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Assessing the Flexibility of Renewable Energy Multinational Corporations

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Abstract: Currently, international business and society are on the eve of large-scale changes. The study aims to develop a methodological approach to assess the energy flexibility of multinational corporations in the context of the structural transformation management of renewable energy production. The methodology of this study is based on a comprehensive approach, which includes the methodology of the United States Agency for International Development (USAID), diagnostics of the level of development and energy flexibility of multinational corporations, regression analysis and scenario modeling. In particular, scenario analysis of renewable energy development in countries of the Commonwealth of Independent States (CIS) and economic analysis of projects for the development of corporate renewable energy industry were carried out. The results showed that the Russian renewable energy business is flexible enough for changes; however, at the same time, changes are needed in the national legislation, the basics of work, the national energy market; the conditions should be formed for the development of this business, a green tariff on a market basis should be formed, etc. The scientific contribution of this study is the proposed indicator in the form of the Multinational Corporation Energy Flexibility Index. It provides an opportunity to diagnose the agility of multinational corporations' development, taking into account changes in their production structure. The developments obtained in the course of the work can be applied for studies related to assessing the flexibility of national energy systems, as well as in the practice of managing multinational corporations operating in the field of renewable energy.

Keywords: renewable energy; multinational corporation; assessment of flexibility; management; energy system

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1. Introduction

In modern conditions, an increasing amount of attention is being paid worldwide to enhanced structural transformations of the fuel and energy complexes of countries. Reducing the anthropogenic load in the context of sustainable development becomes possible if the economic and environmental goals at least partially coincide. This balanced economic model combines significant economic growth prospects while minimizing environmental impact. The basis of such an economy is represented by alternative energy, that is, the replacement of traditional power sources with renewable energy from sun, wind, biomass, and heat. The main goal of these processes is a qualitative restructuring of energy markets to increase the efficiency of the use of energy resources and reduce dependence on their imports [1]. Research into the development of alternative energy is especially relevant in the context of increased competition, globalization, and modern integration processes.

To effectively fulfill its role as an international redistributor, a transnational corporation must freely move capital, technology, business experience, goods, and security around the world in accordance with market opportunities, losses, and competition [2]. Therefore, the contribution of multinational corporations to the efficiency and development of the global economy depends on the policies of national governments on the activities of these companies [3]. However, national governments have little interest in improving global economic efficiency and global economic development since their function is to protect and expand national interests in the international arena. Therefore, national governments treat multinational corporations in terms of political and economic benefits for a nation and not the world as a whole.

At the present stage of the global economy, multinational corporations maintain production, scientific and technological ties between organizations of different countries and also influence international competition through cooperation and rivalry with small- and medium-sized businesses [4]. With significant production and financial resources, international companies are able to take key positions in the economies of countries, threatening the economic security of host countries. The danger to economic sovereignty is also manifested in the fact that multinational corporations control the most important sectors of the economy, such vital products as oil and gas. The latter, due to their high efficiency, remain the most demanded energy sources in the world, despite the fact that their total reserves in the world make up no more than 20% of all natural energy sources [5]. The development of programs to stabilize international energy markets will contribute to strengthening international economic security. In this aspect, it is possible to impose restrictions on speculative transactions of multinational corporations with financial assets tied to their supplies, and the mandatory consumption or production of renewable energy. International coordination can accelerate the development of national energy conservation and renewable energy production programs, as well as the development of renewable energy sources, especially since multinational corporations have the necessary financial resources for this [6]. At the same time, some problematic issues remain insufficiently studied. To date, there is a need to improve the existing scientific and methodological approaches to examining the development of renewable energy in the context of assessing the effectiveness of various types of energy enterprises. This is especially important to further develop recommendations for its improvement. In this regard, this study intends to fill this research gap by analyzing current trends in the development of renewable energy sources and by forming a new business ideology of transnational corporations, which should contribute to more widespread use of clean energy sources and reduce carbon dioxide emissions. The ultimate goal of this work is to implement and test a methodological approach to assessing the energy flexibility of multinational corporations in the context of the structural transformation management of renewable energy production by combining USAID method, ENTSO-209 E practice and EPRI key performance indicators. The study analyzes the possibility of integrating a significant part of renewable energy sources into the existing structure of electricity production of Russian multinational companies from the standpoint of economic efficiency. Within this framework, the economic efficiency of the companies under study is expressed using a taxonomic indicator of their development in terms of financial benefits.

2. Literature Review

There has been significant growth in the renewable energy sector in the context of economic competition between multinational corporations and states, increasing demand for electricity in developing countries, and G20 political initiatives aimed at preserving the natural environment. This is especially relevant for the segments of solar, wind, and bioenergy [7,8]. The data presented in the report “Corporate Sourcing of Renewable Energy: Market and Industry Trends” by the International Renewable Energy Agency (IRENA) are indicative [9]. With the participation of 2410 corporations headquartered in 40 countries, which voluntarily buy renewable electricity or build their own clean generation, it was determined that 200 of them have a share of renewable energy sources in electricity consumption exceeding half, and 50 companies provide 100% energy supply from renewable sources. Companies from different sectors are switching to an alternative power supply, primarily companies in the high-tech sector, where large amounts of electricity are required to provide data processing and storage centers and cloud computing services. These are Apple, Google, Facebook, etc. In addition, financial corporations (Bank of America, Citi, Commerzbank), vehicle manufacturers (BMW Group, GM, Tata Motors), fast-moving consumer goods (FMCG) companies (P&G, Unilever, Cincinnati, OH, USA), medical suppliers (AstraZeneca) also use renewable sources of electricity. Oil and gas companies are also switching to renewable energy sources, for example, Exxon Mobil signed two direct contracts (250 MW each) for a period of 12 years with Danish Orsted A/S, according to which it will provide energy for oil production in Texas using renewable energy sources [9,10].

Among the main factors that determine renewable energy as the preferred source of energy supply today, it is necessary to highlight the approach to grid parity, the possibility of economical and stable integration of energy grids, and the development of technological innovations. According to data provided by Bloomberg New Energy Finance, today the indicator of non-subsidized levelized cost of wind and solar energy is in the range of USD 30–60 per 1 megawatt-hour, while natural gas, as the cheapest fossil fuel, is USD 42–78 per 1 MWh [11]. The growing availability of rechargeable batteries and other innovations is helping to reduce the volatility of wind and solar power generation and improve the reliability of renewable energy sources needed to compete with traditional sources. In terms of price, onshore wind turbines are already the cheapest source of electricity in the world [12,13].

In addition, the use of new technologies such as additive manufacturing, 3D printing, automated drones in wind power, perovskite in solar power plants, automation, and artificial intelligence can increase the competitiveness of renewable energy. It should be noted that the capabilities of solar and wind energy are optimally matched to the requirements in the implementation of smart city projects, power supply to areas outside centralized power grids [14,15].

Despite the obvious advantages of using renewable energy, its full-scale development in Russia is hampered by the surplus of the Russian energy system, where the excess capacity is estimated at 20–30 GW with low rates of growth in electricity consumption and an abundance of cheap fossil fuels. However, general trends in the development of renewable energy also affect Russia [11]. Already, the production of energy from renewable sources is changing the situation in most electricity markets and has an indirect impact on the Russian energy sector. As a result of the partial replacement in European countries of coal and gas power plants with wind and solar generators, the demand for gas and coal is likely to become significantly lower. For long-term planning and pricing, Russian mining companies and power equipment manufacturers need to take into account economic models, advantages and disadvantages of renewable technologies, and their market prospects [16,17]. In addition, new technologies open up new opportunities for Russian investors, while for industrial companies—new markets in the production of equipment for solar and wind power plants, such as turbine blades, rotors, generators, photovoltaic panels, solar storage devices. According to the program of state support for the development of renewable energy sources, which has been extended until 2035, renewable energy projects receive financing under power supply contracts. By 2024 about 6 GW of renewable energy is expected and the share of renewable sources in the total energy balance of Russia will reach 4–5% [18,19].

State stimulation of renewable energy is not the only way to actively spread it. Private financing of renewable energy is dominant in Poland. In addition, the European Investment Bank (EIB) invests between EUR 4 and 5 billion annually to finance Polish projects in the field of renewable energy sources. Although Poland only has a 2% stake in the EIB, the total EIB share in the portfolio is almost 7% [20–22]. Poland's dynamic economic growth in recent years, which has contributed to an increase in the number of enterprises and a domestic market with 38 million consumers and a new energy policy of the country to create incentives to attract investment for renewable energy producers, is driving an increase in demand for clean energy. Expert forecasts for growth in the final consumption of energy from renewable sources by the end of 2020 ranged from 10 to 20% (electricity, fuel, transport, etc.) [23,24].

With the widespread development of renewable energy, there are also certain risks associated with the economic stability of countries and multinational corporations, environmental and climatic features of nature [25]. Nowadays, renewable energy sources transform energy cooperation and markets, reorient trading partners, and change cooperation or conflict resolution patterns used by the world states. In this context, a particularly significant role is played by access to finance and their availability, which is a serious problem for many developing countries [26]. Thus, for example, with a higher level of political risk and increased R&D in the renewable power sector, the use of renewable energy is growing, and the consumption of energy from non-renewable sources decreases [27]. This study is devoted to the analysis of trends in renewable energy sources and the development of a new business ideology of multinational corporations, which should contribute to increasing the share of clean energy and reducing the consumption of hydrocarbons in the world. The considered ideology is expected to be focused on the priority of sustainable development and the formation of the contribution to it of multinational companies that have a significant impact on international markets.

The ultimate goal of this research is to develop a methodological approach to assess the energy flexibility of multinational corporations in the context of the structural transformation management of renewable energy production. It also analyzes the possibility of complex integration of a significant part of renewable energy sources in Russia into the existing structure of electricity production by transnational companies.

3. Methods

The study aims to assess the flexibility of integrating renewable energy businesses.

The research methodology is aimed at finding whether it is possible, with the existing power generation structure of the Russian corporate sector, to integrate most of the renewable energy sources in Russia and whether this option is acceptable and cost effective. The logic of the study process is presented in Figure 1.

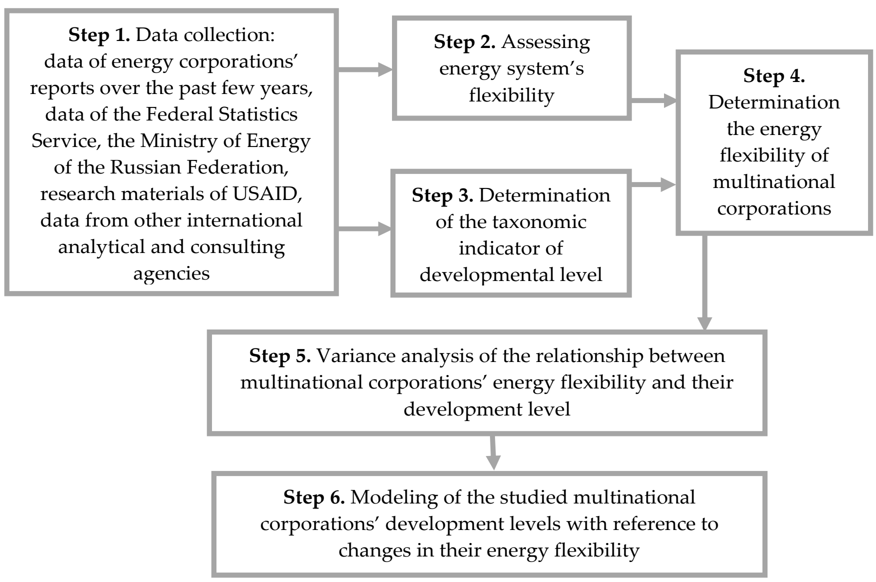


Figure 1. Research logic. Source: developed by the authors.

The following time range was chosen:

- Periods with a two-year interval—for the analysis of baseline scenarios—2021, 2023, and 2025;
- Periods with a five-year interval—for economic analysis (assessment) of the flexibility of implementing projects for the development of the corporate renewable energy—1 year, 5 years, and 15 years.

The forecast was based on the data of energy corporations' reports over the past few years, data of the Federal Statistics Service, the Ministry of Energy of the Russian Federation, research material collected by USAID, data from other international analytical and consulting agencies [22,28].

For the first part of the study (analysis of baseline scenarios), out of 120 scenarios for the development of renewable energy for the CIS countries mentioned in USAID reports, three representative scenarios were selected as basic and most relevant for testing in the Russian energy business.

In general, the research was based on methodology for assessing energy system flexibility (for renewable energy sources) developed by USAID. The study's contribution in this aspect lies in testing this methodology on several Russian alternative energy corporations and selecting relevant tools for assessing the flexibility of the Russian corporate sector of renewable energy. In addition, there was also conducted an analysis of the ENTSO-E practice, as well as an assessment of key performance indicators based on EPRI (Electrical Power Research Institute) guidelines [21,29,30].

The study is limited to a selection of several multinational corporations (not the entire state energy sector) that own assets in the field of renewable energy in Russia, in particular, the Inter RAO Group, RusHydro Group, Enel Russia (Enel Group) PJSC, etc., [31–33].

Determination of the taxonomic indicator of developmental level includes a number of stages. The first stage involves the formation of an observation matrix, which contains the most complete characteristic of the studied set. The matrix indicators are heterogeneous, because they characterize different properties of the object and are measured in different units. At the second stage it is necessary to perform standardization of indicators according to the formula:

$$Z_{ik} = \frac{x_{ik} - \overline{x_k}}{S_k} \quad (1)$$

where

$$\overline{x_k} = \frac{1}{\omega}\sum_{i=1}^{\omega} x_{ik} \quad (2)$$

where k = 1,2, . . . , n; x_{ik}—the value of the indicator k for the unit i; $\overline{x_k}$—the arithmetic mean value of indicator k; S_k—standard deviation of k; Z_{ik}—standardized value of indicator k for unit i.

After the standardization procedure, all selected indicators should be divided by the nature of the impact on the level of multinational corporation development, respectively, into stimulants and destimulants.

$$Z_{0k} = max\ Z_{ik}, \text{if } k \text{ is a stimulant} \quad (3)$$

$$Z_{0k} = min\ Z_{ik}, \text{if } k \text{ is a destimulant} \quad (4)$$

The developmental benchmark has the coordinates:

$$P_0 = (Z_{01},\ Z_{01},\ \ldots,\ Z_{0n}) \quad (5)$$

The distances obtained included the initial values used to calculate the integral indicator.

The calculation of the integral indicator of the level of multinational corporation's development (DI) was carried out according to the formula (6).

$$DI_i = 1 - \frac{C_{i0}}{C_0} \quad (6)$$

where

$$C_{i0} = \left[\sum_{k=1}^{n} (Z_{ik} - Z_{0t})^2 \right]^{1/2} \quad (7)$$

$$C_0 = \overline{C_0} + 2S_0 \quad (8)$$

$$\overline{C_0} = \frac{1}{t} \sum_{i=1}^{t} C_{i0} \quad (9)$$

$$S_0 = \left[\frac{1}{t} \sum_{i=1}^{t} (C_{i0} - \overline{C_0})^2 \right]^{1/2} \quad (10)$$

where C_{i0}—the distance between the individual point-units and the point P_0, which represents the benchmark for development, S_0—standard deviation of C_{i0}.

To determine the energy flexibility of multinational corporations, the study proposed using an indicator that takes into account the structural ratio of the shares of the main sources of energy produced by multinational corporations. The basis for determining this indicator is the Shannon–Wiener index:

$$EFI_i = \frac{-1}{\log N} \sum_{n=1}^{N} sh_n \cdot \log(sh_n) \quad (11)$$

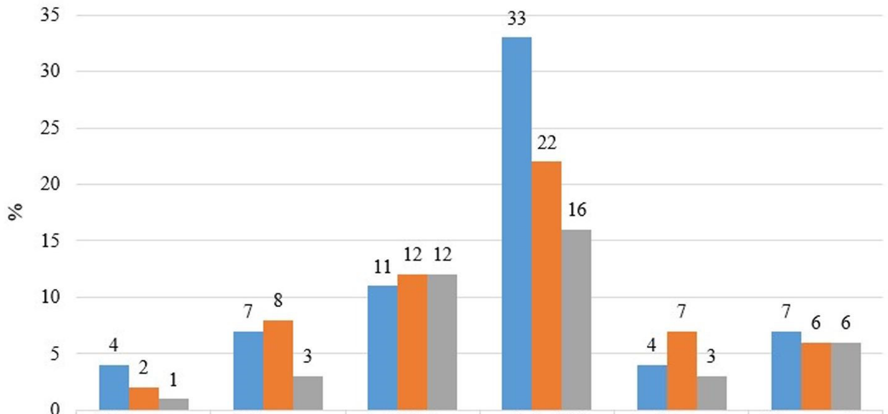
where EFI_i—an indicator of multinational corporation's energy flexibility; N—the number of energy production sources of the i-th multinational corporation; sh_n—the share of the n-th source of energy produced in the multinational corporation structure.

The value of the EFI indicator is close to 1, that is, the higher the indicator, the more flexible in an energy context is the multinational corporation.

The final stage of the study is scenario modeling of the impact of energy flexibility on the level of development according to the obtained regression equation based on analysis of variance [34]. In the process of modeling, three scenarios (1, 5 and 15 years) were formed, in which the assumed increase in the share of renewable energy in multinational corporation production is 1% per year. In this way, changes in the energy flexibility of the studied multinational corporations and the impact on their level of development were determined.

4. Data Analysis

Currently, the trend towards the use of RES is gaining momentum, especially for solar, wind, and bioenergy. By the end of 2020 these three segments should increase their share in the total global installed capacity in the following proportions: solar energy—from 4.5% to 7.7%, wind—from 8.2% to 10.4%, bioenergy—from 2.4% to 2.6%. Solar photovoltaic (PV) installations will continue to grow faster than other RES in the future, especially in projects using concentrating solar power plants [35]. According to SolarPower Europe, the global increase in capacity over the previous year exceeded 100 GW. The leading countries in the growth of solar energy are China—34.5 GW, the USA—14.7 GW, Japan—8.6 GW. Investments in solar energy are on the rise. They were expected to reach USD 50.7 billion by the end of 2020, accounting for 37.5% of global electricity investment. At the same time, investments in the construction of solar power plants bring investors from 8% to 30% income per annum for 10–25 years, depending on the country, currency risks, and the stage of project implementation. With regard to wind energy, in countries such as Germany, Ireland, Spain, and the UK, the share of wind energy in the energy balance in 2019 ranged from 10 to 37%. Wind farms in Germany generate more electricity than coal power plants. According to the World Energy Council, East Asia, including China, and Europe account for about 70% of all global installed wind power capacity and 20% in North America. The average annual growth rate of wind power over the past 10 years has exceeded 20% [36]. The dynamics of the world's renewable electricity generation are illustrated in Figure 2 and the total consumption of renewable electricity on a global scale—in Figure 3, based on the data of the International Energy Agency (IEA) for 2018–2020.



	Hydropower	Bioenergy	Wind	Solar PV	Others	All renewables
2018	4	7	11	33	4	7
2019	2	8	12	22	7	6
2020	1	3	12	16	3	6

Figure 2. Annual growth of renewable electricity generation by source, 2018–2020. Source: developed by the authors based on [17,37,38].

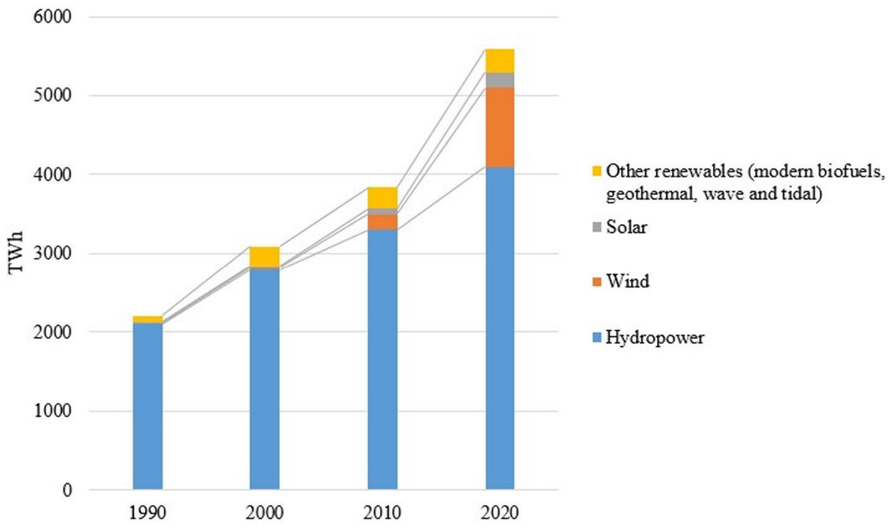


Figure 3. Modern renewable energy consumption in the world, TWh. Source: developed by the authors based on [17,18,38]. Total renewable energy consumption, measured in terawatt-hours (TWh) per year. These data include all renewable energy sources with the exclusion of traditional biomass.

Wind farms are projected to account for 15% of electricity generation by 2030, up from 6% in 2016, with an annual investment of around USD 100 billion.

Today, roughly 60% of the Fortune 100 and Global 100 large multinationals have set ambitious targets to move their businesses to renewable energy sources. This focus of multinational corporations is associated not only with the environmental focus and increasing the attractiveness of their brands by reducing the carbon footprint of the business, but primarily the economic component. On the one hand, investments in energy based on fossil fuels are becoming riskier every year due to constant fluctuations in prices for hydrocarbon energy carriers and changes in regulatory standards, and on the other hand, technologies for producing renewable electricity are constantly being improved and contribute to reducing its cost. Over the past five years, levelized cost of wind and solar energy has declined by 67% and 86%, respectively, due to sharp declines in equipment costs, which in turn have increased efficiency. According to forecasts, both trends will continue in the future. Generation costs for onshore wind turbines and large photovoltaic solar power plants have already dropped by 18% in the first half of 2019, according to Bloomberg New Energy Finance. In Europe, Japan, and China, one of the main incentives to reduce energy prices are competitive energy auctions, which help reduce the cost of introducing renewable energy sources without resorting to subsidies [11,39–41].

The Russian solar and wind energy market is in the stage of formation. According to the System Operator of the Unified Energy System of Russia, the capacity of the Russian power system is 246 GW, alternative energy accounts for only 2% of this volume. In the coming years, Russia's solar and wind energy market will expand thanks to new government targets for generating electricity from renewable energy sources. In 2023 and 2024, solar power plants with 279.6 MW and wind farms with 32.1 MW will be commissioned. By 2024, the total amount of state assignments for the installed capacity of all types of renewable energy will amount to 5863.7 MW, including 415.7 MW of wind power, 2238 MW of solar, and 210 MW of small hydroelectric power plants. Now large Russian solar power plants are located in the Orenburg, Saratov, Astrakhan regions [42].

Poland's position in the field of RES is indicative. Since Poland intends to gradually abandon coal, private companies see the need for investment in renewable energy. According to a report by the think tank WiseEuropa, 8.6 GW of renewable energy capacity has been created in Poland over the previous five years. For comparison, the total installed capacity in Poland is over 44 GW. With a total investment of PLN 48 billion, about 62% was spent on the construction of onshore wind farms. Other 28% of the funds went to the development of solar energy, the capacity of which in Poland is now almost 2 GW. The main role in increasing the share of RES in the Polish energy balance was played by private energy companies and manufacturing firms, which together generated 81% of all renewable energy in 2013–2019. The contribution of the public sector and state energy concerns to the RES in these years was less than 15% [43,44].

Data compiled by Bloomberg NEF and published in the Renewables Global Status Report 2019 [45] for the first half of 2020 suggest that the share of RES in global electricity generation reached almost 28% in the first quarter of 2020, up from 26% in the first quarter of 2019. In the first quarter of 2020, RES (solar photovoltaic and wind energy) reached 9% of production, up from 8% in the first quarter of 2019. Renewable energy has proven to be the most resistant to the COVID-19 quarantine measures. Despite supply chain disruptions that have suspended or delayed operations in several key regions, the expansion of solar, wind, and hydropower will help increase renewable electricity generation by nearly 5% by the end of 2020 [45,46].

The Global Annual Conference on Natural Resources, held in London in 2019, provided a forecast for the structure of energy consumption until 2050, which suggests that energy efficiency will be a fundamental parameter in the transition to renewable forms of energy. Many countries will move closer to grid parity. Innovative technologies, automation, artificial intelligence, blockchain, and advanced materials and operations management will accelerate the spread of renewable energy [19,47,48].

5. Results

The results of the analysis of economic and statistical data indicate that RES makes up a significant share in the structure of the generating capacity of many national energy systems, in particular, countries with a powerful industrial complex oriented towards the raw-material economy (such as Russia). For example, a completely carbon-free energy structure has been formed in Norway. Hydroelectric power plants provide 95% of electricity, thermal power almost does not exist at all, and nevertheless, Norway is a large wind power country. There are 36 wind farms operating in the country with a total capacity of 2444 MW (2019), while in Russia—102 MW [49]. As in many countries with a similar balance of renewable energy generating capacity, an important task is to correctly assess the requirements for reorienting the energy system from fossil fuels to RES.

Considering the growing role of integration and consolidation processes in world business, as well as the fact that the energy business is one of the basic and most attractive in terms of profit, many national energy complexes of both developed and developing countries become corporate. This also affected the Russian renewable energy business, which is increasingly represented by large industrial and financial formations–holdings and groups.

Studying the monitoring data of international organizations that investigate issues related to the development of global renewable energy, one can see a tendency for the growth of intermittent generation power plants based on RES (wind and photovoltaic solar power plants). In turn, in addition to the positive effect of reducing pressure on the environment, this also creates fluctuations in the balance of consumption and generation of electrical energy. Agreeing with the position of USAID, an effective solution in this situation can be to increase the flexible generation of RES. At the same time, other options need to be considered to improve flexibility, which will play a key role in the safe and sustainable operation of national power grids.

In turn, integration effects, which can be expressed in the synergy of renewable energy generating companies participating in the electricity market, can be obtained through the cooperation of these companies within a single corporate structure. For example, a typical corporate structure model consists of a renewable energy generating company (corporate sector), electricity transmission company (most often a state grid company), electricity distribution company (corporate sector), and a company that supplies electricity to consumers (corporate sector). Such corporate business models allow one to be flexible in the national energy market and more equitably distribute and redistribute all types of resources within a single corporate structure. Nevertheless, they can function mainly in liberalized markets. The previous experience of European countries in the introduction of liberalization models for the development of the electricity market (1990–1997), consolidation of liberalization models (1997–2003), as well as the crisis of the original model and the need for conscious regulation of market relations has become the ground for the creation of a completely new design for the European energy market. It is adapted to modern realities and more flexible and adjusted for the integration of a greater share of renewable energy sources.

A thorough scrutinization of the results of studying business practice in this direction allows an inference that corporate business models also contribute to the establishment of a fair (market) level of tariff for renewable electricity (the so-called "green tariff", FiT (feed-in tariff)—in Western terminology) [50]. The solution to the problem of increasing government spending on green energy may be the decision to diminish the rate of the green tariff to the size of the average tariff calculated for consumers. Thus, the state will be able to support energy cooperatives and private households, whose generating facilities produce electricity from alternative energy sources and for whom the green tariff was established as far as they mainly relate to household consumers.

However, at the same time, it is important to assess the total potential of the corporate renewable energy business (in this study, for Russia), as well as to assess the degree of influence of corporatization processes on the national energy (in terms of RES business).

The objects of analysis were controlled assets of international groups that own Russian business in this segment—in particular, the Inter RAO Group, RusHydro Group, Enel Russia PJSC (a structural business unit of the Enel Group).

The increase in FiT in 2019 is associated with a rise in demand for renewable energy and a reduction in renewable energy production by the studied groups. For example, for Inter RAO Group, the energy production of hydroelectric power plants in Siberia reduced to the level of long-term annual average values after the water-rich year of 2018. Figures 4 and 5 show the data of the total annual solar and wind generation of the mentioned groups as part of their corporate investment strategies as of July–August 2020.

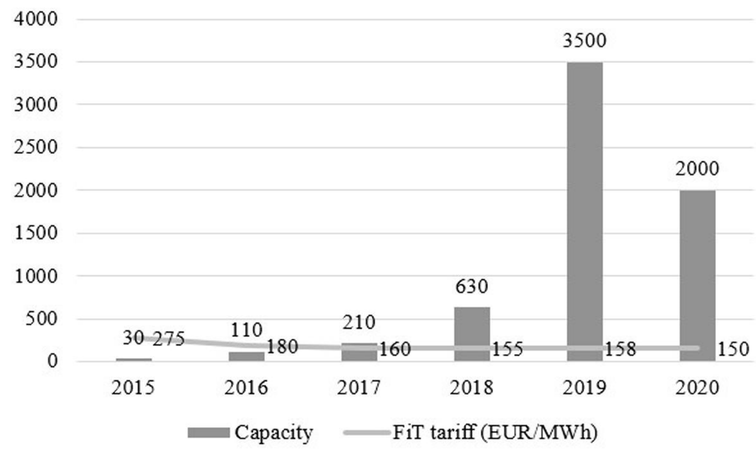


Figure 4. The total capacities of solar power plants and the FiT tariff of the multinational corporations (included in the sample). Source: calculated on the basis of data from official reports of multinational corporations and consulting agencies [21,29–33].

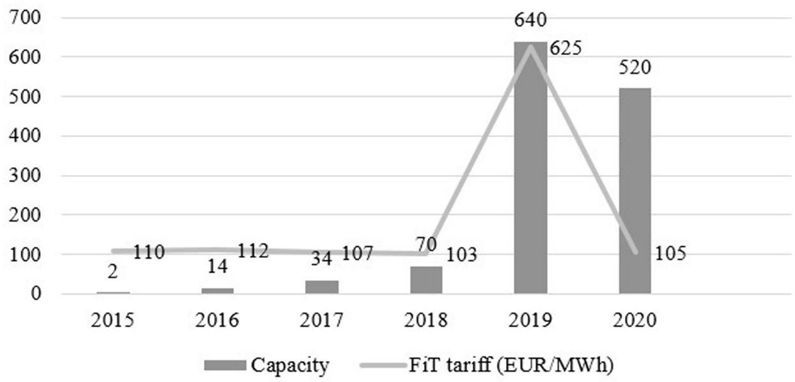


Figure 5. The total capacity of wind farms and the FiT tariff of multinational corporations (study sample). Source: calculated on the basis of data from official reports of multinational corporations and consulting agencies [21,29–33].

It should be noted that historically in most of the post-Soviet countries (Russia, Ukraine, and Kazakhstan), the high level of the renewable electricity tariff (FiT) has led to significant integration of RES. Investors expected a revision of RES legislation, including a reduction in tariffs, distribution of responsibility for imbalances in the market, determination of the deadline for commissioning power plants of this type. Many companies (including the study sample), focusing on the western practice of reforming national RES legislation (for example, the implementation of the European model in Ukraine has been successful recently), expect regulatory changes in terms of fixing the tariff level for RES.

At the same time, the increase in the commissioning of RES power plants, as shown by the infographics (Figures 4 and 5), increases the total wind and solar power. Investment programs and corporate strategies of holdings and groups included in the study sample and the Russian Federation Government Decree No. 449 of 28 May, 2013 “On the Mechanism of Encouraging the Use of RES in the Wholesale Electricity Market” were analyzed [51]. The results of the analysis of mentioned documents indicate that in the future a large number of RES power plant projects will be developed and implemented (for 1 year, 5 years, 15 years). In this regard, it can be concluded that a national energy system, due to the increased load of RES and changes in the overall structure of the energy balance, needs more flexibility. However, at the same time, it is important to find an answer to how to achieve the desired level of flexibility at the lowest cost.

Below, Table 1 shows the results of assessing flexibility for several scenarios of RES integration. The USAID methodology is taken as a basis.

Table 1. Results of analyzing baseline scenarios for the development of corporate renewable energy industry.

Scenarios					Analysis Results					
			Installed Capacity		Within Unloading		Within Load			
Year	Annual Capacity Growth	Operating Mode	Wind Power Plants MW	Solar Power Plants MW	Deviation, Hours	Lack of Capacity MWh	Deviation, Hours	Lack of Capacity MWh	The Need for Additional Installed Capacity (MW, max.)	Installed Capacity Utilization Factor of New Flexible Generation
2021	0.5%	Integrated	2.6	6.25	104	150.1	30.2	11.2	495	0.245%
2023	1.2%	Integrated	3.2	10.1	124	201.2	55	28.1	730	0.43%
2025	1.2%	Isolated	3.2	10.1	250	390.5	200.2	96.3	1.42	0.91%

Source: developed by the authors based on own calculations and official reporting data of multinational corporations [21,29–33].

As Table 1 shows, by 2025, following the scenario of an increase in the number of solar and wind power plants, an increase in deviation and an increase in the hourly capacity shortage for loading and unloading the power system are expected; there will also be a lack of flexible generation. Additional capacity will be required to stabilize the operation of the power system and the energy balance.

This is also evidenced by the projected increase in the installed capacity utilization factor. According to the forecasts of USAID experts, for CIS countries it is expected that the need for flexible generation will be satisfied through the construction of new facilities.

Two scenarios were considered for the operating mode of the united corporate RES assets included in the national energy system:

- an integrated scenario involving long-term synchronous operation of renewable energy generating companies with each other;
- an isolated scenario that provides for the functioning of assets separately, pursuing only their own commercial interests.

As one can see, large positive effects are expected from the implementation of the integrated scenario.

In general, the results of this part of the study indicate the lack of flexibility of the national energy system to increase renewable energy load at the current time, which requires appropriate measures from the government.

Below (Table 2) are the results of the economic analysis (assessment) of the flexibility of implementing projects for the development of the corporate renewable energy industry.

In this analysis, four main scenarios (options/alternatives for increasing the flexibility of the national energy system) for the development of the national renewable energy were considered on the basis of the practices and recommendations of ENTSO-E and EPRI:

1. Proactive limitation of RES;
2. Gas peaking power plants;
3. Electricity storage systems (batteries);
4. Pumped storage station (PSS).

It is important to note that the cost of reducing the share of RES consists of the cost of the load balancing service, which is paid for RES power plants to ensure the load balance according to dispatch commands. Based on this, almost the entire amount turns into additional income for renewable energy plants. This can be considered as a mechanism to support RES.

At the same time, a comparison was made of these four alternatives in terms of costs. The results are shown in Figure 6.

Table 2. Results of economic analysis (assessment) of the flexibility of implementing projects for the development of the corporate renewable energy.

Performance Indicators	Scenarios			
	Scenario of Proactive Reduction in RES	**Scenario for the Development of Gas Peaking Power Plants**	**Scenario of Energy Storage Systems**	**PSS (Based on Speed Control)**
Necessary measures for implementation	RES limitation management system Short-term consumption forecasting system Renewable energy short-term forecasting system Direct integration of wind and solar plants' control systems	Determination of the best capacities for optimal flexibility.	Determination of the best objects and capacities for optimal flexibility.	Determination of the best facilities and capacity for optimal provision of capacity regulation (available PSS). Limiting the use of water
Capital Expenditure (CAPEX) (USD million)	43.0	510.2	713.9	1384.2
Annual Operating Costs (OPEX) (USD million)	4.8	5.8	23.2	18.5
Annual cost of RES restrictions (USD million)	13.2	-	-	-
Total cost of work (1st year of operation) (USD million)	64.5	515.3	746.7	1450.5
Total cost (5 years) (USD million)	145.4	540.1	837.2	1470.3
Total cost (15 years) (USD million)	385.8	671.3	1209.4	1708.3

Source: developed by the authors based on own calculations and official reports of multinational corporations [21,29–33].

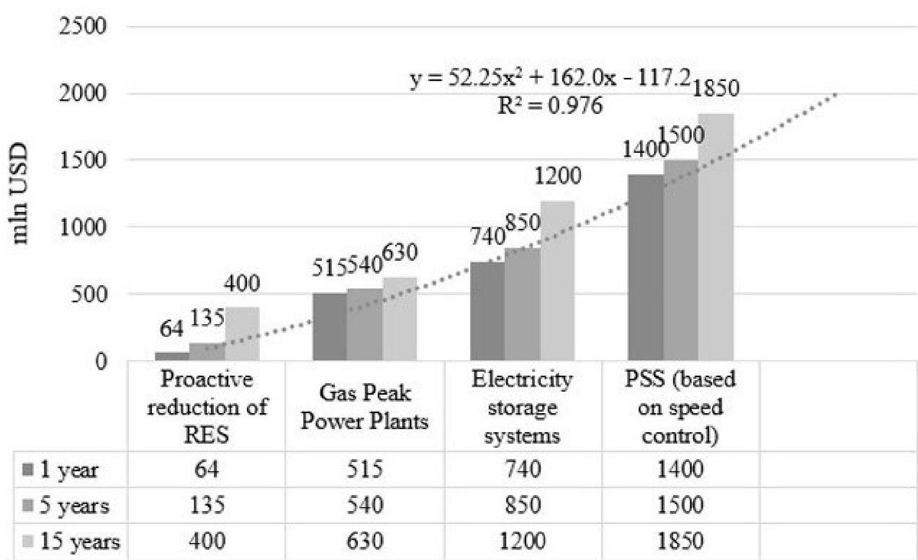


Figure 6. Projected costs for the development of renewable energy in Russia for a sample of multinational corporations for different scenarios. Source: developed by the authors based on own calculations and data from official reports of multinational corporations and consulting agencies [21,29–33].

As one can see, the proactive limitation of RES, as the most affordable solution to overcome the shortage of flexible generation according to the results of the economic assessment (Table 2, Figure 6), shows an obvious advantage both in the short-term (1 year) and in the long-term scenarios (5 years, 15 years). This cannot be said for other options for increasing the flexibility of the power system, such as energy storage systems, internal combustion engines, and new pumped storage plants.

Based on the analysis of the studied multinational corporations' performance for 2016–2020, the level of their development was determined. The results of the development index of multinational corporations for the study period are shown in Figure 7.

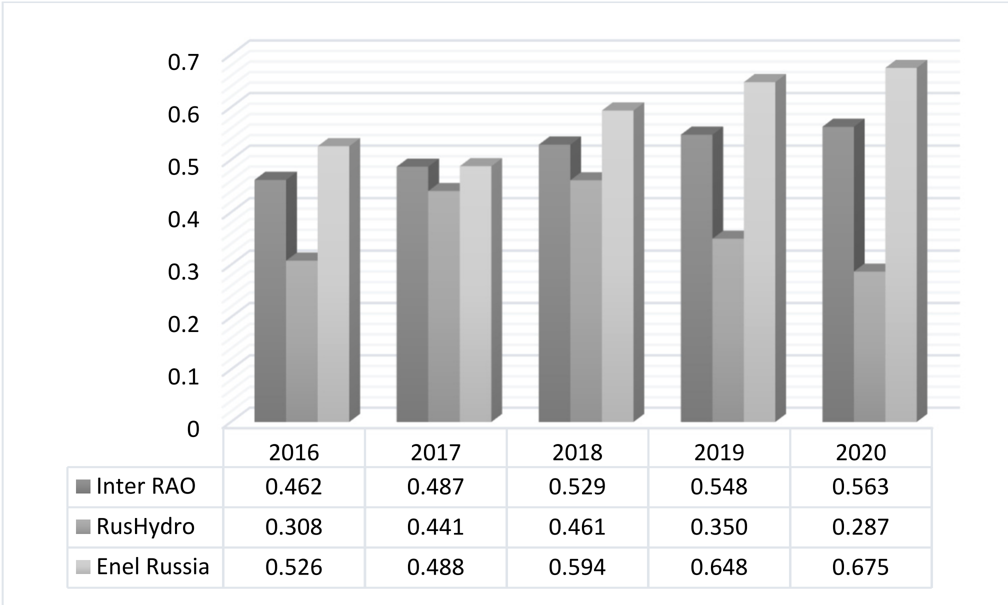


Figure 7. Dynamics of the level of development of the studied multinational corporations. Source: generated by the authors.

For Inter RAO and Enel Russia, positive dynamics of development are observed during the studied period. At the same time, Enel Russia has the highest development indicator among the examined multinational corporations. RusHydro is characterized by an unstable situation and a decrease in the level of development during the study period.

To determine the dependence of multinational corporations' renewable energy production on their development level, an indicator of their flexibility was calculated. To determine the degree of interdependence between the energy flexibility of multinational corporations and their development level, an analysis of variance was conducted, the results of which are shown in Table 3.

Table 3. Results of variance analysis of the relationship between multinational corporations' energy flexibility and their development level.

	df	**SS**	**MS**	**F**	**F Sign**	
Regression	1	0.1135	0.1135	22.3904	0.0004	
Residue	13	0.0659	0.0051			
Total	14	0.1795				
Factor	Coefficients	Standard Error	*t*-Stat	*p*-Value	Lower 95%	Higher 95%
Y-intersection	0.0020	0.1050	0.0190	0.9851	−0.2248	0.2288
Multinational Corporation's Flexibility Index	0.7521	0.1590	4.7318	0.0004	0.4087	1.0955

Source: formed by the authors.

The results of the variance analysis confirm the sufficient level of connection between the energy flexibility of multinational corporations and the level of their development, since the P-value for the variables is less than 0.05. The generated regression model is applicable based on the benchmarks such as Ftabl < F (4.67 < 22.39), tobs = 4.73 exceeds tcrit = 2.16. The obtained results of the analysis of variance in the graphical representation are shown in Figure 8.

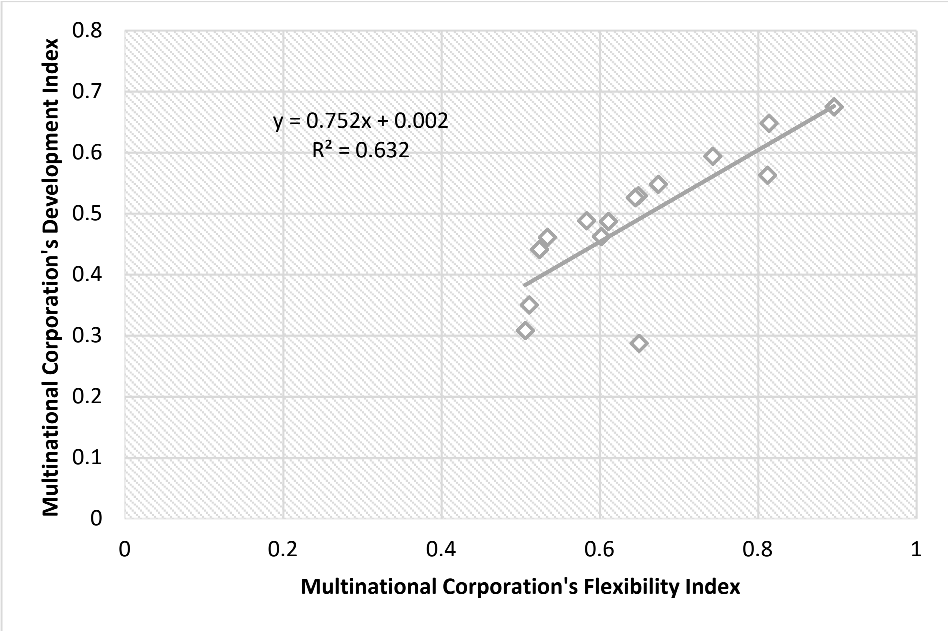


Figure 8. Interdependence of multinational corporations' energy flexibility and their development level. Source: generated by the authors.

The relationship is also confirmed by the determination coefficient $R^2 = 0.63$. It indicates a sufficient level of correlation between the studied indicators, as well as the adequacy of the generated regression equation. Based on the resulting regression equation, the authors modeled the development indicators of the studied multinational corporations, taking into account the increase in energy production from renewable sources (Figure 9).

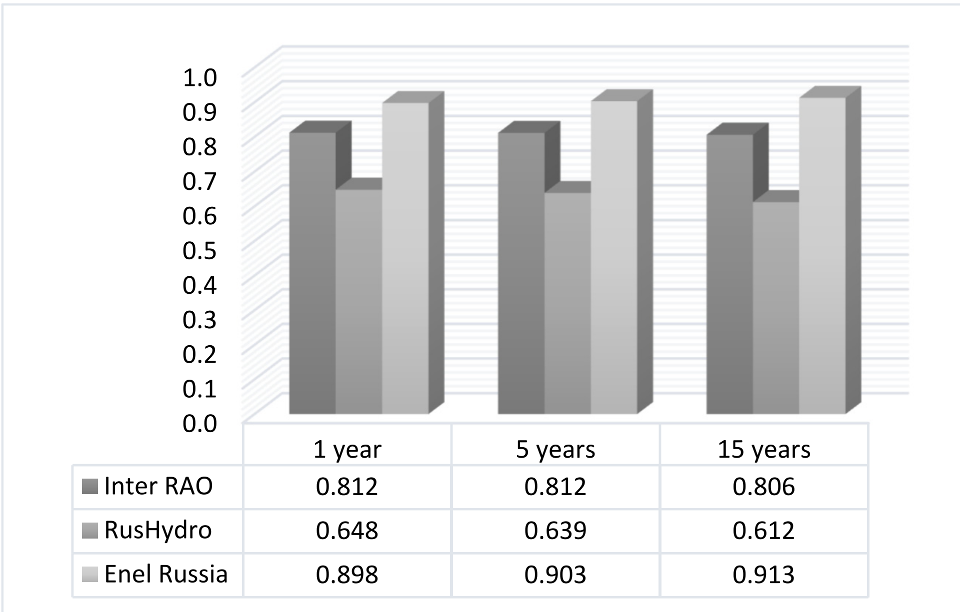


Figure 9. Simulated level of development of the studied multinational corporations with regard to changes in their energy flexibility. Source: generated by the authors.

Despite the positive development trend of Inter RAO and Enel Russia over the study period, the increase in renewable energy production has different implications for these multinational corporations. Only for Enel Russia, there is a positive developmental effect. Inter RAO and RusHydro are characterized by a decrease in developmental efficiency.

This confirms the fact that each multinational corporation is unique in its development. However, it is important to emphasize that multinational energy corporations in Russia are not ready to proactively increase renewable energy production because they currently lack energy flexibility. Besides, renewable energy production requires substantial investments. The profitability and payback period of the latter in Russia have not yet reached a sufficient level to ensure the high energy flexibility of multinational corporations.

6. Discussion

The study confirms that the integration effects, which can be expressed in the synergy of companies engaged in the production of electricity from renewable energy sources and participating in the electricity market, can be obtained through the cooperation of these companies within a single corporate structure [52]. At the same time, the advantage of competitive behavior lies in the formation of a corporate network space formed by companies, which can function in the international arena and influence the development of the global energy market.

The advantage of this study is focusing on the flexibility of implementing corporate renewable energy projects based on alternative scenarios and the possibilities of integrating renewable sources into the structure of energy production [53]. However, the opinions of researchers in this aspect differ. Supporters of the first point of view are of the opinion that the flexibility of an energy system should be understood as its required quality with a high degree of variable generation, in particular, solar and wind energy, which is based on stochastic generation indicators [54,55]. A different view of scientists comes down to the fact that the flexibility of the power system is a kind of market service that is provided on the basis of a set of technical qualities and properties of the generators of a national power system that already exist at the current time [16,27]. The next international discussion revolves around the classification of energy system flexibility management methods and indicators that characterize this category. According to one approach, there are two main methods of managing the flexibility of the power system: distribution (redistribution) of sources of electrical energy and management of demand for electricity [26,56].

This study proves that the recommendation of USAID for the energy systems of CIS states, which consists of analyzing the possibility of modernizing pumped storage power plants or building new units with speed control technology, is also relevant for the Russian energy system [22,28]. Its approbation in this study indicates that the corporatized business of renewable energy in CIS region (e.g., in Russia) currently does not have sufficient flexibility in the energy system, however, the results of the scenario analysis indicate potential and good prospects, taking into account regulatory changes.

The positive side of this study is the emphasis on the fact that the correct distribution of the electric energy market components, as well as the systems of its accumulation, increases the system's elasticity while maintaining its viability at the required level in conditions of natural or human-made disasters. Companies, in turn, representing traditional generation, provide coverage of base loads, contributing to the integration of RES into national energy systems [57].

The limitation of this study is that for the success of integrating RES and traditional generation into a single electrical grid system, it is important to take into account the technological features of the functioning of both systems. For example, daily fluctuations in consumer demand, instability of electricity production due to the natural features of RES generation (weather conditions, wind, and sun) [17,22,36].

Dynamic (proactive) RES limitations should be considered as an important option in view of providing flexibility for infrequent cases of lack of flexible generation. One needs to adapt the operating procedures and tools of the dispatch center to manage proactive RES restrictions [58].

In the future, the study can be supplemented with the following indicators: those characterizing the management of price signals in energy markets; indicators of temporal flexibility (the ability to change market conditions over time); indicators of geographic flexibility (the ability to manage demand and/or supply, the ability to switch to alternative power supply schemes, system flexibility, i.e., the ability to work in the system, for example, frequency regulation in the power grid, etc.) [10,44]. Besides, the research focus can be expanded on the study of the situation in other countries and regions, comparative characteristics, and analysis of efficiency and impact on the development of the economy as a whole [59].

This study may be of interest to those who formulate strategies and policies in the field of renewable energy, scientists specializing in justifying the introduction of renewable energy sources in business, as well as top management of multinational companies expanding their corporate, social, and environmental responsibility to society.

7. Conclusions

As one can see, energy transformation can act as a driver of new large-scale changes in energy business, because, as the study shows, the end of the era of fossil energy generation entails a whole chain of changes and requires greater flexibility of national energy systems and more flexible legislation in this area.

In turn, the integration processes, corporatization of the energy business contribute to changes in international trade, the emergence of new world energy leaders (renewable energy), and the need to switch to clean ecological production, etc. Understanding these global trends and innovative solutions will allow the transformation of the energy sector of an individual state and integration into new economic processes.

In particular, the results of analyzing basic scenarios for the development of the corporate renewable energy industry and assessing projects in the corporate renewable energy industry are as follows:

The lack of capacity for loading and unloading demonstrates a tendency of infrequent occurrence for all baseline scenarios until 2025. If the construction of new power plants meets the requirements for the additional installed capacity, then their installed capacity utilization factor during the year will be below 1–2%.

Concerning the predicted level of restrictions on the development of RES, the need to restrict RES is inevitable for all considered scenarios, in particular for 2021, 2023, and 2025 (about 1–1.5% of the annual supply of RES in the baseline scenarios).

Development of cross-border ties (including within the framework of transnational (international) corporate energy business) is a source of improving the flexibility of a national energy system. Taking into account interactions with neighboring countries as a resource for flexibility is an important enabling factor for increasing the flexibility of the grid.

A decrease in nuclear energy production is expected in the energy balance (green-coal paradox). To increase the flexibility of the energy system, the model tested in the study showed the need to reduce the nuclear power generation by 5–15% (depending on the level of RES integration). Meanwhile, multinational energy corporations in Russia are not ready for a significantly accelerated increase in renewable energy production because they currently lack energy flexibility. The scientific contribution of this study is the proposed indicator in the form of the Multinational Corporation Energy Flexibility Index. It provides an opportunity to diagnose the maneuverability of multinational corporations' development, including changes in their production structure. Modeling this indicator for the multinational corporations under study indicates that the Russian market is not ready for a proactive increase in renewable energy production, as its activation does not guarantee effective development for multinational energy corporations.

In general, the work can be recommended for use in studies aimed at assessing the flexibility of national energy systems, as well as in the business practice of managing international businesses operating in the field of renewable energy.

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