimensions– Energy Security, Energy Equity, and Environmental Sustainability. To be competitive on the world energy market, the country has to organize efficiently the cooperation of

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public/private actors, governments, economic and social agents, environmental issues, and individual consumer behaviors. Ukraine gained 61 positions out of 128 countries in a list in 2019 on the energy trilemma index. In general, Ukraine has a higher than average energy security position and lower than average energy equity, and environmental sustainability positions. Given the fact that the number of renewable energy sources is measured in hundreds and thousands, the network management is complicated and requires a Smart Grid rapid response.

Keywords: economic development, Smart Grid, electricity supply, economic and environmental efficiency.

УДК 330.3:620.9 *JEL Codes:* Q48, K32, O44

Introduction. The electrical network is always constructed as a one-way transmission system. It consists of one or more very high-power generating plants, which distribute the electricity to final consumers. The transition to renewable energy sources and new intelligent devices require a smart approach to the energy system. Unlike fossil fuels, alternative energy sources are not limited to geologically accumulated reserves. This means that their use and consumption does not lead to the inevitable exhaustion of stocks. With the development of sophisticated energy technologies, it arises as a question of applying them in industrial production, since the bulk of the Ukrainian electric power stations and substations work on "the last century" technologies. Therefore there is an urgent issue at the moment to introduce the work of the new high-tech security devices, monitoring, and control, which are related to the Smart Grid concept.

The analysis of the recent literature. The Smart Building were analyzed by A. Buckman, M. Mayfield, and S. B. Beck [1]. Active buildings in smart grids were analyzed by M. Bulut M. Odlare, et al. [2]. The European smart cities were discussed by A. Kylili, and P. A. Fokaides [6]. The Dynamic characteristics of smart grid technology acceptance were discussed by C. Park, H. Kim, and T. Yong [11], while the Smart metering trends were discussed by J. Leiva, A. Palacios, J. Aguado [7]. However, the general approach in relation to sustainability issues is still deserved scientific attention.

The problem statement. Considering the facts of growing energy consumption and energy dependence of consumers, it is needed to estimate the economic aspects of Smart Grid technology implementation in Ukraine and compare the best available practices in the sphere.

Research results. There are many definitions of the smart grid today. The most general and comprehensive interpretation of smart grids driven were by [3], and the smart grid is considered as a smart electric network and intelligent digital communication technology, which is able to generate energy from renewable energy sources, to provide consumers with real-time information about their consumption. It should be noted that smart grids are also very effective in the work of utility companies to reduce downtime.

Today interruptions in electricity supply, such as the shutdown, may have a series of failures that can affect banking, telecommunications, traffic, and safety. This is a threat during a cold season, when the owners of homes may be left without heat. In this case, the smart grid facilitates the stable operation of the entire power system and make it more ready to address emergencies. Due to the two-way interactive abilities, Smart Grid allows consumers to automatically redirect on failure, or shut down the equipment. However, when there is a power outage, Smart Grid technologies detect and eliminate the problems. In this case, the technology of smart grids can minimize the problems associated with power outages. Smart grids can’t operate without smart meters. Smart meters may easily transmit real-time power

consumption data to energy data centers. Such meters do help the consumer to make effective decisions about how much energy to use and at what time of day. For example, if the consumer has a three-zone tariff, then things like a washing machine will work at night. Similarly, the consumer will be able to connect the electric car to charging so that the battery would start charge at night or early in the morning when the cost of electricity is minimal. Smart Grid meters do allow the consumer to track and reduce energy consumption bills during peak hours and increase the corresponding consumption during minimum hours.

Another important advantage of the Smart Grid is power generators owned by business entities, which are able to generate electricity when it is available from public services. By combining the resources received, the entity may provide the work, for example, a medical center, traffic lights, telephone system, and a grocery store. Thus, Smart Grid technology can solve the problem of the old energy system that needs to upgrade energy efficiency and to solve the issue, to raise consumer awareness of the link between the use of electricity and the environment [3].

At a higher level of management (e.g., on the level of separate region or country), the Smart Grid distribution system operators have the opportunity to increase the reliability of power supply primarily by detecting or preventing emergencies. It is worth emphasizing that the Smart Grid contributes to the energy efficiency of the energy system of a country as a whole. Ukraine's energy system is currently outdated and cannot withstand current loads. High levels of wear of the main and auxiliary equipment of the power system and uneven load distribution in the network often lead to emergencies and power outages. It should be emphasized that Ukraine has one of the highest in Europe indicators of the duration of emergency power outages: 696 minutes per year on average in the country. For comparison, the duration of an emergency power outage in Poland is 180 minutes, in Latvia, it is 104 minutes, and in Germany 13 minutes.

The NRG Expert Research report [9] justified that the introduction of smart grids could reduce CO2 emissions throughout the world. Furthermore, it was found that the intelligent network reduces energy losses and better integrates renewable energy. Therefore, the increased use of intelligent power in the energy system can contribute to reducing carbon emissions. Thus, the introduction of the intelligent network can lead to a reduction of CO2 emissions on 0.9-2.2 gigatons by 2050 [10]. To achieve the goals of the country, it is needed to actively invest in the development of renewable energy sources since the smart grids around the world are linked with the development of renewable energy. In 2017, investments in renewable energy around the world amounted to 279.8 billion US dollars, and China accounted for 126.6 billion US dollars or 45 % of global investment, the United States – 40.5 billion US dollars, and Europe – 40.9 billion US dollars [15].

According to the results shown in Table 1, it is clear that investment in the development of renewable energy sources does not have a permanent nature that may be due to cyclical economic processes – however, the existing capacity of renewable energy sources from year to year increase. In addition, the number of countries that have political interests in the use of renewable energy sources increased by more than 2.2 times.

A recent review of research revealed that the greenhouse gases (GHG) polluters are beginning to take responsibility for damage caused by GHG emissions that can lead to climate change. In this regard, energy generation companies have a strong incentive for the development of energy generation from renewable sources technology [12]. Thus, according to the International Energy Agency, the global investment needed in the development of global energy to 2030 will be about 16 US trillion dollars, including more than $ 2 trillion on

the development of smart grids. The total investment required for the development of the EU energy system (including the expansion of networks (including "smart" grids), the development of renewable energy sources and energy efficiency measures) by 2020, the European Commission assesses the level of 1 trillion euros. According to the Commission, half of the necessary funds can be obtained on the energy market, and the shortfall is proposed to involve the expense of private investment [5].

Table 1

Selected global Indicators for Renewable Energy in 2010 - 2017.

Selected global indicators on renewable energy	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Investment in new renewable capacity (annual) ($10^9$$)	237	279	256	232	270	285	241	279
Power Renewable Energy (existing) (GW)	1 320	1 360	1 470	1578	1 712	1 849	2 017	2 167
Hydroelectric power (current) (GW)	945	970	990	1 018	1 055	1 064	1 096	1 086
Wind power (current) (GW)	198	238	283	319	370	433	487	539
Solar photovoltaic power (from the network) (GW)	40	70	100	138	177	227	303	402
Power solar hot water (existing) (GVtt)	185	232	255	373	406	435	456	472
Production of ethanol (annual) (10^9liters)	86	86	83	87	94	98	98.6	106
Biodiesel production (annual) (10^9liters)	18.5	21.4	22.5	26	29.7	30	30.8	31
Countries with political interests the use of renewable energy sources	98	118	138	144	164	173	176	177

Build by authors according to [17]

In addition, the increase in the consumption of electricity by households leads to the occurrence of peak loads in the network. Some Ukrainian city completely abandoned in favor of the district heating heat due to electrical appliances. This caused additional strain on networks and utility personnel, who have to react quickly to changes in demand. However, Smart Grid technologies can automatically control all processes while minimizing the negative consequences for consumers.

In Ukraine, work on the implementation of Smart Grid technologies began through cooperation with foreign partners, in particular, the Belgian company Tractebel is developing and implementing a number of pilot technologies and Smart Grid projects at the level of the system operator – NEC "Ukrenergo". Distribution system operators at the level of regional energy companies are trying to implement elements of smart electricity networks.

An increase in energy demand among enterprises in different sectors of the economy does indicate the development of production. Failures in the power supply in industrial facilities lead to downtime and disruption of stable operation. In this regard, the development of the Smart Grid concept could improve network reliability and economic security of separate business, while providing immediate user switch to the backup power source when a primary failure occurs [7].

According to the rating Doing Business in Ukraine, some of the indicators make it possible to evaluate the investment attractiveness of almost all countries and compare them. One of its key indicators and important criteria of business interest in the country is the speed of the connection to the power grid. Therefore, the full Smart Grid implementation increases the reliability of the network, allows business and consumers to more quickly eliminate emergency situations and rapidly connect new businesses to the electricity network [14, 15].

Smart Grid achievements and energy sustainability are also related to the so-called energy trilemma. According to the World Energy Council [16], energy trilemma consists of key core dimensions – Energy Security, Energy Equity, and Environmental Sustainability. Only progress in all three dimensions (Energy Security, Energy Equity, and Environmental Sustainability) promotes positive changes in the energy development of a specific country. To be competitive on the world market, the country has to organize efficiently the cooperation of public and private actors, governments, economic and social agents, environmental issues, and individual consumer behaviors. The top ten countries in 2019 according to the energy trilemma index are Switzerland, Sweden, Denmark, the United Kingdom, Finland, France, Austria, Luxembourg, New Zealand. To be more specific, Ukraine in 2019, has a 61 position out of 128 countries in a list. In general, Ukraine has a higher than average energy security position and lower than average energy equity and environmental sustainability. The Ukraine progression in 2019 is shown on figure 1.

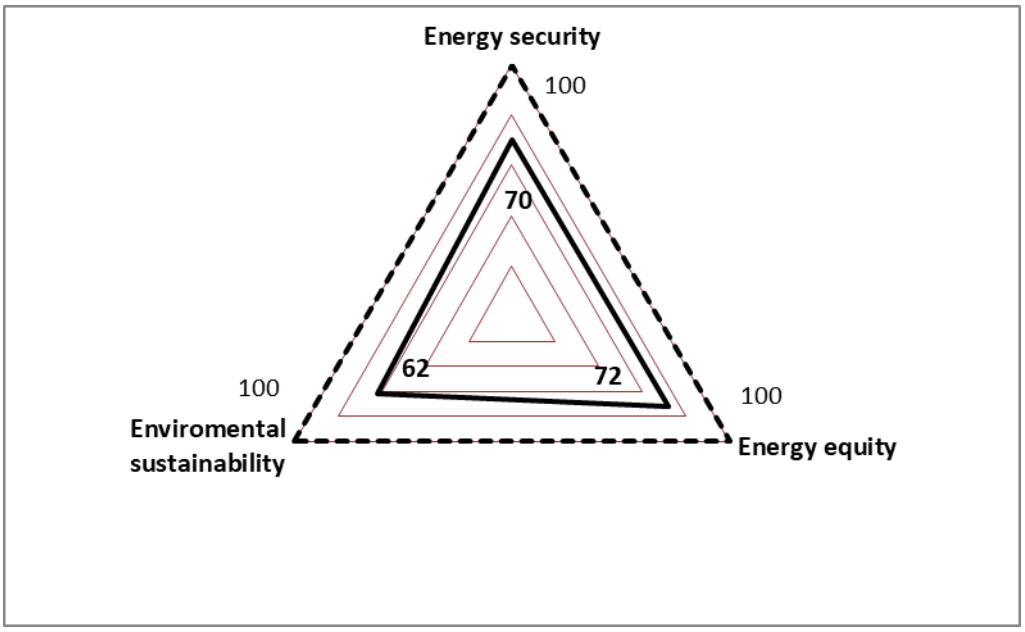

Figure 1. Energy Security, Energy Equity, and Environmental Sustainability of Ukraine in 2019 (build by authors according to data [16])

Decisive action on the implementation of smart grids was held by the Ministry of Energy and Coal Industry of Ukraine. For example, November 8, 2017, under the chairmanship of the Director of the Department of Electricity Sector O. Buslavets at the annual International

Forum "Fuel and Energy Complex of Ukraine: Present and Future" held a roundtable on the topic: "The concept of Smart grid and the need to introduce elements of Smart grid-technologies in the context of electricity market reform. "Ministry of Energy and Coal Industry of Ukraine with the support of the World Bank is currently implementing a comprehensive development of smart grids Concept project in Ukraine until 2035 and the medium-term plan for the implementation of measures for their implementation" [8]. To achieve its goals it is necessary to create a working group with the participation of relevant central bodies of executive power, electricity market participants, and experts in the field of energy for the development and approval of the Concept and Action Plan. In addition, the implementation of the of Smart grid concept plan includes the development of an appropriate legal and regulatory field and technical support, the ability to integrate green energy sources and to ensure the implementation of international standards for interoperability of equipment intelligent network conforming to the regulations and specifications [12, 13].

National Energy Company "Ukrenergo" is actively working on a project for the implementation of the country's system of Smart Grid intelligent networks. The project has implemented smart grid power transmission-2, funded by the International Bank for Reconstruction and Development (IBRD), with the assistance of Clean Technologies Fund. In particular, it provides for the introduction of a number of pilot technology and Smart Grid project at the System Operator (Table. 2).

Table 2

The pilot technology implementation and Smart Grid projects at the level of the system operator [13]

Hosting Project component	Characteristic
Observability	To ensure 100 % real-time observability in its substations and create the conditions for the adoption of new telemetry volumes with distribution companies and distributed generation from renewable energy sources.
RES Forecasting	The introduction of prediction generation system generating RES
Virtual Power Plant & Demand Response & V2G	Levelling effects of the stochastic generation of renewable energy generation and consolidated with the generation of the RES
Grid CIM Modeling & Transparency	The creation of an integration platform for the collection of technical data of the power system

The aim of implementation of pilot technology and Smart Grid projects at the level of the system operators are to reduce CO2 emissions by ensuring the technical possibility of increasing the share of generation from renewable energy sources (RES) in the total energy balance of the country [13].

One important point in the work of Smart Grid is the ability to effectively integrate power plants into renewable energy sources to combat climate change. The current global trend in energy is reducing CO2 emissions, i.e., reducing the share of power plants that burn coal, gas, and fuel oil. An important step towards decarbonization is the development of the green energy sector. However, the production of renewable electricity sources is very dependent on

weather conditions, and therefore variable over time. Given the fact that the number of such stations is not measured in units, but in hundreds and thousands, network management is complicated and requires such a rapid response that a human can no longer cope with such a large amount of information. It is needed to combine thousands of power systems into one to use Smart Grid automation.

Conclusions. Thus, there is a vivid need to implement Smart Grid technologies due to the economic aspects, both for individual households and for business in general. As for the business, it constantly contributes to the timely release of the product, its sales, and profits, and as a result of the replenishment of the state budget. Currently, the appropriate steps to stimulate the introduction of smart grid projects are actively taken at the legislative and organizational level, to make a proper field and technical support to integrate RES and ensure the implementation of international energy security standards. The Smart Grid contributes to the efficiency of the energy system as a whole. Ukraine's energy system is currently outdated and cannot withstand current loads. The positive influence of Smart Grid technologies is empowering the higher level of management and creating an opportunity to increase the reliability of electricity supply primarily by detecting or preventing emergencies. According to the energy trilemma approach, only the progress in energy security, energy equity, and environmental sustainability promotes positive changes in energy development. Ukraine has a higher than average world energy security position and lower than average the energy equity and environmental sustainability position, which leads to 61 positions out of 128 countries in a World energy council list.

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Экономические и экологические аспекты внедрения технологий Smart Grid в Украине

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Перебои в электроснабжении, такие как отключение, могут привести к ряду сбоев и повлиять на банковскую деятельность, телекоммуникации, трафик и безопасность. Благодаря двусторонним интерактивным возможностям Smart Grid позволяет потребителям автоматически перенаправляться при сбое или выключать/включать оборудование. Технологии Smart Grid являются дорогостоящими, однако из-за уменьшения возможных проблем они экономически выгодны. Интеллектуальные сети не могут работать без интеллектуальных счетчиков, которые могут легко передавать данные о потреблении энергии в режиме реального времени в центры энергетических данных, помогая потребителю принимать эффективные решения о том, сколько энергии использовать и в какое время суток. Счетчики Smart Grid позволяют потребителю отслеживать и сокращать счета за потребление энергии в часы пик и увеличивать соответствующее потребление в течение минимальных нагрузок на энергосистему. На более высоком уровне управления (например, на уровне отдельного региона или страны) операторы распределительной системы Smart Grid имеют возможность повысить надежность

электроснабжения, прежде всего, путем обнаружения или предотвращения аварийных ситуаций. Энергетическая система Украины в настоящее время устарела и не может выдерживать текущие нагрузки. Высокий уровень износа основного и вспомогательного оборудования энергосистемы и неравномерное распределение нагрузки в сети часто приводят к аварийным ситуациям и отключениям электроэнергии. Достижение цели Smart Grid и энергетическая устойчивость также связаны с энергетической трилеммой, которая состоит из ключевых аспектов – энергетической безопасности, энергетического равенства и экологической устойчивости. Чтобы быть конкурентоспособными на мировом энергетическом рынке, стране необходимо эффективно организовать сотрудничество государственных и частных субъектов, правительств и регулирующих органов, экономических и социальных факторов, национальных ресурсов, экологических проблем и поведения отдельных потребителей. Украина получила 61 позицию из 128 стран в 2019 году по индексу энергетической трилеммы. В целом Украина имеет более высокие, чем в среднем, позиции в области энергетической безопасности и ниже, чем в среднем, позиции в области энергетической справедливости и экологической устойчивости. Учитывая тот факт, что количество возобновляемых источников энергии измеряется сотнями и тысячами, управление сетью является сложным и требует быстрого реагирования Smart Grid.

Ключевые слова: экономическое развитие, Smart Grid, электроснабжение, экономическая и экологическая эффективность.

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Економічні та екологічні аспекти впровадження технологій Smart Grid в Україні

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Перебої в постачанні електроенергії, такі як відключення, можуть мати ряд збоїв, які можуть вплинути на банківську діяльність, телекомунікації, рух транспорту та безпеку. Завдяки двостороннім інтерактивним можливостям, Smart Grid дозволяє споживачам автоматично

перенаправлятись на інше джерело та вимикати/вмикати обладнання. Технології Smart Grid є зазвичай дорогими технологіями, однак через зменшення можливих проблем вони є економічно обґрунтованими. Розумні енергомережі не можуть працювати без розумних лічильників, які можуть легко передавати дані споживання електроенергії в реальному часі в центри даних енергоносіїв, допомагаючи споживачеві приймати ефективні рішення щодо використання енергії в кожен окремий час доби. Smart Grid лічильники дозволяють споживачеві відстежувати та зменшувати рахунки за споживання енергії у години пік та збільшувати відповідне споживання протягом мінімальних енергозавантажень системи. На більш високому рівні управління (наприклад, на рівні окремого регіону чи країни) оператори розподільної мережі Smart Grid мають можливість підвищити надійність електропостачання насамперед шляхом виявлення або попередження надзвичайних ситуацій. В даний час енергетична система України застаріла і не витримує поточних навантажень. Високий рівень зносу основного та допоміжного обладнання енергосистеми та нерівномірний розподіл навантаження в мережі часто призводять до аварійних ситуацій та відключення електроенергії. Досягнення Smart Grid та енергозбереження також пов'язані з енергетичною трилемою, яка складається з ключових основних аспектів - енергетичної безпеки, енергетичної справедливості та екологічної стійкості. Щоб бути конкурентоспроможною на світовому енергетичному ринку, країна повинна ефективно організувати співпрацю державних та приватних суб'єктів, урядів та регуляторів, економічні та соціальні фактори, національні ресурси, екологічні проблеми та поведінку споживачів. Україна отримала 61 місце із 128 країн у 2019 році за індексом енергетичної трійки. У цілому Україна має вищу середню позицію щодо енергетичної безпеки та нижчу за середню позицію щодо енергетичного капіталу та екологічної стійкості. Зважаючи на той факт, що кількість відновлюваних джерел енергії вимірюється сотнями і тисячами, управління мережею є складним і вимагає швидкої реакції Smart Grid.

Ключові слова: економічний розвиток, розумні енергомережі, електропостачання, економічна та екологічна ефективність.

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