DIGITAL ENERGY. WHY THIS IS THE FUTURE OF ENERGY MARKETS?

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Abstract.

The rapid development of renewable energy leads to a significant increase in their share in electricity generation, therefore the issue of integrating unstable energy sources into the network without weakening the reliability of the system is on the agenda in many developed countries. In addition to the increase in the share of RES in the national energy balance, the instability of energy supply and demand is exacerbated by the development of distributed generation, the electrification of passenger transport, as well as the heating and cooling sectors. Ukraine cannot ignore the fact of global changes in the technological model in the power industry and related challenges and shifts in the development of the industry. Otherwise, the country will face a number of risks. The first of them is the risk of getting more expensive and less flexible electricity compared to other industrialized countries, losing a number of new markets (for example, the energy storage market) and significantly limiting the development of a new (digital) industry.

Basic concepts (Introduction). A comprehensive approach to energy transformation is developed in the trendy concept of "3D" (Decarbonization, Decentralization, Digitalization). Decarbonization ("decarbonization") - the transition to an ecologically clean "carbon-free" economy and energy, which is combined in an increase in the share of RES in the energy balance, an increase in the share of electric transport and high taxes on the use of fossil fuels. Decentralization ("decentralization") - the transition to a territorially distributed electric power industry with a large number of different level producers and consumers, which is expressed in the growth of the share of low-power and diverse energy sources connected to distribution networks; the emergence of prosumers - a new type of electricity industry entities that are both producers and consumers of electricity; the emergence of active consumers who use electricity flexibly, including by remote commands, capable of changing the profile of their consumption from the network. Digitalization ("digitalization") - the transition to large-scale use in the electric power industry of digitally controlled devices connected to the Internet information network at all levels of the energy system from production and electrical networks to end-user devices. Electricity consumers, which provide the possibility of implementing intelligent management of power systems, based on the basics of machine (M2M, IoT) interaction. In this article we will be using a few more new terms that describe the functioning of the 3D energy system, so let's define them to avoid conflicting interpretations and use modern definitions freely.

Blockchain is a distributed database that stores information about all transactions of system participants in the form of "chains of blocks" (that's how Blockchain is translated from English). Access to the register is available to all users of the block, who act as collective notaries, which confirms the truth of the information in the database.

Smart contract (English Smart contract - smart contract) is a computer algorithm designed for concluding and maintaining commercial contracts in blockchain technology. For the first time, the idea of a smart contract was proposed in 1994 by Nick Sabo (USA) - a scientist in the field of informatics, cryptography and law. He described a smart contract as "a digital representation of a set of obligations between parties that includes a protocol for fulfilling those obligations."

A modern example of the idea of a smart contract can be called the work format of Uber companies. Aggregators play the role of an intermediary and arbitrator, who ensures the execution of the agreement between the taxi driver and the client: the client agrees to pay for the trip at a price

determined in advance by the intermediary system (aggregator), and the driver, in turn, undertakes to perform the service of transporting the client to predetermined place.

Peer-to-peer, P2P (from English - equal to equal) is a variant of the system architecture, which is based on a network of equal nodes. Computer networks of the peer-to-peer (or P2P) type are based on the principle of equality of participants and are characterized by the fact that their elements can communicate with each other, unlike the traditional architecture, when only a separate category of participants, called servers, can provide certain services to others.

One of the possible areas of application of such an approach is the "Internet of Energy" - a type of decentralized electric power system in which intelligent distributed management is implemented through energy transactions between its users.

"Internet of energy" - according to the Navigant research "Transactive Energy Markets", which was published in 2018 - is a peer-to-peer electricity industry, in which interaction between producers and consumers of electricity, trade in electricity and various services, as well as regime management of the energy system are carried out through direct transactions between users. Simply put, the energy system becomes multi-vector, all participants of the energy market will have many functions, such as the supply of electric energy, participation in mode control and maintenance of frequency and voltage level, provision of energy equipment for "virtual" rent, provision of power reserves and any other types services that can be provided in the power industry.

Basic information. Many international energy companies are currently developing projects that in the future will unite all consumers in one network - a decentralized system. There is an opinion that in 2050, the entire global energy industry will work like this. Closer to the consumer. With a decision-making center distributed evenly among all participants. Let's do a little research. What are the advantages of such a system? With the help of smart contracts, the existing multi-level system consisting of electricity producers, distribution network operators, billing operators, a provider of payment banking services, traders and consumers themselves will be simplified. All transactions for receiving and paying for energy will be performed directly in the network, which unites equal participants - energy producers and consumers. Thanks to this, electricity will become cheap. But you and I are not simple readers, we understand that there will never be cheap energy again.

A set of such microgrids will minimize the amount of energy lost through long-distance transmission. The World Bank website has statistics on losses in main and distribution transmission lines. Interestingly, Ukraine loses 11% of the produced energy. They say this is mainly due to losses in low-voltage networks. It is neither much nor little. Leave such assessments to the "experts". This is a number. And where else is so much? Bangladesh. Botswana. Colombia. Costa Rica. Egypt. Salvador. Jordan. Oman. Peru. Romania. Sri Lanka. The lowest figures are 2-3%. Trinidad and Tobago - due to distributed generation. the place of generation and consumption coincide. Or Korea - at the expense of manufacturability. The maximum is 73% in Togo and 70% in Libya. And it's not about worn equipment. Electricity is stolen there. There is no money to pay. Microgrids provide alternative both technological chains and business models.

And if you focus on manufacturability, such an energy system will allow adding flexibility to all participants. Energy system flexibility is a new term that originates from the Western energy business environment. Two sources of flexibility are distinguished: distributed energy sources and electricity demand management. The English network operator Ofgem defines flexibility as the ability to change patterns (modes) of energy production and consumption in response to external, usually price signals for the provision of system services. The economic benefit from increased flexibility in the English energy system is estimated at £17-40 billion in 2020-2050.

The first case of energy transfer using blockchain was recorded in 2016, when a resident of Brooklyn sold excess renewable energy to his neighbor using a smart contract on the Ethereum platform. After that, many Western energy companies became interested in this technology. Over $300 million was invested in energy projects based on the blockchain during the year.

Projects like the one implemented for the first time in Brooklyn allow the community to choose a green energy alternative. That is, your coffee shop can buy electricity from a local solar power plant, instead of coal, which is unfriendly to the environment of the holding company. Another motive is the

reliability of localized sources of electricity. For example, hurricanes like Sandy caused a series of power outages in the US in 2012 and experts questioned the reliability of the network. Long power lines aren't needed for the Brooklyn Energy Cooperative, so they can't be damaged by increasingly regular extreme weather. Thanks to Brooklyn-based LO3 Energy's partnership with Siemens, the project already includes a grid management system that allows electricity to be generated when needed and delivered to hospitals, shelters and community centers.

"This whole concept is very beneficial for the region in which you live. When buying energy locally, rather than from a national authority, the money goes back into the pockets of people living in the community. We have established a transactional network platform that is largely self-powered, resulting in energy being priced automatically and consumers taking care of it. We believe that in this way we will be able to better meet the needs of consumers. Going forward, we plan to empower people, set preferences for maximum savings, do good in the community, and potentially sell energy more cheaply to lower-income residents" - Joseph Lubin, co-founder of the network. We are now considering expanding such microgrids to other communities in New York State, to reduce the cost of electricity to consumers and promote clean energy.

World trend.

On the eve of the Blockchain2Energy Asia forum, which will be held on November 27, 2018 in Singapore, a fresh "hit parade" of Asian blockchain projects in energy was released. These projects claim to become the "main caliber" of future trends.

Many of the projects are led by technological consortia, which, in addition to technological startups, include banks, large companies of the industry, retailers and universities.

The rating includes services for the sale of surpluses from RES-microgeneration, p2p electricity markets, emission reduction accounting and "carbon credits", "green" certificates and consumer ratings, "flexibility" markets and even the usual energy retail.

The business model looks like this (figure 1).

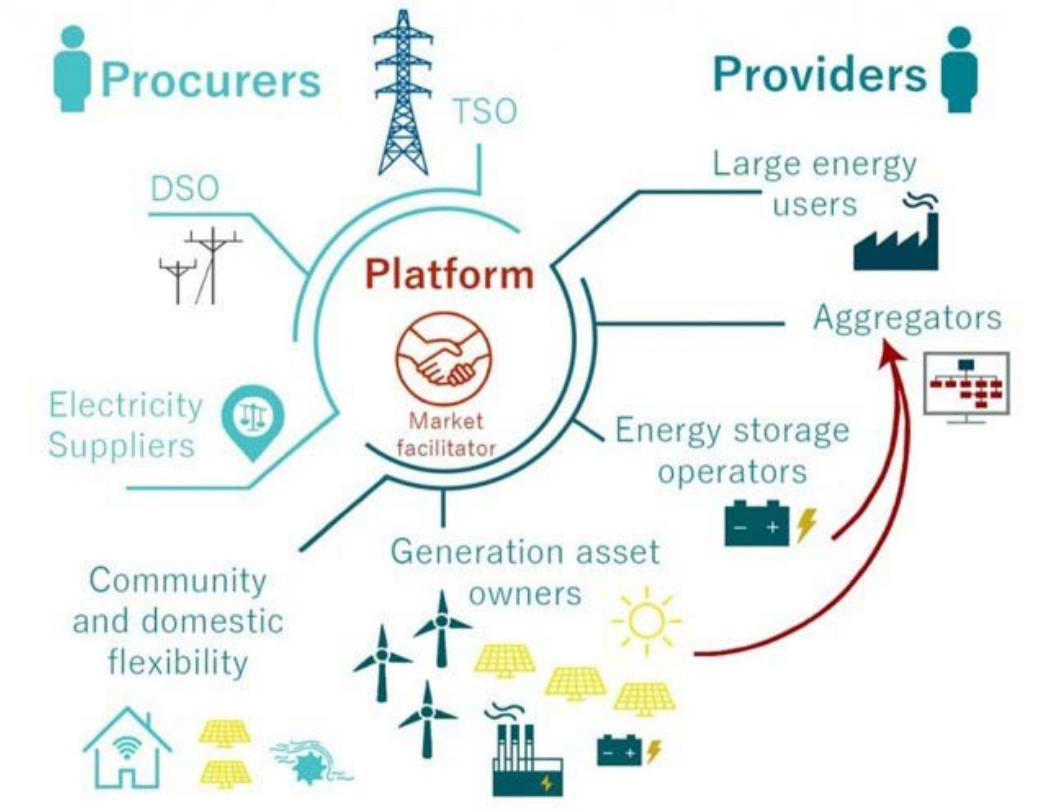

Figure 1. The structure of the local flexibility market. Source: Regen SW.

Since the start of the decision, when the Japanese government allowed retailers to sell surplus "green" energy on the open market, the number of customers of the energy company Tokyo Electric Power has fallen by 15%. In Japan, the world's largest cluster of distributed electricity storage systems, controlled by artificial intelligence, was launched. It is created by UK-based MOIXA, one of the portfolio companies of First Imagine! The system connects more than 3,500 households and 35 MW · h of battery capacity and ensures coordinated optimal charge and discharge management of batteries connected to the grid.

The project is implemented by an international technological consortium: the trading house ITOCHU manufactures and sells Smart Star storage units, the sales company TRENDE sells electricity to households at a special idenki tariff that encourages the use of storage units for offloading the energy system, NF Corp. provides an IoT platform for remote access to drives, finally, MOIXA acts as an AI service provider for coordinated management of the Grid Share network of drives.

The further plans of the consortium to deploy a p2p market for households, electric car charging networks, demand response services, including the possibility of participating in frequency support in the network and operation in the mode of a virtual power plant (VPP) are impressive on the basis of the same infrastructure.

Great prospects are seen in the development of decentralized digital energy technologies in the desert states of the Persian Gulf - Bahrain, UAE, Qatar. Well, first of all, because of the colossal potential of solar energy, which few paid attention to due to the rich, almost inexhaustible, reserves of oil and gas. Well, imagine, in Bahrain, the capacity of solar power plants is about 10 MW. This is 100 times less than in Ukraine. In the United Arab Emirates, the installed capacity of solar photovoltaic plants is only 160 MW. The SES indicators in Qatar are somewhat similar to the UAE. But, already today these countries are preparing for the implementation of grandiose plans for the deployment of solar energy and smart systems for managing these assets based on digital technologies. And this is not surprising, because the solar insolation there is one of the highest in the world, and this is their new oil.

Another interesting aspect of the development of decentralized digital energy structures is the life support systems of famous skyscrapers in the Persian Gulf. It is promising to implement integrated solutions using renewable energy in a building-to-grid approach: solar panels or wind generators as an architectural element of the structure, built-in storage devices, smart meters, demand management systems aimed at total optimization of consumption and management of the skyscraper. An example of such a system is the Burj Khalifa Tower - a "vertical city". Imagine - 35,000 visitors-residents-workers, 57 high-speed elevators, 30,000 thermal panels that equalize the temperature of the building's surface, a single system of air conditioning and aromatization (the unique aroma - an integral component of the design of the tower - was created by Armani), a water supply and water supply system cooling with a turnover of 946 thousand liters of water per day and hundreds of other unique engineering systems. All this, despite compliance with the very strict LEED energy efficiency standard, makes the skyscraper a very large consumer, the peak power of which reaches 50 MW. But 828 meters is not the limit, only two even more ambitious projects are currently being implemented in neighboring countries: The Tower in the Dubai Creek Harbor area with a height of 928 meters and Jeddah Tower in Saudi Arabia with a height of 1007 meters for 80 thousand people. And their effective and reliable livelihood system is impossible without digital technologies. Imagine a state that is a collection of energy-independent island cities, megacities formed from skyscrapers that provide themselves with energy, or buy surplus production from a neighboring skyscraper using smart contracts that function on blockchain platforms. This is significantly different from how the system works now and what we are taught by professors in universities.

Prospects and challenges.

Let's remember what we started with - the 3D energy system of the future consists of three components - decarbonization, deregulation, digitalization. The first step in the evolution of energy systems should be the transition to comprehensive planning of the development of energy systems based on the indicator of the system value of variable energy sources - value of VRE. This indicator evaluates the reduction of fuel consumption and greenhouse gas emissions, optimization of capital costs of

generation, as well as transportation and distribution of energy instead of the existing simplified approach - estimation of the normalized cost of electricity (LCOE). This is about the balanced distribution of low-emission electricity generation and the need to ensure system reliability.

As for the spread of the smart contract mechanism in unregulated markets, they are guaranteed to develop, but for their effective use, you need:

First, overcome the lack of a technological base in the form of solar panels, wind turbines, energy accumulators on a national scale. When new technologies become widespread, or are implemented concentratedly in local communities, then people will be able to use the blockchain for their own purposes, unite in conglomerates, implement mutually beneficial technological strategies and financial mechanisms.

Secondly, due to the uncertain legal status of the entire crypto industry, public and private energy companies cannot fully implement projects based on smart contracts due to the growing reputational risks, system failures, job guarantees and other aspects that can affect the functioning of power networks. That is, the system will work when the banner "To prepare your favorite dishes, we buy only ecologically clean energy from local rooftop solar power plants for bitcoins" will appear on the window of your usual restaurant.

Domestic perspectives. There are 6.5 million private households in Ukraine. As of the end of the II quarter of 2018, the total number of solar stations of private households with a "green" tariff is 4,660 stations, of which 1,650 stations were installed in the I half of 2018. Thus, even less than one percent of private households are equipped with rooftop solar power plants. In 6 months of 2018, the total installed capacity of solar stations of private households increased by 38 MW and amounted to 89 MW. Since 2015, more than 88 million euros have been invested in the installation of solar power plants by private households. The notional cost of one kilowatt of installed capacity for the average household was $1,000, although we understand that this has changed over the years. The leaders among the regions of Ukraine in terms of the total number of private households that have installed solar power plants are: - Kyiv region – 602 households; - Dnipropetrovsk region – 541 households; - Ternopil region – 365 households. Such players can become the first pool of smart contract participants based on blockchain technology.

In addition, the business community and large enterprises may be interested in their own participation in distributed generation, regulation and system optimization of financial settlements. Why so? First of all, because the cost of electricity for large consumers in Ukraine already in some places exceeds the prices for industrialists in the United States and Europe. And its quality often leaves much to be desired. This negatively affects the export potential of Ukrainian enterprises, because the high cost of electricity reduces competitiveness, especially taking into account the high energy intensity of domestic production. In many countries of the world, this situation motivates the development of new methods of energy production, the localization of networks to avoid losses during transportation, and the creation of independent financial settlement tools that will allow to ensure access to clean and reliable energy for associations of like-minded people, such climate pragmatists. People who want to use clean energy, know how to implement the latest technologies and are used to valuing their own investments.

Wars have shown that the world turned out to be more pragmatic than we thought, and the arrangement of its energy forces greatly affects the course, results and, unfortunately, the beginning of new wars. The new order of arrangement of the world and security, of course, cannot take place without the new order of the energy market.

Politically, a number of interventions have been made, which indicate that the stock markets of Europe will also change. For many years, Russia also worked on building a favorable architecture of the energy world. The EU's dependence on gas supplies allowed the aggressor to control energy prices there and influence the economy.

The jump in gas prices was the cause of unprecedented peaks in the price of electricity in the second half of 2021 and in the first half of 2022. Countries with low capacity for cross-border flows of electricity and relying on gas for its generation were the most affected.

As early as October 2021, the European Commission began to respond to the increase in the price of gas and electricity, and in August 2022, gas prices reached an unprecedented peak - 1000% compared

to prices in previous decades. It is clear that the cost of natural gas is naturally reflected in the price of electricity.

First of all, this is explained by the fact that the basis of the reliability of electricity supply is ensuring the flexibility of the electricity network, that is, its ability to respond to sudden changes in demand and supply.

Actually, for the second year, experiencing attacks on the energy sector, every Ukrainian understands well what balancing of the power grid is and how it is ensured at the expense of flexible generation. But even in peacetime, this is not an easy job, especially in periods of active generation of renewable electricity, the share of which should increase within the framework of the Fourth Energy Package.

There is another technical factor that provides a mechanism for determining the price of electricity, depending on the price of fossil fuels. Commission Regulation (EU) 2015/1222 (Article 38) introduced European market practice, according to which the unification of electricity exchanges in the day-ahead market should be based on the rule of marginal pricing.

This means that all accepted supply requests have the same price per trading area and time unit, and are satisfied at the highest rate. As a rule, this limit price is set by power plants operating on fossil fuels (coal, oil or gas).

This method should guarantee that "green" generation will receive a profit for the return of its investment, increase such green generation, which will further reduce prices.

However, the current energy crisis demonstrated the insufficient readiness of the pricing mechanism in crisis situations. Although in 2014 the Commission assessed the impact of its pricing guidance, it did not analyze the consequences or alternatives to the model in situations where the resource balance is disturbed, such as the price of gas.

Critics of the pricing model point out that the model is not able to ensure investments in low-carbon generation, because only state investments in such support have been growing in the last 10 years.

In the event of a sharp price increase, the method can generate unreasonably high profits for power producers who operate at much lower cost. Thus, gas prices increased by 400% in the second half of 2021, and average electricity prices increased by 200%. No previous analysis of long-term scenarios in the EU included such a price jump. Attacking in February 2022, Russia understood that a second wave of price shocks would occur in the EU, which, by design, should influence the EU's determination to support Ukraine. It is very easy to influence the price in conditions where demand for gas has been stable and other supply alternatives are limited (domestic EU production has fallen by 2/3 since 2010). Initially, in 2022, the increase in electricity prices was higher than for gas, so gas generation even made money from it. And then this increase in gas generation consumption provoked a jump in short-term hub prices.

The average monthly TTF in 2022 was 7 times higher than that of the previous 5 years and was 130 EUR/MWh, and in the injection season (2nd and 3rd quarter) it was 160 EUR/MWh.

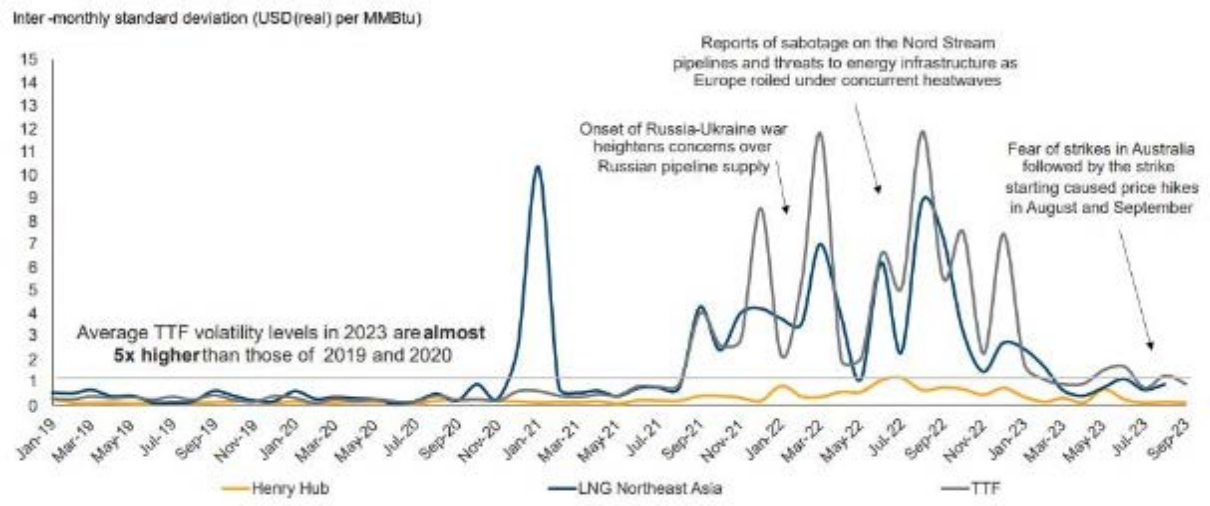

Figure 2. Current energy deviation (USD/MMBtu).

The enemy's plan did not work and the EU reacted. The series of measures implemented gives us a clear understanding that we are entering a new era of the energy world. So far it only looks like a sketch, but the basic framework is already drawn. To be able to imagine a comprehensive picture of the future, it is worth dealing with the input data.

The first thing to understand is that the EU gas market also exists far from under conditions of perfect competition. Pricing relies on two purchasing models: competitive transparent bidding on organized markets (hubs) and long-term and bilateral contracts.

At the same time, indexation to the hub is often used in the prices of direct contracts. Some experts point out that it is the dependence on short-term dynamic hub trade that made gas prices more sensitive to the factors that caused the price jump in the summer of 2022.

In March 2022, the EU agreed on a plan of measures to reduce gas dependence on Russia by reducing imports of Russian pipeline gas, reducing dependence on fossil fuels, diversifying energy supply (including LNG and infrastructure for its supply), accelerating the development of RES and hydrogen, increasing energy efficiency. Most of the measures were unveiled in May in the REPowerEU plan, covering the following aspects:

- New rules for gas storage, so that storages in the EU are filled before winter (80% of capacity for 2022/2023 and 90% for the following winter periods) and can be distributed among member states in a spirit of solidarity.

- Joint procurement of gas, LNG and hydrogen through the EU Energy Platform. Aggregation of demand should cover at least 15% of storage in each country and exclude Russian gas.

- EU Regulation 2022/2576 "Strengthening solidarity through better coordination of gas purchases, reliable price benchmarks and exchange of gas across borders" introduced a mechanism of solidarity of flows in the event of gas supply interruption, when the affected country must be supplied with gas by another country with appropriate compensation. The regulation mandates ACER to develop and publish a new daily LNG price indicator and a daily LNG benchmark. The goal is for LNG buyers and sellers to rely on the new benchmark in their contracts, instead of tying them to turbulent TTF pipeline gas prices.

- In February 2023, the Market Correction Mechanism (MCM) was introduced, which sets the gas price limit in the EU. MSM applies to one-month, three-month and one-year forward exchange derivative contracts and should be triggered automatically if the price of TTF M+1 exceeds 180 EUR/MWh for three working days and if it exceeds by 35 EUR the base price of LNG on world markets for the same three days.

- A complex of actions to reduce demand and increase energy efficiency set the goal of voluntarily reducing gas demand by 15%. As a result, the reduction was 19%, but it was partly achieved due to the high cost of gas for the consumer.

- As electricity prices will remain high while the EU refuses Russian gas, an emergency aid resolution was adopted.

The measures included accelerating the use of RES, reducing total electricity consumption by 10% and by 5% during peak hours, allowing the temporary introduction of regulated electricity prices for small and medium-sized businesses and households, limiting the income of non-gas electricity producers to 180 euros per MWh (RES, nuclear power, lignite) to pass on the surplus to consumers and the revenues of other fossil fuel producers, whose profits have increased by more than 20% compared to the average profit of the previous 4 years.

The final confirmation that the new stock exchange world will not be the same as before is given by the vision of the reform of the structure of the electricity market (Electricity Market Design - EMD). On October 17, the EU Council reached an agreement on the design change and negotiations with the European Parliament will begin.

The process continues these days and the final decisions have not yet been made, but it is clear that the stability of energy prices is the basis on which the new design is planned to be built. The reform aims at stable long-term markets by encouraging PPAs, bilateral contracts for difference (CfD) and improving the liquidity of the forward market by providing new hedging elements.

As part of this, ACER proposed a complete change in the landscape of the forward market, which involves the creation of virtual trading hubs and the issuance of transmission rights. That is, the idea is for the forward market to work as a single integrated EU market, when the price according to the generally accepted methodology is calculated at the central hub (for example, the weighted average of regional hubs), and the participants get the opportunity to hedge at the price of the regional hub, while the trade at the regional hub is supplemented trading of financial transfer rights.

The EU stock exchange community has criticized some aspects of the EMD. In particular, the nominated operators of the electricity market are against the introduction of a single legal entity to manage the unified market, which, in their opinion, may threaten the already established unified short-term electricity market (Single Day-ahead Coupling - SDAC and Single Intraday Coupling - SIДC) and may become the first step to a de facto monopoly of stock trading.

In general, the concern of our European colleagues is quite understandable, as they protect their business when they have to fundamentally rebuild their well-established markets, which nullifies their achievements in creating forward market hedging mechanisms.

EU exchanges also do not support mandatory PPA, exchange of order portfolios on the short-term physical market (currently exchange is carried out only if there is cross-border capacity), limitation of cross-border income and obligations to purchase additional flexibility products of OSP and OSR.

In 2023, the volume of exchange trading increased significantly, because lower prices required less capital to hold futures positions, and because price volatility stimulated the need for hedging and speculative trading (including the exhaustion of bilateral credit limits with most counterparties).

After the summer of 2022, some EU countries have even provided financial assistance and guarantees to support the liquidity of organized markets to help participants, in particular electricity producers, cope with margin requirements on previously exposed futures positions.

The transition from OTS to the exchange market was also caused by the need for clearing due to high risks of non-execution of transactions. The EU continues to call for new price hedging strategies, including the use of forward and long bilateral contracts to reduce price pressure, but for this there must be high liquidity outside the spot market.

Preliminary estimates indicate that prices will continue to depend on global competition for LNG with Asian markets. As such, the availability of infrastructure to be able to physically obtain gas and transparent access to new LNG terminals remains a key factor.

The redistribution of electricity producers' income will obviously continue to be used as a source of funding for decarbonization goals, the speed of which will affect the volume of sustainable LNG needs. The market for relationships with liquefied natural gas has not yet been formed.

Therefore, opinions in the EU are polarized between the understanding of some that it should be a long-term import with an appropriate legal basis, and the understanding of the fighters for the preservation of the already established order - that spot and short-term contracts on hubs remain decisive

in price formation, since such an approach can even out the disparities of equal and transparent access to the infrastructure of terminals.

There is no way back. The global world has set itself the goal of transitioning from unlimited energy use to a more environmentally friendly approach to energy resources. This approach is recorded in the Sustainable Development Goals of the United Nations until 2030, which Ukraine also supports. The existing world trend of appropriate use of energy resources is also aimed at reducing the negative impact on the environment.

However, it is one thing to declare, another to fulfill the declaration. Changing the outlook on energy production and consumption in society is not an easy task.

Ukraine is confidently following the course of energy efficiency, but it is still not enough. Ukraine's relatively small economy consumes quite a lot of energy. Thus, Ukraine's share in world energy consumption is 0.6%, which, at the same time, is three times higher than its share in the world economy, which is 0.2%.

In addition, taking into account the fact that energy consumption in Ukraine largely depends on the available volumes of gas, the price of which shows a significant increase in European markets, it is worth using all available opportunities to reduce dependence on natural gas, and use this resource only as an energy carrier for balancing capacities in the transition period.

According to the data of the State Agency for Energy Efficiency and Energy Saving of Ukraine, 45% of final gas consumption falls on the household sector, and it is here that low energy efficiency can be noted. In particular, low thermal insulation of buildings leads to irrational use of gas as a source of energy for heating. Energy efficiency measures, in turn, can reduce total gas consumption by 10-20%.

One possible way to improve the situation is to use renewable energy sources. Of course, there are challenges here as well, in particular with network integration and balancing, but this is already the path on which we should walk together with the international community, albeit somewhat catching up with it. In this direction, investors in Ukraine give priority to solar plants, which is due to a significant decrease in cost and relative ease of installation.

There are a number of opportunities for the implementation of energy efficiency measures on the ground, both for insulation and energy modernization of buildings, and for more rational consumption of electricity.

For example, since October 2014, the Government program of "warm credits" developed by the State Energy Efficiency Agency and implemented has been in effect. Since the beginning of the state program, the amount of compensation from the state budget is 3.46 billion hryvnias. This year, as of August, 131.31 million hryvnias were reimbursed from the state budget for "warm loans".

Also, as of September 17, 2021, 606 projects of energy modernization of buildings under the Energy Efficiency Fund's "Energodim" program have entered the design, implementation, or final stages. The total cost of these projects is UAH 5.2 billion. The Foundation notes that the leading regions in terms of the number of submitted applications are Volyn, Lviv and Mykolaiv.

These programs help owners of houses and apartments, condominiums, insulate buildings, install heat meters and implement other energy efficiency measures.

In turn, opportunities for the use of RES are being actively implemented by private households, which prefer the installation of solar power plants. Although a certain stagnation can be observed in this direction in the last two years. Dnipropetrovsk, Ternopil, Kyiv, Zakarpattia and Ivano-Frankivsk regions are the leaders among the regions of Ukraine, both in terms of capacity and number of installations.

At the same time, in regions that are not leaders in the introduction of energy-efficient technologies or the use of RES, they still find ways to more rational energy use.

So, for example, Kharkiv is known for its ability to consolidate the efforts of private business in achieving a certain goal. If a business decides to help, it cannot be stopped. So, a private company engaged in installing SES decided to help "Regional Children's Home No. 3". To do this, together with partner companies, they installed solar panels on the roof of the building at their own expense. The power of the installed SES is 5 kW. In less than a month and a half, the station generated 1,500 kWh of electricity. In this way, the institution can now save about 700-800 kW per month.

Another example in the city of Kharkiv already concerns the building of the Cathedral Cathedral of the Assumption of the Blessed Virgin Mary. Solar panels were also installed on the roof of the building adjacent to the cathedral, which serves as a social shelter. According to the rector of the cathedral Hryhoriy Sebankov, this will enable the institution to cover approximately 80% of its own electricity consumption needs. This project is implemented as part of the all-Ukrainian program "Energy of Unity", the goal of which is to convert all temples to solar energy. In our opinion, in addition to the obvious advantages of an economic and environmental nature, such projects have an impact on decision-making in the transition to clean energy sources of private households and small businesses, because they are examples of a modern view of energy. In addition, a similar program has been successfully implemented in the buildings of religious institutions in Germany for more than ten years.

State institutions are constantly working on new incentives for the development of clean energy sources that will contribute to efficient energy production.

In particular, the State Energy Efficiency Agency recently presented such an approach to the production of energy from RES as Net Energy Metering (NEM), i.e. - System of net metering. Net Metering assumes that the surplus of generated electricity will be consumed in the next billing period. This calculation is designed primarily for budgetary and non-profit organizations, households and small businesses and includes all types of renewable energy generation. At the same time, there will be no fee for imbalances for this category of manufacturers.

It is worth giving credit - this proposal tries to take into account both the needs of the population and business, that is, those who invest in RES and other energy-efficient technologies, as well as the capabilities of the energy system and the market in general. Of course, these proposals still require discussions in specialized committees and changes to existing legislative acts.

As they say: "What has been seen, what will be seen." While this publication was being prepared, the prices of natural gas in European hubs were rising, and the specialized committee of the VRU recommended for adoption in the second reading the long-awaited draft law "On energy efficiency", which can replace the outdated law from 1994. There is hope that with the adoption of the new draft law and the implementation of appropriate energy efficiency measures, Ukraine's path to clean energy and its efficient use will be successful.

The launch of the electric energy market takes place within the framework of the Third EU energy package. This is one of the conditions of cooperation between Ukraine and the IMF to receive macro-financial assistance from the EU in the amount of 500 million euros this year. For market players, this is a new "window of opportunity" and huge challenges, and is the end consumer waiting for another energy crisis in the country?

It is predicted that electricity prices for non-household consumers will increase by 5-6% already during the biggest month with the introduction of the new market model. This is confirmed by the official statement of the Minister of Energy and Coal Industry, who appeals to the fact that in Ukraine the tariff for both the population and industry is 2-2.7 times lower than in neighboring belarus and the russia.

At the penultimate meeting, the Cabinet of Ministers of Ukraine tried to temporarily adjust the tariff for the population, which is already significantly lower than the market rate. First of all, maintaining the tariff for the population has a political genesis and is connected with the elections to the Verkhovna Rada, which will take place this month. For the population, the tariff may increase by 40%, provided it is "allowed to float". But politically, the tariff will be maintained by both the current Government and, potentially, the new one after the election of the Parliament.

At the same time, if the cost of electricity is raised by at least 5%, the number of subsidized workers in the country will increase by at least 150-200 thousand people, which is proportional to the population of Ternopil or Lutsk. Imagine the burden on the budget from transferring an entire regional center to housing and communal subsidies.

So far, the Cabinet of Ministers has imposed special duties on compensating low prices for the population in the tariff of SE "NEC "Ukrenergo" for the transmission of electric energy. But the case is that such a decision will lead to the distribution of additional load between consumers, and not electricity producers, since electricity producers do not pay the tariff for transmission, this tariff is paid

exclusively by the consumer. According to the head of Ukrenergo, and according to the calculations of the NCRECP, this model of compensation will lead to a 42% increase in prices for the industry. According to the official information of the NCRECP, the additional burden on industry (and, therefore, ultimately on the population) and the budget as a result of the implementation of such a compensation model will amount to UAH 37 billion per year (which is twice the amount of macro-financial assistance that Ukraine expects in 2019).

Therefore, an increase in the tariff for industry is inevitable. And this will be reflected, first of all, in the increase in the cost of at least 1/3 of the "grocery basket" (such electricity-intensive food products as bread, milk, sausage) and the cost of communal electric transport services, the difference between the cost price and the price for the passenger, which municipalities are unable to cover, since the budgets are already planned, and new significant revenues are not expected.

Ukrainian TPPs, as a basis for balancing the energy system, are not a model of technical progress today. Therefore, the country's thermal power plants gradually reduce electricity production from year to year. Modernization of TPP power units is a costly and long-term process. So, for example, the transition of one of the four power units of the Zmiyiv TPP of PJSC "Centerenergo" (Kharkiv region) from anthracite coal to gas-rich coal cost 50 million US dollars. At the moment, this financing is placed on the shoulders of Ukrainian taxpayers, since PJSC does not have such funds to invest in its own energy division, and European financial institutions do not lend to projects that contradict the latest EU energy packages. Therefore, it is predicted that the generation of electrical energy at the TPP will gradually decrease. And it is necessary to find an alternative for maneuvering during peak hours of load on the power grid. The situation looks better in the field of hydropower.

First of all, PJSC "Ukrhydroenergo" is actively receiving loans from the European Investment Bank for the reconstruction of equipment and turbines, so, just in February, another tranche of a loan for 22 million euros was received. Thus, with the preservation of the development trends established today by PJSC "Ukrhydroenergo", Ukrainian hydroelectric power plants can maintain the level of electricity production both due to the maintenance of installations and due to the commissioning of the new Kaniv hydroaccumulating power plant (HAPP) and new units of the Tashlytsia HPPP.

At first glance, the situation is more optimistic in nuclear energy. A nuclear power plant is a basic generation that is permanent and designed to ensure the satisfaction of the necessary minimum needs. The total generating capacity of the Ukrainian nuclear power industry is slightly more than 13 GW. This is a lot, but not enough to meet all the needs of the state. Moreover, the NPP is unable to quickly increase/decrease electricity production. SE NAEK "Energoatom" got rid of its dependence on Russian fuel, switching to replacement of TVELs from the American Westinghouse. And here it would be possible to keep calm, counting on this basic type of electricity generation, but 12 out of 15 operating power units have practically exhausted their resource (according to the IAEA and SE NAEK "Energoatom"), but they are working, according to the decision to extend the period of operation. At the same time, this is not a panic phenomenon, since each of the reactors has a designed margin of safety, and requires a major repair of the reactor body.

However, such actions cannot be unlimited, and according to the IAEA, the 2nd reactor of the Southern Ukrainian NPP will be the first to shut down in 2025. On the power system, this will be reflected in minus 1 GW of generating capacity. During the period 2030-2035, a wave of shutdown of reactors will begin, and in 2036, only 3 GW will remain out of 13 GW of generating capacity. And this - under the condition of high-quality and professional maintenance of NPP power units. It should be noted that this is quite difficult, since, according to the data of SE NAEK "Energoatom", the power units of Ukrainian nuclear power plants had emergency shutdowns 9 times in the first half of 2016.

Taking into account the facts given above, by 2035, the generation of electrical energy in Ukraine, under a pessimistic development scenario, will decrease by three times. And this means the arrival of irreversible energy hunger. Salvation from which will be falling into energy dependence on another state. And, most likely, after getting rid of the long-term gas needle of the northern neighbor, the country will be forced to get a new historic turn in its dependence on energy resources, now on electricity. According to the scenario of the least resistance to the development of the energy industry, it is necessary to increase the generating capacity of the heat and hydropower industry.

However, Stakhanov's pace will not work here. Firstly, the hydropower resource of rivers is limited, however, the economically effective hydropower potential in Ukraine is only 60% used, so 4 GW (which is equivalent to 4 NPP power units) are available for development. At the same time, this figure is realistic, since today the unified power grids of Ukraine are able to receive 5.4 GW of electricity (according to the data of SE "NEC "Ukrenergo"). Secondly, the development of thermal power plants requires the use of additional resources of fuel minerals (scarce coal or gas) or environmentally hazardous fuel oil.

A significant obstacle to the development of heat generation is the impossibility of crediting the construction of new generating capacities at the expense of international, primarily European, financial institutions (due to environmental restrictions), so such projects will either be included in the electricity tariff as an investment component, or they can be implemented for the account of funds from the state budget and internal investments, which is a rather limited resource and will allow the construction of no more than 2.3-3 GW in the next 7-8 years.

Conclusions.

According to the technocratic scenario, the Ukrainian energy system should be enriched by the construction of new nuclear power plant reactors. On average, the construction of a power unit of 1 GW costs 5 billion US dollars. World practice shows that the construction of one power unit will take 10-12 years (these are world averages). However, such a project is credited by countries that are reducing nuclear dependence, but have a need for electricity. The foreign exchange earnings of a 1 GW NPP power unit from the export of electricity to the EU are up to 2 billion US dollars. Therefore, the repayment of such a loan does not exceed 8-10 years and is a successful state investment. However, there are social and environmental risks in the area of construction of new reactors.

At the same time, the restoration of 10 GW of NPP power units requires an investment of 50 billion US dollars, which is extremely "difficult" for the Ukrainian credit history to obtain an international loan. In addition, there is a problem with the design and construction of reactors, in which the Russian Federation has considerable success, but in geopolitical terms it is an extremely unfavorable partner. There are developed and implemented projects in China and the Czech Republic, but there are risks of operation, the American school of nuclear energy is ready to provide Ukraine with projects with a full cycle of erection, but this will increase the investment estimate of construction, almost twice.

"Green" (alternative) energy is actively spreading around the world, which in a number of countries, such as Germany, Iceland, Sweden, Denmark, is displacing, and in some cases, replacing nuclear and thermal energy. There are many advantages: from a high level of environmental safety to ease of construction (especially solar power plants) and quick payback.

We will give a simple calculation of the economic efficiency of alternative energy. Modernization of one power unit of the Zmiivska TPP of PJSC "Centrenergo" is worth 50 million USD, which will increase the production of electric energy by 10-15 MW (the project will take 2 years). Using an investment of USD 50 million, 55-60 MW of solar power plants can be installed and connected to the grid in six months.

However, this project will require 110-115 hectares of land, which is extremely difficult in Ukraine, with the highest arable area ratio in Europe. Therefore, the issue of promoting land reform, introducing an open and transparent land market is one of the most important obstacles to the development of alternative energy.

On the other hand, obstacles to development form the absence of a green light for "cheap" loans for the purpose of developing Ukrainian green energy. It should be noted that economic calculations for determining the payback period of "green" energy are made on the basis of the sale of energy to the state at the "green tariff", which today in the country varies (set for each seller separately) from 15 to 19.5 euro cents per 1 kWh. Converted to hryvnias, the cost of "green" energy on the wholesale market is approximately 5 hryvnias 63 kopecks.

For the consumer (taking into account the cost of transportation, losses and the surcharge of the selling organization), the price rises to approximately 7.5 hryvnias per kWh. It is clear that end consumers do not pay such a price - compensation of various tariffs is carried out at the expense of

cheap energy from nuclear power plants, where the cost price is kWh. is approximately 42-45 kopecks - 13 times lower than the "green tariff". If nuclear power plants disappear and their capacities are replaced by stations operating on a green tariff, then Ukrainians (both household consumers and industry) will be forced to pay for electricity at least 5-7 times more expensive (given the Government's stated plans to gradually reduce green tariff).

However, amendments to the Ukrainian legislation regarding green auctions for the generating capacity of solar power plants from 1 MW will lead to a significant slowdown of the solar energy market and reduce the inflow of foreign investments.

In 1991, when Ukraine received the power system of the Ukrainian SSR (it has not changed much since then), household consumption did not exceed 30% of the total volume. Today, with a multifold increase in the number of household appliances, the growth of the country's housing stock by 38%, led to the absorption by household consumption of up to half of the total produced electrical energy. And here arises the problem of peak load on the power grid, which occurs in the evening. On the one hand, industrial facilities continue to work, the number of city electric transport units is increasing, and water heating devices and coolants, lighting, electric stoves and TVs are being turned on in homes.

It is precisely to overcome these peaks that the generation of electrical energy increases due to the burning of a larger volume of coal at Ukrainian thermal power plants. It should be noted that in such a culture, or rather its absence, energy consumption, the issue of the country's energy independence and the threat of energy starvation is not only before the Government, but also before every citizen. So, for example, if you replace 10 incandescent lamps in 15 million Ukrainian households with energy-saving ones, this will allow you to save 2,200-2,500 MW of electricity during peak load hours - exactly as much as the Zmiivskaya TPP generates.

And such a project, with its complex financing, will have a very quick effect. At the same time, Ukraine has one of the highest shares of energy consumption per 100 dollars of GDP - as much as 42, while in China it is 14, and in Germany - only 4. Therefore, on a level with the modernization of energy-generating capacities, Ukraine should become a European leader in the trends of introducing energy-saving technologies both in industry and in everyday life, forming a culture of rational use of electrical energy. And this is already the name of a whole government program.

So, probably, Ukraine is "recovering" from the rapid increase in electricity prices due to the introduction of a new market, primarily due to the reduction of energy consumption at the household level and the energy saving policy. But - there is a big energy crisis ahead, which is connected with the obsolescence of technologies and generating equipment, which may be decommissioned by more than 50% in the next 10 years. And this is a challenge facing the energy sector and the entire population of the country.

REFERENCES

1. Abyzov, V., Bulakh, I., Ustinova, I., Safronova, O., Safronov, V., & Semyroz, N.: Sustainable design in architecture (The case study of the educational process at universities in Poland and Ukraine), 2023.

2. Gu, W., Li, G., Xiermaimaiti, A., & Ma, T.: A review of recent techniques in performance augmentation and evaluation metrics of Trombe walls. Energy and Buildings, 2023, 113693.

3. Han, Y., He, T., Chang, R., & Xue, R.: Development trend and segmentation of the US green building market: corporate perspective on green contractors and design firms. Journal of Construction Engineering and Management, 2020, 146(11), 05020014.

4. Klassen-Wigger, P., Geraets, M., Messier, M. C., Detzel, P., Lenoble, H. P., & Barclay, D. V.: Micronutrient fortification of bouillon cubes in Central and West Africa. In Food fortification in a globalized world, 2018, 363-372. Academic Press.

5. Krueger, K., Stoker, A., & Gaustad, G.: “Alternative” materials in the green building and construction sector: Examples, barriers, and environmental analysis. Smart and Sustainable Built Environment, 2019, 8(4), 270-291.

6. Mokal, A. B., Shaikh, A. I., Raundal, S. S., Prajapati, S. J., & Phatak, U. J.: Green building materials–a way towards sustainable construction. International Journal of Application or Innovation in Engineering and Management, 2015, 4(4), 244- 249.

7. Nguyen, H. D., & Macchion, L.: Risk management in green building: a review of the current state of research and future directions. Environment, Development and Sustainability, 2023, 25(3), 2136-2172.

8. Patel, P., & Patel, A.: Use of sustainable green materials in construction of green buildings for sustainable development. In IOP Conference Series: Earth and Environmental Science, 2021, June, 785(1), 012009. IOP Publishing.

9. Pryhara, O., Kozak, M., Molnár, M., Berezovetska, I., Bykova, M. (2022). Current Trends in the development of rural green tourism in the post war period. Ad Alta, 12(2), Special Issue XXXL.

10. Ragheb, A., El-Shimy, H., & Ragheb, G.: Green architecture: A concept of sustainability. Procedia-Social and Behavioral Sciences, 2016, 216, 778-787.

11. Reijenga, T. H., & Kaan, H. F.: PV in Architecture.Handbook of Photovoltaic Science and Engineering, second ed., John Wiley & Sons, Chichester, UK, 2011, 1043-1077

12. Sabadash, V.: Adsorption of Oil Products by Natural Sorbents. InModern Technologies in Energy and Transport, 2023, 137-158. Cham: Springer Nature Switzerland.

13. Sangmesh, B., Patil, N., Jaiswal, K. K., Gowrishankar, T. P., Selvakumar, K. K., Jyothi, M. S., ... & Kumar, S.: Development of sustainable alternative materials for the construction of green buildings using agricultural residues: A review. Construction and Building Materials, 2023, 368, 130457.

14. Sinha, A., Gupta, R., & Kutnar, A.: Sustainable development and green buildings. Drvna industrija, 2013, 64(1), 45-53.

15. Taner, T., Tiwari, A., & Ustun, T. S. (Eds.): Renewable Energy: Technologies and Applications. BoD–Books on Demand, 2021.

16. Tran, Q., & Huang, D.: Using PLS-SEM to analyze challenges hindering success of green building projects in Vietnam. Journal of Economics and Development, 2022, 24(1), 47-52.

17. Veselka, J., Nehasilová, M., Dvořáková, K., Ryklová, P., Volf, M., Růžička, J., & Lupíšek, A.: Recommendations for Developing a BIM for the Purpose of LCA in Green Building Certifications. Sustainability, 2020, 12(15), 6151.

18. Wang, D., Hu, L., Du, H., Liu, Y., Huang, J., Xu, Y., & Liu,J.: Classification, experimental assessment, modeling methods, and evaluation metrics of Trombe walls. Renewable and Sustainable Energy Reviews, 2020, 124, 109772.

19. Wang, X., Xi, Q., & Ma, Q.: A review of current work in research of Trombe walls. In E3S Web of Conferences, 2021, 248, 03025. EDP Sciences.

20. Yang, B., Lv, Z., & Wang, F.: Digital Twins for Intelligent Green Buildings. Buildings, 2022, 12(6), 856.

21. Yuan, Y., Yu, X., Yang, X., Xiao, Y., Xiang, B., & Wang, Y.: Bionic building energy efficiency and bionic green architecture: A review. Renewable and sustainable energy reviews, 2017, 74, 771-787.

22. Zhang, Y., Wang, H., Gao, W., Wang, F., Zhou, N., Kammen, D. M., & Ying, X.: A survey of the status and challenges of green building development in various countries. Sustainability, 2019, 11(19), 5385.

23. Zhou, F., Ning, Y., Guo, X., & Guo, S.: Analyze Differences in Carbon Emissions from Traditional and Prefabricated Buildings Combining the Life Cycle. Buildings, 2023, 13(4), 874.

24. Iryna Sotnyk, Tetiana Kurbatova, Galyna Trypolska, Inna Sokhan and Vsevolod Koshel (2023). Research trends on development of energy efficiency and renewable energy in households: A bibliometric analysis. Environmental Economics, 14(2), 13-27. doi:10.21511/ee.14(2).2023.02