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Prosuming Business Models in Transition to a Sustainable Bioeconomy

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Abstract— **The development and implementation of innovative business models in the energy sector and their integration into the production processes of the industrial sector for the creation of highly productive and cost-effective production facilities is an important prerequisite for the successful bio-economic transformation of industries and the creation of added value and benefit for the consumer. Such integration is expected to lead to positive developments in strategic sectors of the economy, mainly related to energy security, by gradually reducing dependence on fossil fuels and mitigating environmental problems such as global warming and toxic waste and emissions. The transition from a traditional economy to a bioeconomy requires adapting the way of energy production and consumption. The introduction of energy prosuming models will help radically change the energy system, as it allows to reduce the cost of electricity, which can serve as an economic and environmental stimulus for the bio-economic transformation of the national economy, but on the other hand, it can create problems for traditional energy producers and power grid operators. The purpose of this study is to analyze the prospects for the introduction of innovative business models in energy, such as prosuming, energy cooperation, green energy storage systems, etc., and their impact on the development of the bioeconomy. To achieve the goal, an analysis of the dynamics of changes and trends in the EU energy market and their impact on bio-economic transformations was carried out. The main problems and issues for the widespread introduction of renewable energy sources in Ukraine were identified and innovative business models for the development of alternative energy in modern conditions were investigated. A dynamic model of the bio-economic transformation of industries by stimulating Self-Consumption Energy Cooperatives has been developed, and the main directions of regulatory and financial support for prosumerism in Ukraine have been determined based on world experience.**

Keywords—prosuming, energy market, power grid, Self-Consumption Energy Cooperatives.

I. Introduction

The main prerequisites for the emergence of the concept of bio-economic transformation of industries are the need to introduce sustainable management of natural resources, ensure the country's food and energy security, mitigate the consequences and adapt to climate change and maintain the country's competitiveness [1]. At the same time, modern society is concerned with complex issues of sustainable development both from the energy point of view, in a narrow sense, and in a wider range of issues, such as responsible consumption [2, 3], ecological products [4], sustainable marketing [5] and logistics [6], etc.

Basic research in the field of minimizing greenhouse gas emissions demonstrates the ability of bioenergy to provide 25% of primary energy consumption [7]. Conventional large power block burning fossil fuels are being slowly replaced with smaller units base on renewable energies. Solar power plants and wind farms as well are nowadays operated and owned not just by large commercial consorciums but also by local communities of various scale. These consumers / prosumers need any technical advices. These scenarios and assesments and methodologies based on bussinness models are the main objectives of this paper.

To conduct this research, methods of economic analysis were used in the process of substantiating the theoretical and methodological foundations for studying the general trends of bioenergy production and its economic, ecological and technological dimensions; the method of comparison in the analysis of global trends in the development of innovative technologies for the use of distributed energy resources; methods of generalization, systematization, synthesis, study of phenomena and processes in their development and interrelationships, comparison, analogies, classification, grouping, etc. The experience of the countries of the European continent was chosen for the study.

Bioeconomy can be interpreted as an economy where the main resources for industry are renewable biological resources, materials, chemicals or energy [8]. Current economic growth depends on the production and consumption of energy [9], including renewable energy [10]. Bioenergy can become the driving force needed for the sustainable development of the bioeconomy [11]. In addition, Ukraine's energy security and reducing its energy dependence is and will be the number one topic. The transition from a traditional economy to a bioeconomy requires adapting the way of energy production and consumption. Consumers of electricity, who both consume and produce electricity ("prosumer" from

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producer + consumer), can fundamentally change the energy system. The policy of active use of low-carbon technologies requires the formation of an appropriate effective environment - institutional and technological infrastructure. The central place in this process is occupied by the issue of forming a new energy system that will meet the current trends in global politics: decarbonization, decentralization, and digitalization. Decarbonization policies are also associated with the widespread adoption of renewable energy sources (RES), decentralization involves the growing role of new electricity producers, with minor, decentralized and intermittent periods of overproduction of electricity. Digitization of the energy sector involves the introduction of innovative approaches to the power supply system, and is associated with Smart Grid (SG) technology, which allow for the modernization of electrical networks through the use of the latest IT solutions. Communication technologies are integrated into the network, as well as technologies for collecting information about the production, transmission and consumption of electricity, effective control and management of the network. These opportunities are extremely important to ensure the energy transition. In turn, the integration of distributed energy resources together with achievements in the information and communication sphere enable the emergence of electricity consumers who produce, consume and distribute energy among other network users in a single system. Such users are called "prosumer" [12-19]. In connection with this, an important question is the assessment of the impact of alternative energy and innovative business models in energy, in particular, it concerns the concept of prosumerism, on the bio-economic transformation of industries. The relationship between green energy and bioeconomy. The concept of bioeconomy involves the introduction and development of alternative management approaches capable of replacing fossil fuels with alternative ones in the economic activity of economic entities. The bioeconomy includes the following elements: (a) sustainable production of renewable biological resources to minimize climate change and fossil fuel dependence; and (b) increasing the added value of biomass materials while minimizing resource consumption [20]. To ensure the development of a sustainable bioeconomy of the country, it is necessary to pay attention to the following directions: assessment of the potential of biological resources; development of alternative accompanying types of bio products; processing of waste and production losses; interrelationships between climate change adaptation strategies [21].

The main areas that require strategic changes in accordance with the policy of bio-economic transformation of industries include: investment in research, innovation and skills; (2) changes in regulatory policy; and (3) strengthening markets and competitiveness in the bioeconomy [22]. The main indicators of the development of the bioeconomy in the EU include employment, added value and annual turnover in bio industries. The growth dynamics of the main indicators of the EU bioeconomy for 2008-2019 are presented in Fig. 1.

According to the EU Directive 2009/28/EC on renewable energy sources, member states are obliged to implement renewable energy development strategies [24], which shows the commitment of member states to biomass production. A biologically oriented economy involves the replacement of fossil fuels with an alternative and a significant increase in the demand for biomass [25].

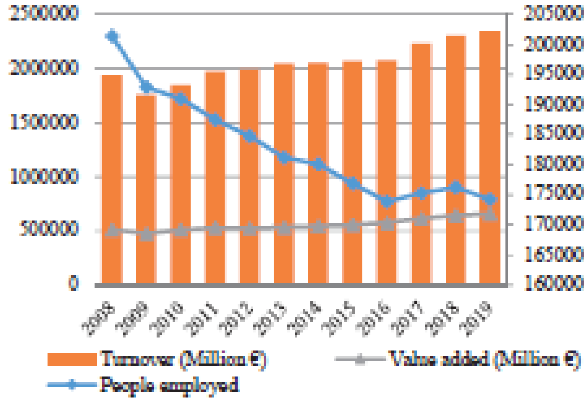

Fig. 1. European Union Bioeconomy Share [23]

To assess the dependence of bioeconomic transformation on the development of renewable energy, it is necessary to follow the dependence between bioenergy production and its economic, ecological and technological dimensions. The following indicators were used to quantify the development of the EU bioeconomy (Fig. 2.):

- Bioenergy generation (Tj) (BIO_GEN);
- CO_2 emissions (CO2_EMIS);
- Electricity production from coal sources (% of total) (EL_COAL);
- Electricity production from natural gas sources (% of total) (EL_GAS);
- Electricity production from oil sources (% of total) (EL_OIL);
- Renewable electricity output (% of total electricity output) (REO);
- Combustible renewables and waste (% of total energy) (CR&Waste).

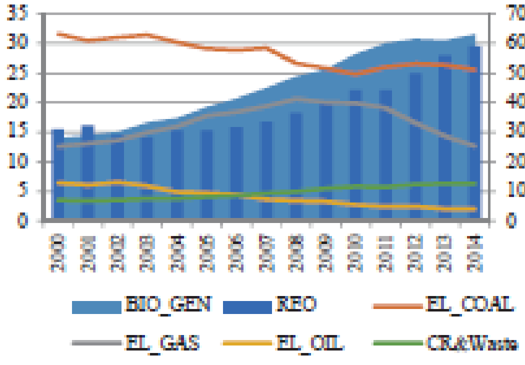

Fig. 2. Dynamics of changing trends in the EU energy market

An important role in achieving the decarbonization policy is played by increasing the share of energy from renewable sources in the energy balance. According to Yang et al., [26], consumers are mostly willing to pay extra for the use of clean energy. Bioenergy has many advantages over other technologies. According to IRENA, the cost of bioenergy production remains lower compared to other renewable technologies such as photovoltaic or wind technologies [27, 28]. In addition, bioenergy can be stored and transported, which in combination with wind and solar generation can provide solutions to problems with imbalances and excessive energy generation [29]. The dynamics of changing trends in the EU energy market is presented in fig. According to the obtained data, the production of energy from renewable sources contributes to increasing the energy independence of the country, reducing the level of use of fossil fuels, reducing the level of losses in supply chains due to the creation of added value and reducing CO_2 emissions (Fig. 3), which in turn creates prerequisites for sustainable bioeconomic transformation of the national economy. Countries with a significant share of renewable energy sources traditionally have a large share of bioenergy in the energy balance [30]. Climate change and energy independence are the main prerequisites for the development of bioenergy and imperatives for the bioeconomic transformation of industries, which simultaneously provide important socio-economic impacts, creating jobs along the value chain [31].

In developed countries, bioenergy is often a sustainable alternative to hydrocarbons in the field of transport, combined power and heat production, and heating of residential buildings, while in underdeveloped countries bioenergy is often the dominant type of fuel, due to the lack of access to electrical networks [32].

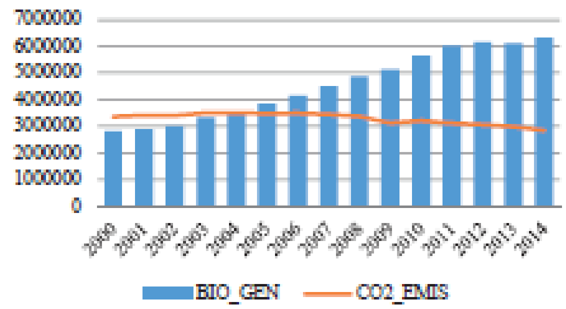

Fig. 3. Impact of bioenergy development on the level of CO_2 emissions

A dynamic model of the bio-economic transformation of industries by stimulating self-consumption energy cooperatives has been developed, and the main directions of regulatory and financial support for prosumerism in Ukraine have been determined based on world experience. The practical contribution of the paper is the development model a microgrid (prosumers based on modern technology: charging vehicle station, hydrogen technology.

II. Prosuming Models in Bioeconomy.

Optimizing network modes resulting from the rapid integration of RES is a challenge for electric network operators (ENOs). Currently, the problem of the quality of electricity is acute. Power quality is a very important characteristic of RES systems. Today's consumers are more sensitive to network failures. The chaotic integration of RES and non-linearity of the load of most powerful consumers is a common phenomenon in REM, which negatively affects the energy efficiency of RES with a naturally uneven electricity generation schedule [33]. According to NEC "Ukrenergo" (UES), Ukraine already needs the use of approximately 2 GW of highly maneuverable capacities, which can provide at least 4 starts per day and have a significant range of regulation (80% of the installed capacity).

The situation with COVID-19 [34], namely an 8% decrease in consumption, and the placement of electric filling stations [35] led to changes in the load structure. Taking into account previous studies [36, 37], it is proposed to update the graphical interpretation of the power balance in the local electrical system, based on the typical scheme presented in [37] (see Fig. 4 a) and b)). But war strongly impacted on balancing system and deficit power in all system.

It was noted that due to the repair of a number of power units and increased consumption against the background of warm, and sometimes hot, weather conditions, a deficit of about 1,200 MW is expected in the energy system of Ukraine in August [38]. There should be no blackouts, because the deficit can be covered by importing electricity from Europe. After the increase in the maximum prices for electricity (price caps) and under the conditions of deficit capacity, the prices on the Ukrainian market became more competitive for the import of electricity from neighboring Western countries.

Power balance in the UES: a) typical; b) taking into account modern trends: installation of charging stations for electric vehicles (EVs) and the use of hydrogen technologies and modern storage devices.

In Fig. 4. the process of forming the power balance in the UES with combined power supply is interpreted. According to the scenario presented in the study [37], electricity is supplied from internal sources of wind power plants and thermal power plants, small hydroelectric power plants (HPP), cogeneration (CGU) and biogas (BGU) plants and centralized power sources. The load of transformer substations consists of the load of consumers and the generation of electricity sources that are on their balance sheet (see Fig. 4. a)).

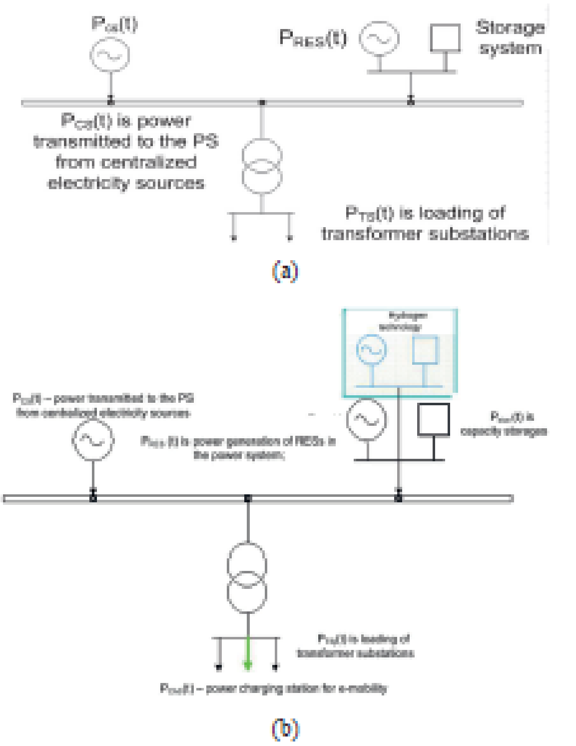

Fig. 4. Power balance in the UES: a) typical [36]; b) taking into account modern trends: installation of charging stations for electric vehicles (EVs) and the use of hydrogen technologies and modern accumulators

Modern conditions of operation of RES are characterized by stricter conditions of liability for imbalances, the expansion of the latest technologies, for example, hydrogen plants (HPP), a decrease in total consumption, and the introduction of a new type of consumer - electric charging stations (ECS) (see Fig. 4. b)). Model of power system with prosumers presented on Fig. 5., shows connections and power and resources.

III. CALCULATION OF BUSINESS MODELS

Smart networks make it possible to ensure the power balance of the UES in accordance with the modern scheme. They actually provide an opportunity to form a new active model of consumer behavior that can control their consumption and production, while traditional consumers, buying and consuming energy from the network, are passive participants in the process [18]. Under such conditions, active consumers have the opportunity to reduce energy costs, due to the consumption of energy produced by their own photovoltaic installations [38]. In addition, scientists Espe et al. [18] note the importance of the participation of prosumers in the formation of smart grids to ensure the sustainability and long-term efficiency of the energy distribution process. Digital technologies in SG enable instant interaction between participants and the network, as they allow agents to be informed about prices, in return for which they can receive cash as a counterparty.

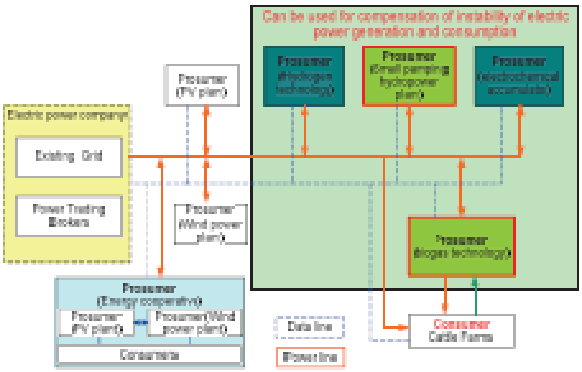

Fig. 5. Model of power system with prosumers

These two main advantages of prosumers (own consumption and selling surplus to the network) add flexibility, but increase the cost of the required investment [39]. In addition, the actual consumption of green energy for production purposes increases the bioeconomic potential of added value in supply chains. Another advantage provided by digital technologies in the energy sector is the possibility of energy exchange also between agents [19], in a peer-to-peer (P2P) system of energy trading in energy communities [12] or so-called integrated energy cooperatives. P2P energy trading is a direct energy trade between participants, namely the sale of energy from small DERs of houses, offices, and enterprises to local energy consumers [14, 41]. Participation in energy cooperatives can involve both individual citizens and social entrepreneurs, municipalities and public organizations that directly participate in the energy transition through joint investment, production, sale and distribution of renewable energy. Prosumers include homeowners who generate electricity mainly with solar PV panels on their roofs; cooperatives or condominiums are communal prosumers, the main task of which is not to sell, but to save electricity for public and private premises, such as schools or hospitals, private houses, representatives of the business environment, who use RES for their own production needs and related savings Lowering the cost of renewable energy technologies, especially solar panels, reducing the investment attractiveness of the "green tariff" and its complete elimination by 2030 will contribute to the growth of the number of such active participants in the energy production and distribution market in the coming years. In a number of EU countries, electricity is produced at a price equal to or lower than retail prices. For example, according to data from the European Consumer Organization (ECO), 80% of households in the EU are located in regions where a kilowatt-hour of electricity produced by rooftop PV panels is already cheaper than the average national retail energy price. In Ukraine, there are still no regulations, principles, or even a legally defined term "prosumer", and the problem of prosumers already exists, because the current market rules do not allow participants to conclude bilateral direct contracts for the supply of "green" electricity, and payments are made according to the state-guaranteed "green" tariff are not carried out in full. Meanwhile, the EU Energy Efficiency Directive, the EU Renewable Energy Directive and the State Aid Guidelines include provisions that apply to small electricity producers. The European Parliament called on EU member states and countries of the Energy Community, of which Ukraine is a member, to assist prosumers, energy cooperatives and aggregators, those who receive energy from various producers and can further sell it to consumers. Development of definitions and improvement of legislation in the field of energy, taking into account new trends, to stimulate investments in self-generating capacities by all categories of consumers, including the smallest. Taking into account the preparation of a package of changes to the legislation in Ukraine, which should offer an alternative to the "green tariff", which is gradually losing its investment attractiveness and "auctions", which have never worked, the urgent issue today is the development of effective business models of prosuming and the assessment of their potential in stimulating the bio-economic transformation of Ukrainian industries. In the study of the Sweco consulting company on the effective integration of distributed energy resources (DER, Distributed Energy Resources), a number of problems related to the increase in the number of small independent energy producers from renewable energy sources are identified - a reduction in electricity fees, part of which goes to support the infrastructure of energy networks, imbalance networks, infrastructure mismatch, etc. An increase in the number of prosumers will lead to an increase in the cost of energy delivery and distribution for other, traditional consumers. In addition, due to the volatility of RES generation, "overgeneration" occurs, for which fines are provided in Ukraine.

In Europe, with its developed electricity market, daily regeneration instantly lowers the price. And the price can become negative - consumers will be paid for the electricity they consume. According to Bloomberg, this has already happened twice in Germany: in the spring of 2016, and in the fall of 2017. In effect, prosumers going off the grid reduce utility profits, which adversely affects those customers who remain. According to research by the Institute for Sustainable Development in Zurich University of Applied Sciences (ZHAW) and the Institute for Economy and the Environment University of St. Gallen, Switzerland, the apocalyptic spiral of rising electricity bills can be stop due to the support of prosumers, especially that part of them that has its own energy storage systems (ESS) and can influence the discharge of surpluses into the grid. In fig. the conceptual prosuming model of the Institute for Sustainable Development in Zurich University of Applied Sciences, ZHAW, is presented. Mathematical modeling showed that the reduction of peak demand is achieved by increasing the share of consumption of produced energy for own needs. With "self-consumption" up to 30-35%, prosumers do not affect the smoothing of peaks at all, however, in the range of 35% - 75% (see Fig. 6), it is possible to reduce the peak demand in the network by 30%. Increasing the level of self-sufficiency in energy above 75% leads to losses of energy distribution companies, which causes an increase in tariffs for energy supply and distribution and leads to a shortage of funds for their maintenance and modernization [40-42]. The model of increasing the level of "self-consumption" is quite simple - at the expense of ESS and other methods of useful utilization of electricity in prosumer farms (for example, pumping water for the water supply system, heating water in DHW storage tanks, etc.) it is necessary to redistribute the daily schedule among the prosumers themselves. It is necessary to shift the consumption peaks to the zone of maximum generation, and to store the excess generation at the expense of the ESS. Lower prices for ESS partially motivates prosumers to install them, but this technology is still quite expensive in Ukraine. The environmental motivator, even in developed countries, usually does not exceed 31 %, the remaining 69 % of business is driven solely by financial benefits.

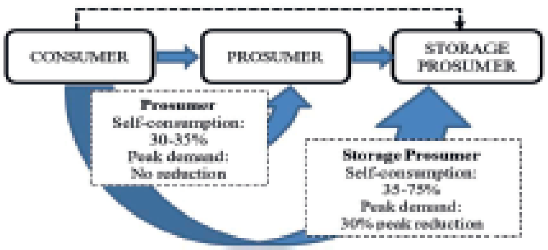

Fig. 6. . Conceptual prosuming model [42]

The increase in energy supply prices is the primary but insufficient motivator for stimulating investment in ESS and the development of Self-Consumption Communities – Energy Cooperatives (SCEC). This state of affairs requires the development of an effective system of financial incentives for the introduction of innovative Storage Prosumer Models, which will contribute to the storage of excess energy during peak loads and vice versa. Such models make it possible to launch feedback spirals that ensure sustainable bio-economic transformation of industries (see Fig. 7).

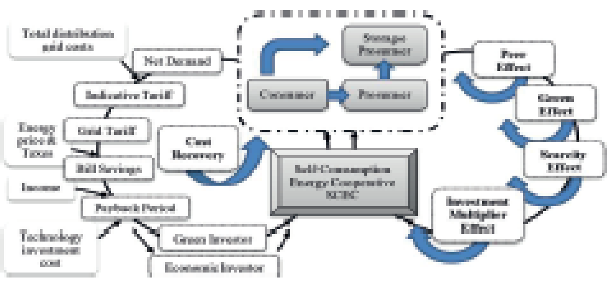

Fig. 7. Dynamic model of bio-economic transformation of industries due to stimulation of Self-Consumption Energy Cooperatives

The discussion concerning the financial and regulatory mechanisms of energy system modernization and optimization of energy consumption in industry is relevant not only in Ukraine, but also throughout the world. Today, the following methods of stimulating prosumerism are known:

- reduction of the "green" tariff and introduction of an incentive system for connecting EPS prosumers to the general network (EU);
- general modernization of the network infrastructure due to the creation of parallel distributed networks for the supply of energy separately to consumers and separately from producers, storage of prosumers at all levels - from individual prosumers to regional and national level networks (USA);
- reduction of the unit capacity of individual power plants, introduced instead of outdated traditional generation. Maximizing the use of distributed production and storage capacities, bringing them closer to consumers, effectively using the capabilities of local networks (Germany);
- facilitating the connection of new energy producers to the grid, to ensure the positive effect of mass distributed generation (France);
- stimulating the involvement of prosumers who own EPS in local smart grids and "smart" redistribution of energy by "aggregators", i.e. companies that take on not only the functions of daily accounting of energy demand and supply, but also "instantly" carry out price regulation.

In practice, to maximize the share of RES and other types of distributed energy resources (DER) in a single energy system with traditional sources, different business models are used in the world, see Fig. 5, including distributed energy generation and storage, microgrids, electric vehicle charging and "demand response" (DR) –responding to demand in real time thanks to artificial intelligence systems and instant "blockchain" - transactions (see Fig. 8) [43].

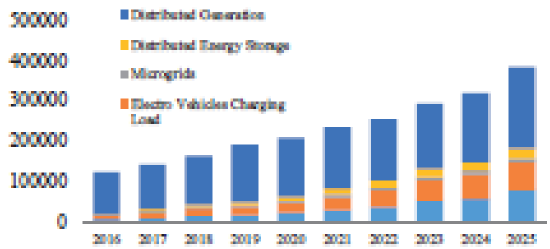

Fig. 8. Global trends in the development of innovative technologies for the use of distributed energy resources (DER) by type, MW. 2016-2025.

Such steps are impossible without "digitalization" of all power system components. At the beginning of November 2017, Bloomberg analysts published a study according to which investments in digital energy management technologies will reach the level of $64 billion by 2025. At the same time, investments in traditional energy systems will decrease by half.

IV. CONCLUSIONS

This work presents an analysis of the prospects for the development of innovative business models in the energy sector as an engine of bio-economic transformation of industries that can be usage for recover energy sector Ukraine. Trends in the implementation of innovative business models in the energy sector were considered to ensure the widespread introduction of RES in production processes and the transition to a low-carbon development strategy.

To simulate the bio-economic transformation of industries at the expense of RES, a system dynamic model of stimulation of Self-Consumption Energy Cooperatives was built. The analysis of the model gives an idea of the sensitivity of the simulated process of bio-economic transformation to various economic, regulatory and social factors, i.e. to socio-economic categories that increase the investment attractiveness of the self-consumption energy cooperatives prosuming model. According to world experience, for a confident transition to RES, it is necessary to stop creating regulatory barriers for connecting to networks of energy producers from RES and to ensure the stimulation of the transition to energy storage in EPS. Another powerful direction of the development of prosumerism is "agrivoltaics", that is, PV generation for the production of agricultural products (irrigation, energy for technological transport and agricultural machinery, heat and light for greenhouses, primary processing and much more), which is one of the promising directions further research.

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