Journal of Cleaner Production 269 (2020) 122110

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Risk assessment in renewable energy projects: A case of Russia

Galina Chebotareva [a], Wadim Strielkowski [b], Dalia Streimikiene, PhD [c, *]

[a] Ural Federal University, Academic Department of Energy and Industrial Enterprises Management Systems, Mira street 19, 620002, Ekaterinburg, Russian Federation

[b] Department of Trade and Finance, Faculty of Economics and Management, Czech University of Life Sciences Prague, Kamýcká 129, 165 00, Prague 6, Prague, Czech Republic

[c] Sustainable Management of Natural Resources and Environment Research Group, Faculty of Environment and Labour Safety, Ton Duc Thang University, Ho Chi Minh City, Viet Nam

ARTICLE INFO

Article history:
Received 4 March 2020
Received in revised form
3 May 2020
Accepted 5 May 2020
Available online 15 May 2020

Handling Editor: Giorgio Besagni

Keywords:
Renewable energy sources
Investments
State support
Risk assessment
Project management
Russia

ABSTRACT

The support of the renewable energy sources (RES) is an important endeavor that might help to reduce the impacts of global warming and prevent the depletion of world's energy resources. However, it calls for the application of special government-funded plans envisaged for its support and stimulation. Political uncertainties and ineffectiveness of the state support often tend to increase the risks associated with the RES projects and, as a result, hinder their successful development. Hence, the assessment of the soundness of the current government-sponsored policies on renewable energy development becomes a very relevant and important task. Our paper presents the results of a theoretical analysis of the main types of state support measures for renewable energy in Russia. Furthermore, it employs an energy-specific logit-model that allows to assess the external and internal factors having an impact on default of the Russian RES projects. Moreover, the paper studies the risk dynamics at all stages of the life cycle of RES projects and evaluates the effectiveness of state measures to support the RES sector. In addition, we carry out the assessment of the "real" efficiency of state support mechanisms without "zero-risk" projects. Our results might be used for improving the existing approach to risk assessment in the RES market, as well as for the development of a concept of competition between traditional and renewable energy at the global energy market.

© 2020 Elsevier Ltd. All rights reserved.

1. Introduction

Renewable energy sources (RES) constitute a very promising, yet quite novel and risky asset within the global electricity system. Thence, the state support is often required for stimulating the development of the renewable energy on the new markets, especially in the countries that do not seek to implement alternative energy resources (Smeets, 2018). By "state support" we understand government incentives and funding targeted at the development of the renewable energy through the policies of regulating energy markets, as well as the usage of government programs and instruments for stimulating the investments in RES. Russian energy market is a typical example of this case. Being very tiny, immature, and dependent on fossil fuels (in which Russia is abundant), it constitutes just a tiny fraction in comparison with the renewables markets in European Union (EU), United States, Japan, China, or, Australia (Szulecki and Westphal, 2018). However, the trend reverses and the global warming and climate change start to affect Russian traditional attitudes and preferences for energy. Russian stakeholders are becoming increasingly engaged into RES promotions and initiatives, perhaps due to realizing the role of the country in its contribution to the global climate change (Pristupa and Mol, 2015). Even though Russia possesses limited and highly seasonal solar availability (since it belongs to those 30% of the global population that does not benefit from living in the sunbelt), there are other renewable sources that can be developed in the local conditions (e.g. hydro power, biomass, or wind power). Surely, there are also other limitations too that are linked, for example, to the immaturity and size of the Russian RES market (20 times less installed renewables per person per year in comparison with EU or USA, and 80 times less in comparison with Australia), as well as to such factors as poor and highly seasonal solar availability (Panepinto et al., 2017; Proskuryakova and Ermolenko, 2019).

* Corresponding author.
E-mail addresses: g.s.chebotareva@urfu.ru (G. Chebotareva), strielkowski@pef.czu.cz (W. Strielkowski), dalia.streimikiene@tdtu.edu.vn (D. Streimikiene).

https://doi.org/10.1016/j.jclepro.2020.122110
0959-6526/© 2020 Elsevier Ltd. All rights reserved.

Despite the continued dominance of traditional energy in recent years, the situation with RES in Russia is changing. The development of the economically feasible regional energy development programs based mainly on renewable energy technologies is justified by the need to develop advanced energy technologies, increase energy efficiency of production, comply with the environmental standards, and to expend the significant potential of renewable energy in the country. This potential is due to the presence of vast territories (about 60–70% according to experts) where the development of renewable energy technologies is economically, environmentally, socially appropriate and might involve the following aspects:

- replacement of low-power diesel and gasoline generators operating on expensive imported fossil fuels and physically worn-out traditional power equipment;
- introduction of the renewable energy technologies in settlements isolated from centralized energy supply systems, particularly in the areas with a large power shortage or with complex environmental conditions.

The most promising RES sectors in Russia are wind and solar energy, hydropower (on small rivers), and biomass (vast areas covered by forests). According to some estimates, they might increase the share of renewable energy sources in Russia up to 25–30% of the total energy balance.

Some experts disagree on the effectiveness of existing state support mechanisms for renewable energy, thence there is currently a “conflict of two restrictions” which means that attracting new players to the industry and increasing the production of equipment would require to increase the selection of projects to 10–15 GW, however this would lead to the unacceptable shift of the burden on the consumers (Dyatel, 2017; Shimbar and Ebrahimi, 2019). On the one hand, the development of renewable energy requires attracting new players to this market and increasing the production of special energy equipment (Bohnsack et al., 2016; Karimi and Komendantova, 2017). This becomes possible thanks to an increase in the number of the RES projects of up to 15 GWh and above as illustrated by the recent statistics (IRENA, 2019). On the other hand, it might lead to an excessive financial burden for the consumers. Thus, according to some experts, with the increased competition in the Russian renewable energy market, consumers would have to pay about 1.63 trillion rubles ($ 22 billion at the current exchange rate) for the green energy from 2018 to 2024. In this regard, consumers are in favor of abandoning existing measures to support the sector, and renewable energy investors, on the contrary, for their extension and increase in government support in the form of subsidies and state guarantees (Dyatel, 2017).

Nowadays, the main tool for stimulating RES in Russia is the selection of projects and the provision of contracts for capacity supply. Thus, capital expenditures (CAPEX) are refunded by charging higher tariffs (Lisin et al., 2015; Kaček et al., 2019; Rullo et al., 2019). As a result, consumers consider state support to be ineffective, demanding that it should be discontinued, and investors require new mechanisms of state support (Adams et al., 2018; Hu et al., 2018; Trinks et al., 2018; Wei et al., 2019). Regarding all of the above, it becomes apparent that the effective state support can become an effective tool for overcoming the fossil fuel era not only in Russia but also in the sunbelt countries facilitating the direct transition to the renewable sources of energy (Argentiero et al., 2018; Carfora et al., 2018; Strielkowski et al., 2019; Zhang et al., 2019). Commercial considerations and the “invisible hand” of the free market might be a good basis for small-scale RES projects (e.g. peer-to-peer (P2P) energy markets run by the prosumers) (Gui and MacGill, 2018; Abrishambaf et al., 2019), but in order to provide a steady supply of energy to such country as Russia (in fact, the largest country in the world according to the total territory), strict political control and supervision (including imposing the regulations “from the above”) might be required (Morozov, 2016; Chebotareva, 2018b).

Therefore, there appears to be a complex and urgent need for conducting an applied study into the effectiveness of modern instruments of government support for renewable energy (Li et al., 2018; Perlaviciute et al., 2018; Xie et al., 2019) from the standpoint of assessing specific risks. In this way, the main objectives of this paper are the following: 1) to assess the level of risk by three main stages in Russian renewable energy projects based on a sector-specific approach; 2) to study the dynamics of risk in such projects by groups depending on the peculiar types of state support of the RES sector in Russia (including the absence of state support); 3) to evaluate the current “real” (in) effectiveness of existing types of support for renewable energy in Russia in terms of reducing the risk of projects and study the reasons; 4) to develop the recommendations, mainly methodological, for the future areas of research on the effectiveness of state support for renewable energy.

Our paper features a comprehensive systematization of significant features of investors in the global RES market (Section 2). It also provides some theoretical generalizations of the existing specific risks in renewable energy projects (Section 3). We conduct a comprehensive review of the primary types of specific risks that are typical for renewable energy and present the results of quantitative assessment of the profitability factors of RES projects. In addition, the paper offers a comprehensive study of the overall impact on the effectiveness (as well as riskiness) of RES projects (Section 5). Furthermore, it analyses the dependence of the risk value on various types of government support (including the absence of this support). On the basis of our assessment, we draw conclusions about the effectiveness of modern instruments of government support of the RES sector in Russia and beyond. Even though Russia is not a typically RES-advanced country, according to our analysis and the review of available literature, the potentials and the RES sector in Russia remains an underdeveloped and poorly researched topic. Thence, our paper constitutes a valuable endeavor that might shed some light on this issue and bring some novel findings.

Our results might be of practical importance for researchers, stakeholders as well as policymakers and thence can be used in the development of a methodical approach to risk assessment in RES projects and in assessing the effectiveness of new mechanisms of state stimulation of this sector. These results can also be used for studying competition on the global energy markets among such key players as United States (Talipova and Parsegov, 2018), Russia (Oppong et al., 2016; Lanshina and Kulakov, 2017), China (Lai and Warner, 2015; Lanshina and Kulakov, 2017; Bai et al., 2019; Khuong et al., 2019), or EU (Fouquet and Johansson, 2008; Borawski et al., 2019; Su et al., 2020) helping to understand the trends and challenges of the energy sector.

2. Mechanisms of state support of renewable energy

This section presents a brief overview of the existing pathways of state support (or “stimulation”) of the renewable energy projects (see Table 1 that follows). It is based on the results of a theoretical analysis of the characteristics of global practice of supporting RES and takes into account the regional distribution and the effectiveness of impact of these pathways on renewable energy development.

As it stems from the results of EU-funded Dia-Core project (2016), it appears possible to reflect on the main specifics of private and public investors in the global renewable energy market including the main types of investors, their degree of participation

Table 1
Pathways of governmental support for the renewable energy projects on the global market.

Pathway	Characteristics		Countries and regions	Impact	References
Feed-in Tariff (FIT)	Fixed tariff (usually for small RES objects)	The price is officially set by the authorities to be higher than the average market price	France, Austria, Latvia, Lithuania, Bulgaria, Ireland, Luxembourg, Greece, Hungary, Slovakia, China, Russia	In a 15-year period, Austria was able to become one of the EU leaders in RES utilization (hydro and bioenergy)	Gonzalez et al. (2018); Govender et al. (2019)
Feed-in Premium (FIP)	Preferential tariff depends on the prices for electricity on the market electricity prices (typically for large-scale RES projects)				
Trading of renewable energy certificates	Quotas for RES sources are being delegated	All agents on the market are obliged to engage in generating and distributing RES	Sweden, Poland, Romania, Russia	In Sweden, renewable energy certificates increased the share of RES to more than 50%	Gui and MacGill (2018)
Tenders and auctions	Electricity is supplied via competitive projects	Focuses on large-scale projects	Almost all EU countries	Cheaper electricity for consumers	Hu et al. (2018); http://investing.com/ Investing.com, 2018
Photovoltaic energy preferences	Photovoltaics (PV) and solar energy receive support	Regulations and directives for ensuring the amount and the requirements for generating heat	Denmark, Ireland, France, Germany, Greece, and Spain	Photovoltaics used in district heating. Wider use of geothermal plants	Jenniches (2018); IRENA, 2019; Johnston (2019)
Technology-neutral obligations	Support for heating technologies				
Grants, preferential loans, tax incentives	Competitive compensations for investors. Substantial tax benefits for the production of RES at specific facilities		Almost all EU countries	RES projects' share increases	Kabir et al. (2018)
"Green" subsidies	Envisaged for supporting sustainable projects within RES initiatives		Almost all countries	Improved environmental sustainability of RES	Karimi and Komendantova (2017); Karunathilake et al. (2019)
EU Member States working together	Mechanism of mutual assistance for helping to achieve RES targets for all EU Member States		All EU countries	Greenhouse gases reduction around 40%, improvements in energy efficiency	Gonzalez et al. (2018); Keček et al. (2019)
Renewable Heat Premium Payment (RHPP)	Households are reimbursed for the RES heating equipment		Great Britain	Novel and unique initiative for supporting RES heat	Kost and Längle (2019)
Renewable Heat Incentive (RHI)	Businesses and households installing RES heating equipment are reimbursed (by fixed amounts)		Great Britain		
Collaboration between EU and the third countries	Introducing special policies, tax incentives, and economic incentives		EU Member States	"One stop shop" agencies envisaged to help RES startups	Kozlova and Collan (2016)
Green Patent Pilot Program	Fostering patent applications on RES		United States	RES-related patents are given special priority	Kozlova et al. (2018); Kruger et al. (2019)
Centers of Energy Innovations	Recruiting experts and teams of professionals for boosting RES-related projects and technologies		United States	Increasing expert engagement	Lai and Warner (2015)

Source: Own results.

in renewable energy projects, their attitude to risk, profitability requirements, as well as the duration of their involvement in the project.

It has to be noted that the Dia-Core project is dedicated to researching the impact of risks on renewable energy investments under the European Union's implementation of a target of "at least 20% renewable energy in final energy consumption by 2020" with co-financing by the Intelligent Energy Europe Program of the EU. The main results of this project are: 1) to study of the specifics of investment activity in renewable energy sources; 2) to assess the current cost of capital of renewable energy projects in the EU and the influence of political factors on the change in this value; 3) to identify the risk categories that affect renewable energy projects throughout their term (including development and sudden changes in renewable energy policy, licensing procedures, access to networks, etc.); 4) to develop the measures for reducing investment risks in the field of renewable energy.

With regard to the above, Ermolenko et al. (2016) discuss the specifics of the investors in RES. First of all, there are large power generating companies that prefer long-term projects and accept all associated risks. Then, there are municipal power generating companies (MPGC) that offer state-provided incentives for participation in long-term project but are only able to accept partial risks. Furthermore, there are independent energy producers that prefer to hold a controlling stake and are capable of accepting higher risks for the price of higher profitability.

As a rule, original equipment manufacturers invest in renewable energy projects in order to sell equipment, therefore they select only economically feasible projects and participate in them for 2–3 years after putting the facility into operation. Infrastructure investment funds are passive investors with the high aversion to risk. On the contrary, private investment funds represent proactive investors who are willing to accept higher risks and who get involved in the project lasting up to 7 years.

On the contrary, pension funds and insurance capital companies are typically conservative investors who demand 5–10% level of income per annum and also prefer long-term projects. YieldCos (companies that own operating assets producing a predictable cash flow) set up independent companies in RES sector and are highly sensitive to risks preferring project yielding profits after just 3 years or so. Green bonds help to finance RES technologies for their entire lifecycle, but they are subjected to risks due to the regulation mechanisms. Finally, companies attempt to reduce the risks associated with RES projects using their portfolio diversification with the help of funding sources.

Therefore, RES initiatives offer various levels and options for both the investors who are willing to take the risk or those who want to remain risk averse. Both options are predetermined by the current level of RES technology development, the situation on the market, the political trends and tendencies, as well as with many other specific factors.

However, in Russian practice, the renewable energy market is relatively young, so it is not characterized by such a large set of support mechanisms that can actually be used. Initially, the development of the sector was supported by the electricity premium scheme (Boute, 2012). Currently the main tools for stimulating the development of renewable energy in Russia are provided at various levels (Boute, 2012; Kozlova and Collan, 2016; Kozlova et al., 2018; Federal Law, 2019). At the federal level, support for the development of renewable energy sources is mainly associated with:

- capacity-based support scheme (CBSS) depending on geographic, technical and other characteristics. This is an economic mechanism of a non-market nature that shifts to consumers the costs of modernization and construction of generation based on renewable energy sources;
- establishing a mandatory rule for the network companies to purchase electricity in the retail market from renewable energy facilities in the amount of 5% of electric losses in networks;
- provision of subsidies from the Federal budget to compensate up to 50% of the cost of technological connections to the renewable energy facilities.
- the provision of price and other benefits for the supply of power, depending on the degree of localization of renewable energy generating facilities. The degree of localization is the share of equipment at the renewable energy facility which is produced in Russia. If the target degree of localization is not met, penalty factors are applied back to the calculated value of the capacity charge;
- using a special currency adjustment coefficient for the currency component of planned capital expenditures for projects launched in 2013–2014. This tool is used to compensate for project costs caused by a sharp depreciation of the ruble in 2014.

However, due to the huge area of the country and the significant differences of each region (climatic, natural, social, demographic and economic), federal programs are supplemented by specific tools to stimulate renewable energy at the level of each region, including:establishing a mandatory rule for the network companies to purchase electricity in the retail market from renewable energy facilities in the amount of 5% of electric losses in networks;

- establishing the long-term tariffs (price formulas) for the purchase of electricity from renewable energy facilities for the payback period;
- ensuring priority loading of renewable energy generating facilities in isolated power systems;
- providing tax incentives for the sale of electricity generated using RES micro-generation for households own needs.

In the future, the retail market plans to introduce a mechanism of green certificates for their sale to consumers and reduce the total amount of payments under existing support mechanisms.

However, all tools are based primarily on the provision of preferential resources. In a practical assessment of Russian renewable energy projects (in Section 5), these will be precisely the ways to support the sector related to concessional project financing and subsidizing.

3. Specific features of risks in renewable energy projects

A number of studies (see e.g. Chebotareva (2018a), or Mokhov et al. (2018)) demonstrated that renewable energy represents one of the most "non-conventional" sectors in terms of assessing the effectiveness (Mignon and Bergek, 2016; Sisodia et al., 2016; Child et al., 2019) and risk of sector projects (Kruger et al., 2019; Rosales-Asensio et al., 2019). The features presented below are fully characteristic not only for the global, but also for the Russian renewable energy market, as they are caused by similar principles of regulation of this sector (see e.g. Kozlova and Collan, 2016; Kozlova et al., 2018; Leisen et al., 2019; or Shimbar and Ebrahimi, 2019). Its specific nature is due to several reasons that have a direct impact on the ways of studying individual risks of RES projects. For example, it becomes apparent that profitability of companies and projects belonging to the renewables sector does not always depend on the main financial indicators including short-term and long-term liabilities, income, total and equity capital, operating profit, as well as depreciation and amortization (Malhotra et al., 2016).

The results of our own qualitative assessment comprising official data from 30 RES companies with leading positions in the market conducted by Chebotareva (2018b) revealed that the effectiveness of RES projects is strongly influenced by such common factors as:

- an insufficient number of qualified personnel in the industry;
- high pace of development of traditional (non-renewable) energy;
- wrong choice of location for renewable energy facilities.

However, the most specific feature of the sector is reflected in the influence of political factors associated with a high dependence of investors on state support measures (Lin and Omoju, 2017; Liu, 2018; Mittlefehldt, 2018; Ebers Broughel, 2019). Within the framework of the Dia-Core project (2016) presents the risk ranking of the survey results among EU member states (see Fig. 1).

The survey in question was conducted among more than 650 stakeholders who participate in renewable energy investments: representatives of the electric power industry, developers and investors of renewable energy projects, renewable energy equipment manufacturers, banks, public organizations and relevant government agencies. Representatives of each country identified the three most dangerous threats (from the first (highest) to the third (lowest) level) for the development of renewable energy in the territory of their state. A detailed structural analysis of these risks reveals the following significant details: political risk appears in the

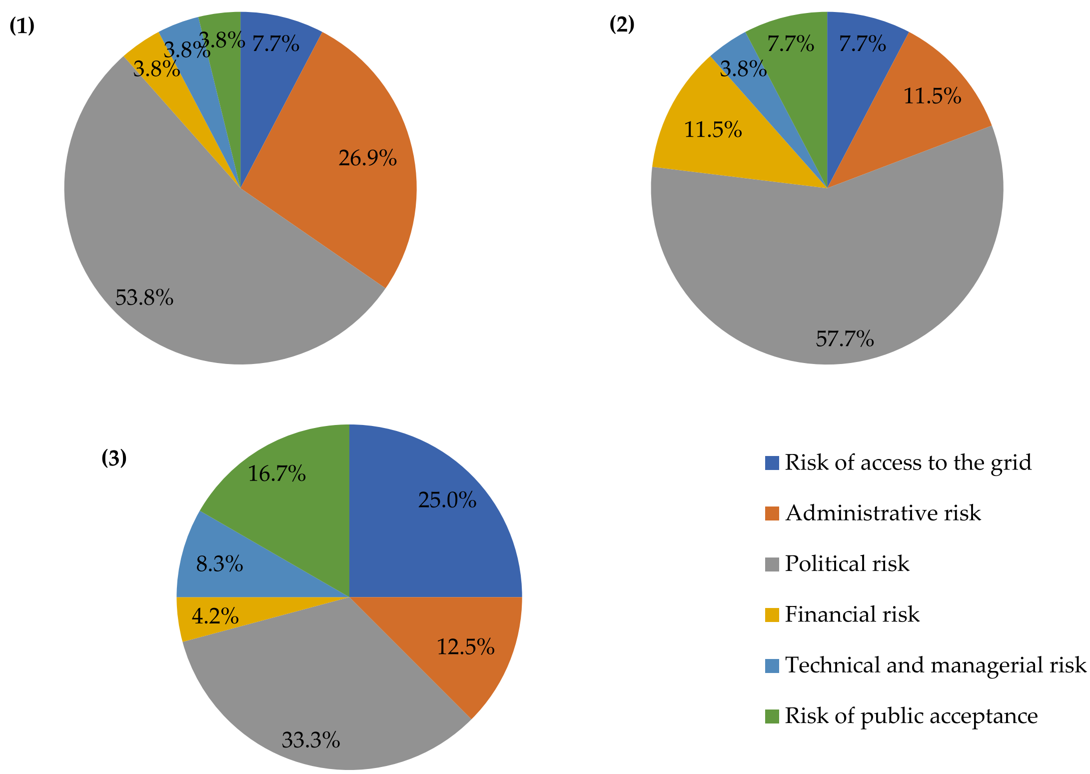

Fig. 1. Rankings of RES risks by the level of hazards (EU countries): first "highest" (1), second "medium" (2), and the third "lowest" (3) levels. Source: Own results.

top 3 for many countries of Eastern Europe (Czech Republic, Bulgaria, Hungary, Slovenia, Latvia, Slovakia), and financing risks are among the leaders for only a few southern member states EU (Cyprus, Greece, Portugal, Romania). Between all regions there is practically no difference in the perception of network access risks and a relatively small difference in the assessment of political risks. As a result, the political risk is recognized as the most dangerous for the sector. It implies a high dependence of the sector on state regulation, political administration and state support schemes for RES projects. Financial risks, in turn, naturally occupy one of the last places in this rating. With regard to the above, we can observe a very similar situation that is typical for the Russian renewable energy market – there is the overwhelming influence of political factors on renewable energy projects caused primarily by government support of the sector.

Moreover, several similar studies (Campatelli et al., 2015; Chioncel et al., 2017; Shimbar and Ebrahimi, 2019) demonstrated that risks stemming from the wide-scale deployment renewable energy sources in the economy might be further deepened by a set of political factors such as the following ones:

- unexpected turns and alternations in the renewable energy strategy and support scheme such as stopping support schemes, revoking investments into the RES, or stopping governmental support programs;
- unclear amount and length of state funding programs for RES which brings uncertainty for potential investors;
- legal barriers for the new entrants to the market for electricity, lack of the independent regulator, or legal uncertainty.

4. Methodology of risk assessment in RES projects: a logit-model

The study of the level of risk of RES projects is based on a well-known and globally recognized approach: assessment of the forecast logit-model in eqn (1) (Khaidarshina, 2009; Sorland and Rudel, 2015; Deetjen et al., 2018; Dupont et al., 2018; Kabir et al., 2018; Mokhov et al., 2018; Ellabban and Alassi, 2019; Govender et al., 2019; Karunathilake et al., 2019). The choice of logit modeling as the main method is due to its wide practical applicability in modern industry risk management; its purpose is to assess the probability of default based on a combination of financial and non-financial indicators.

$$PD = 1/(1+e^{Y}), \tag{1}$$

where:

PD – Probability of Default of RES project;
e = 2,71,828;
Indicator Y – an integral indicator estimated by the proposed model.

The calculation of the probability of a default of RES projects is based on the model (2), taking into account the specific characteristics of the Russian economy, local as well as international energy market (Khaidarshina, 2009; Li and Adachi, 2017; Xie et al., 2018). This model (2) was developed on the basis of a statistical sample of data directly from energy companies (bankrupt and non-bankrupt) that implement projects in the Russian and international energy markets. The advantages of model (2) are the assessment of not only the data of the RES project itself, but also the energy company - its initiator, as well as taking into account foreign economic features of the functioning of the market; additional inclusion in the model of a set of external indicators allows us to solve the problem of taking into account the regional specifics of each project. At present, the lack of sufficient experience in the bankruptcy/non-bankruptcy of renewable energy projects makes it impossible to develop and apply a new logit model specific only to the renewable energy sector

$$Y = a_0 - a_1K_1 - a_2K_2 - \ldots - a_{11}K_{11}, \quad (2)$$

where:

$a_0, a_1, \ldots, a_{11}$ – the industry-specific constants of significance of the coefficients for the fuel and energy sector;
$K_1, K_2, \ldots, K_{11}$ – the indicators specialized for fuel and energy sector.
The qualitative assessment of energy projects is provided by the dummy-variables K_1, K_2, K_7, namely:
K_1 takes into account the factor of "age" of the energy company - project initiator;
K_2 – the characteristics of the credit history of the energy company;
K_7 – reflects the regional affiliation of the project.

They take values according to conditions (3):

$K_1 = 0$, if the energy company was created more than 10 years ago,

$K_1 = 1$, if the energy company was created less than 10 years ago,

$K_2 = 0$, if the energy company has positive credit history,

$K_2 = 1$, if the energy company has negative credit history,

$K_7 = 0$, if the RES project is located in the capital,

$K_7 = 1$, if the RES project is not located in the capital. (3)

The quantitative assessment of the risk level is based on the calculation of other exogenous and endogenous financial and economic indicators both the project itself and the initiating company:

- K_3 – the current ratio (liquidity ratio);
- K_4 – the ratio of profit before tax and interest paid for the period;
- K_6 – the weighted average key interest rate of the Central Bank;
- K_8 – Return on Assets (RoA);
- K_9 – Return on Equity (RoE);
- K_{10} – growth rate of the project equity capital;
- K_{11} – the growth rate of assets of the project for the period.

$$K_5 = \ln(\text{sum } EC_\beta), \quad (4)$$

where:

K_5 – the weighted average capital of the company;
EC_β – the equity capital of the energy company for the β period;
β period is from 1 to m.

Taking into account the specific features of the fuel and energy sector in Russia, the distribution of industry-specific constants is presented in Table 2. These indicators are calculated on the basis of an analysis of the statistical data sampling: the data covering the success stories of the implementation of solely Russian renewable energy projects (those that went bankrupt and those that remained in operation on the market) directly on the set of indicators and conditions presented above.

Table 2
The value of the constant coefficients of the model for the fuel and energy sector.

Indicators	a_0	a_1	a_2	a_3	a_4	a_5
Value	30,7371	3,7033	8,9734	−8,6711	−7,0110	−1,6427
Indicators	a_6	a_7	a_8	a_9	a_{10}	a_{11}
Value	−0,1399	−0,6913	−5,0894	−15,3882	7,3667	−22,0294

Source: Own results.

The proposed model assumes the following total values (5):

If PD is [0; 0,2), the RES project has minimal risk,

If PD is [0,2; 0,4), the RES project has low risk,

If PD is [0,4; 0,6), the RES project has average risk,

If PD is [0,6; 0,8), the RES project has high risk,

If PD is [0,8; 1,0], the RES project has maximum risk. (5)

In the framework of this article, the practical use of the presented logit-model under conditions (1) and (2) will allow a comprehensive assessment of the risk level of Russian renewable energy projects. The purpose of this assessment is to study how the level of risk varies during the stages of renewable energy projects under the influence of various methods of state stimulation of renewable energy in Russia. As a result, this allows us to evaluate the current effectiveness of existing support mechanisms. The results of this assessment and the findings are presented below.

5. Practical assessment of risk in RES projects

This section presents an assessment of the risks associated with the Russian renewable energy projects depending on the type of state support. In the framework of this article, risky is understood to mean projects that have an average, high or maximum risk level in the first year of implementation in accordance with conditions (5); project default - the case when the project *PD* value is maximum by the end of the project term under conditions (5).

At present, the Russian renewable energy market is still quite immature because the number of renewable energy projects and the volume of commissioned capacity are significantly inferior to the situation abroad. Therefore, a total of 25 RES projects in the most priority areas of renewable energy development in Russia (Resolution of the Russian Government, 2013) were selected as research objects: among them wind (36%), solar (52%), and hydro power (12%) ones.

All projects in our study are divided into three main groups depending on the measures of state support (Tables 3–5). The following measures were identified in the projects as being examples of direct state support mechanisms in Russian renewable energy sector:

- concessional government lending,
- non-repayable subsidies,
- absence of any state support.

The initial information for the analysis is based on the official data (confirmed by the findings of international audit agencies) of

Table 3
Distribution of risks in RES projects in the case of concessional government lending.

RES types	Project	Initiator	Period	Name of the project stage	The duration of the stage	Risk (avg.)	Risk profile
Wind power	Adygeyskaya 1–3: onshore WPP	State corporation "Rosatom"	2016 –2020	Pre-investment	2016	0,00	Minimal
				Investment	2016–2020	1,00	Maximum
				Post-investment	From 2020	No data available	
	Wind measurement complex in Stavropol region	Private company JSC "Vetrogeneriryuschaya companiya"	2013 –2015	Pre-investment	2013	0,332	Low
				Investment	2013–2015	0,777	High
				Post-investment	From 2015	1	Maximum
Solar power	Kalmykskaya SPP	Private company LLC "Solar Systems"	2015 –2019	Pre-investment	2015	0	Minimal
				Investment	2015–2019 (avg. 2015 –2018)	0,384	Low
				Post-investment	From 2019	No data available	
	SPP Staromaryevskaya	Private company LLC "Solar Systems"	2014 –2018	Pre-investment	2014	0	Minimal
				Investment	2014–2018	0,599	Average
				Post-investment	From 2018	1	Maximum
	SPP in Abakan	Private company PJSC "Kracnoyarskaya HPP"	2013 –2014	Pre-investment	2013	0	Minimal
				Investment	2013–2014	0	Minimal
				Post-investment	From 2014	0	Minimal
Hydropower	Beloporozhskaya HPP-1	Private company LLC "NGBP"	2015 –2019	Pre-investment	2015	0,979	Maximum
				Investment	2015–2019 (avg. 2015 –2018)	0,510	Average
				Post-investment	From 2019	No data available	

Source: Own results; Note: WPP – wind power plant; SPP – solar power plant; HPP – hydro power plant.

Table 4
Distribution of risks in subsidizing RES projects.

RES type	Project	Initiator	Period	Name of the project stage	The duration of the stage	Risk (avg.)	Risk profile
Wind power	Wind farm-1	Private company PJSC "Fortum"	2016 –2018	Pre-investment	2016	0,162	Minimal
				Investment	2016–2018	0	Minimal
				Post-investment	From 2018	0	Minimal
	WPP "Fortum Simbirskaya"	Private company PJSC "Fortum"	2015 –2017	Pre-investment	2015	0	Minimal
				Investment	2015–2017	0	Minimal
				Post-investment	From 2017	0	Minimal
	WPP Priyutnenskiy	Private company LLC "ALTEN"	2014 –2016	Pre-investment	2014	1	Maximum
				Investment	2014–2016	1	Maximum
				Post-investment	From 2016	1	Maximum
	WPP in the far East of Russia	Private company PJSC "Peredvijnaya energetika"	2014 –2020	Pre-investment	2014	1	Maximum
				Investment	2014–2020 (avg. 2014 –2018)	1	Maximum
				Post-investment	From 2020	No data available	
	Wind-diesel complex at oil field (Tatarstan)	Private company LLC "Aktiviti"	2013 –2014	Pre-investment	2013	1	Maximum
				Investment	2013–2014	0,5	Average
				Post-investment	From 2014	0	Minimal
	WPP in Western Siberia	Private company LLC "Teploenergoservis"	2015 –2016	Pre-investment	2015	0	Minimal
				Investment	2015–2016	0	Minimal
				Post-investment	From 2016	0	Minimal
Solar power	SPP Aleyskaya	Private company LLC "Green Energy RUS"	2017 –2020	Pre-investment	2017	1	Maximum
				Investment	2017–2020 (avg. 2017 –2018)	1	Maximum
				Post-investment	From 2020	No data available	
	Buribaevsky SPP-3	Private company LLC "Avelar Solar Techology"	2016 –2020	Pre-investment	2016	0	Minimal
				Investment	2016–2020 (avg. 2016 –2018)	0	Minimal
				Post-investment	From 2020	No data available	
	SPP Caspian	Private company LLC "MEC-Engeneering"	2013 –2016	Pre-investment	2013	1	Maximum
				Investment	2013–2016	0,75	High
				Post-investment	From 2016	0	Minimal
	Sunny Park in Belgorod region	Private company LLC "Alt-Energo"	2016 –2017	Pre-investment	2016	0	Minimal
				Investment	2016–2017	0	Minimal
				Postinvestment	From 2017	0	Minimal
Hydropower	HPP Sengileevskaya	Public company PJSC "RusHydro"	2013 –2016	Pre-investment	2013	0	Minimal
				Investment	2013–2016	0	Minimal
				Post-investment	From 2016	0	Minimal

Source: Own results.

the renewable energy projects (Investing.com, 2018), as well as that of the administrator of the energy market trading network (AtsEnergo, 2018). It also has to be clearly noted that the names of all the projects can be disclosed in this paper, since they represent publicly open information and can be found in open access at the official websites, reports of energy agencies, as well as press releases. We do not report any conflict of interest or violation of any possible information restriction policies.

Table 5
The distribution of risks in RES projects in the case of absence of state support.

RES type	Project	Initiator	Period	Name of the project stage	The duration of the stage	Risk (avg.)	Risk profile
Wind power	WPP Aksarayskaya	Private company LLC "ComplexIndustria"	2013–2017	Pre-investment	2013	0,41	Average
				Investment	2013–2017	0,227	Low
				Post-investment	From 2017	0,018	Minimal
Solar power	SPP Borzya Zapadnaya	Private company LLC "Green Energy RUS"	2016–2022	Pre-investment	2016	1	Maximum
				Investment	2016–2022 (avg. 2016–2018)	0,89	Maximum
				Post-investment	From 2022	No data available	
	SPP Zarya	Private company LLC "MRC Energoholding"	2014–2018	Pre-investment	2014	1	Maximum
				Investment	2014–2018	0,4	Average
				Post-investment	From 2018	0	Minimal
	SPP Kabanskaya	Private company LLC "ComplexIndustria"	2014–2018	Pre-investment	2014	1	Maximum
				Investment	2014–2018	0,6	High
				Post-investment	From 2018	0	Minimal
	SPP Aleksandrovskaya	Private company LLC "MRC Energoholding"	2013–2017	Pre-investment	2013	0	Minimal
				Investment	2013–2017	0	Minimal
				Post-investment	From 2017	0	Minimal
	SPP Derzhavinskaya	Private company LLC "Avelar Solar Techology"	2013–2017	Pre-investment	2013	0	Minimal
				Investment	2013–2017	0,4	Average
				Post-investment	From 2017	1	Maximum
	SPP in Volgagrad	Private company LLC "Energiya prirody"	2016–2017	Pre-investment	2016	0	Minimal
				Investment	2016–2017	0	Minimal
				Post-investment	From 2017	0	Minimal
Hydropower	HPP Boguchanskaya	Private company LLC "Sibir Engeneering"	2012–2015	Pre-investment	2012	0	Minimal
				Investment	2012–2015	0	Minimal
				Post-investment	From 2015	0	Minimal

Source: Own results.

The main feature of renewable energy projects is their relatively short life cycle of investments. Therefore, within the framework of our study, the following assumptions are conditionally accepted for the purposes of quantitative risk assessment:

- the first six months of the project are a pre-investment stage,
- the final six months of the project are a post-investment stage.

5.1. Risks assessment in the case of concessional government lending for RES projects

The distribution of risks by stage of RES projects in the case of concessional government lending is presented in Table 3 (AtsEnergo, 2018; Investing.com, 2018).

The projects that were funded with a concessional government loan included three solar power plant (SPP) projects, two wind power (WPP) and one hydro power (HPP) ones. Our calculations revealed that practically all the projects studied by us had a minimal or low level of risk at the pre-investment stage. However, by the time they reached the investment and post-investment stages the level of risk significantly increased to high and even reached the maximum value. Only two projects presented the exceptions: 1) the SPP project in Abakan which has a constant zero value of risk; and 2) "Beloporozhshkaya HPP-1" project, in which the risk was reduced to an average value closer to the end of the investment stage. It is not possible to assess the risk of this project at the post-investment stage due to a lack of data.

Therefore, there is a high probability that the initial minimal risk value of the most projects did not require direct financial support by the state. It led to an increase of the level of risk. The average risk values for this group of projects (see Fig. 2) confirm the findings. This result is largely due to the inefficiency of state support, as well as a significant influence of various political factors (Chebotareva, 2019).

5.2. Risks assessment in the case of subsidies for RES projects

The distribution of risks by stages of RES projects in the case of non-repayable subsidies is presented in Table 4.

One half of the presented RES projects seem to yield the maximum risk at the pre-investment stage. It necessitates the use of special support measures. The subsidy tool demonstrated great effectiveness (Ascione et al., 2016; Lombardi and Schwabe, 2017; Johnston, 2019): none of the projects showed an increase of the risk level. The calculated average risk values also indicate the same (Fig. 2). However, a reduction of risk (to the minimal value) is observed only in two projects; in two more there are no actual results for the post-investment period (after 2018). The project "WPP Priyutnenskiy" consistently exhibited the maximum risk at all stages, and for the "Wind farm-1" the risk value was always within the minimal range but decreases to a zero value. Other projects are also characterized by the minimal risk.

5.3. Risks assessment in the case of the absence of state support of RES projects

The distribution of risks by project stages in the case of the absence of any state support is presented in Table 5.

Among these projects, more than half yielded an initial minimal or average level of risk. At the first stage, such projects do not require state support as a tool for minimizing risk. Only three of the RES projects were characterized by the maximum risk. As a result, the increase in risk was observed only in one case – "SPP Derzhavinskaya". The remaining projects showed a reduction of risk to the minimal level by the end of the project term, which is additionally confirmed by the dynamics of the average risk value (Fig. 2). Among the reasons for this we can identify the initial low risk of these projects, the need to rely on private investment resources only, and the lack of influence of political risks.

Fig. 2 above demonstrates that the dynamics of average risk in cases of subsidized projects and projects without government

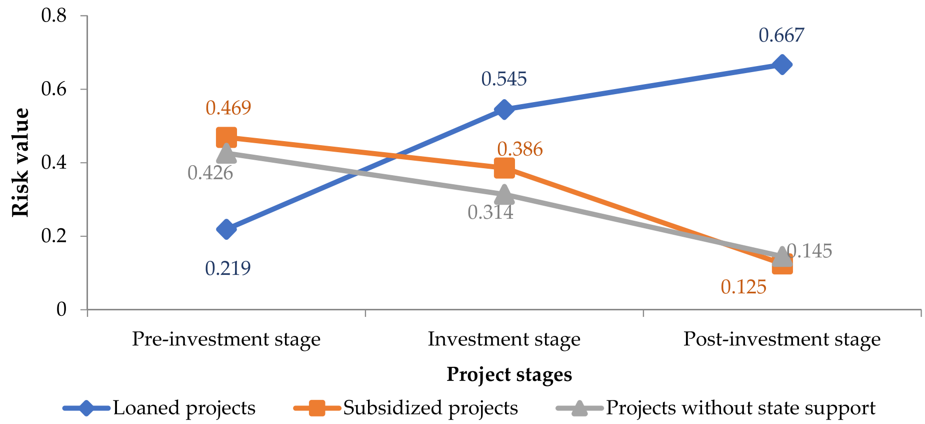

Fig. 2. Distribution of average risk values by stages of RES projects. Source: Own results.

support is quite similar. However, at the pre-investment stage, subsidized projects generally had a higher value of risk. This suggests that initially such projects require the use of specific support measures as a mechanism to reduce risk. As a result, by the post-investment stage, the use of a non-repayable subsidy tool has significantly reduced the average level of risk, including compared to projects without government support which involve the use of (predominantly) private investment. The resulting fluctuations in the final PD indicator are mainly related to the unstable situation on the foreign market: fluctuations in exchange rates, an increase in the cost of investments, a decrease in the profitability of operating activities of energy companies, etc. It appears important to note that considering some peculiarities, all the presented RES projects were successfully implemented in the Russian energy market.

5.4. Evaluation of the “real” efficiency of state support for Russian renewable energy projects

One of the identified reasons for the ineffectiveness of state support mechanisms for the sector is the promotion of the several renewable energy projects that have a zero level of risk at the pre-investment stage for the cases of concessional government lending and non-repayable subsidizing (see Tables 3 and 4). This is due to the imperfection of the mechanism for selecting the sector projects for state support. At the pre-investment stage, such projects do not need state support as a tool to reduce the level of risk. Therefore, to assess the “real” effectiveness of state support, those renewable energy projects that initially have zero risk value are excluded from the total initial sample. Calculations are made for mechanisms of concessional state lending and subsidizing the sector. The results of our evaluation are shown in Fig. 3.

Overall, it becomes apparent that the average value of risk in public sector lending increased by more than 1.5 times. If, during the initial sample, the value of risk gradually increased from low to high, the subsequent sample yielded an increase in the risk level from rather high to the highest possible rate. At the investment stage, the risk levels of the two samples are as close as possible to each other. In this case, the crediting mechanism showed efficiency: the average value of risk decreased by 0.012 points relative to the pre-investment stage. However, at the post-investment stage, the risk level reached its maximum. Our analysis confirmed the initial results of the current inefficiency of concessional state lending of renewable energy. Such a tool to support the sector only contributes to the increase in risk.

In contrast, the subsidy mechanism demonstrates higher efficiency. At the pre-investment stage, the average risk value falls into the maximum risk group. However, towards the subsequent stages, the absolute value of the risk decreases and reaches a low level towards the final stage. This indicates that the subsidy mechanism does not provoke an increase in risk in projects with initially minimal risk, and also helps reduce the risk in other renewable energy projects.

All in all, it becomes apparent that the task of studying the impact of state support mechanisms on renewable energy projects for the Russian market is quite complicated. The RES sector in Russia is relatively immature, the level of development of government incentives, as well as their own specialized tools for assessing their impact, is still in its early stage. Therefore, the authors of this paper employed an analogy and conducted a study of the influence of state support mechanisms in the context of the global renewable energy market - first of all, the countries which are the leaders of the RES sector (including China, USA, and theEU). Based on our results, a comparative evaluation of the effectiveness of various state support mechanisms for Russian and foreign renewable energy projects can be conducted:

- Government lending in foreign projects demonstrates greater efficiency compared with Russian experience. Thus, the selection of projects from a risk management position appears to be the most appropriate: from the initial sample at the pre-investment stage, almost half of foreign projects required minimization of risks against only a third of the Russian projects in question. Initially, the average risk of foreign projects increases by 1.3 times (against 3.1 times as in the case of the Russian market) and does not go beyond the low risk group;
- The average risk of Russian RES projects tends to be high. By the post-investment stage, the growth of the “real” risk of foreign projects slows down to 1.1 times and is 0.7 compared to the maximum value of 1.0 in case of Russian projects;
- The mechanism for subsidizing renewable energy operates more efficiently on the Russian market. According to calculations, almost 55% of selected Russian projects required minimization of risks against a third of foreign ones. Both initially and in the calculation of “real” efficiency, the risk of foreign projects increases, including up to a maximum, to the post-investment stage. Conversely, Russian projects in each case are characterized by a decrease in the average value to a low risk group;

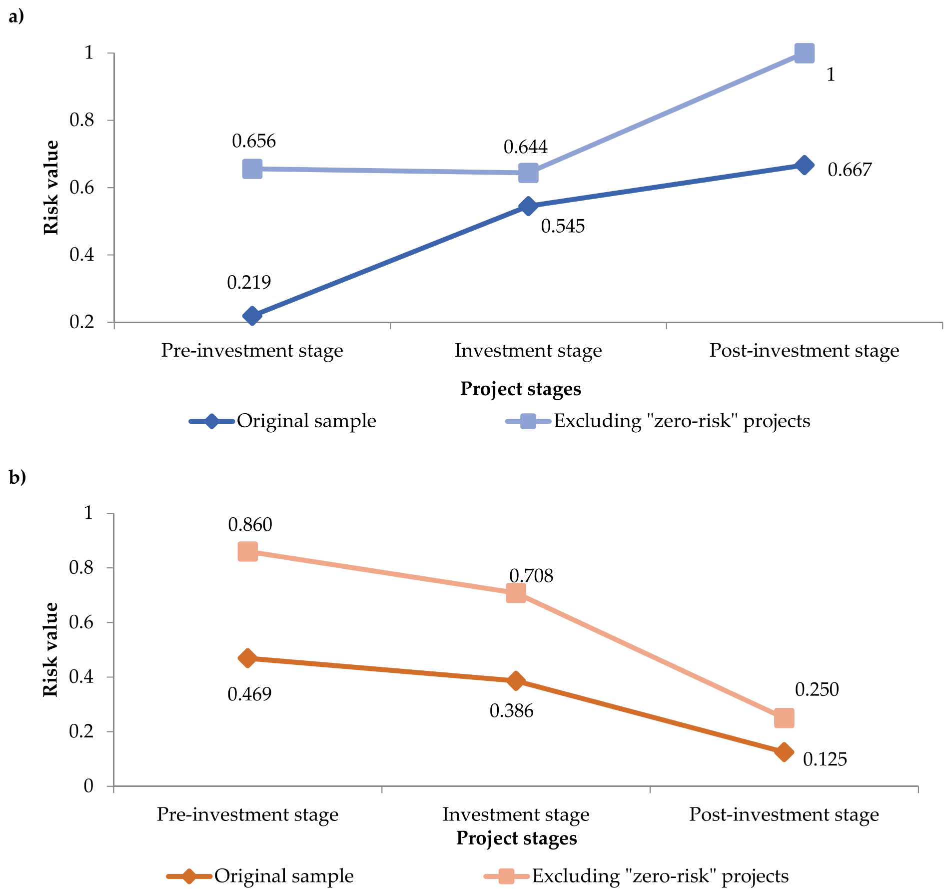

Fig. 3. The average level of risk for RES excluding projects with zero risk: a) preferential government loans, b) subsidies. Source: Own results.

- In the absence of government incentives, the Russian and foreign markets at the pre-investment stage are characterized by the same conditions: a roughly equal share of projects with "zero" risk and initially a group of average risks. However, by the post-investment stage, the risk of foreign projects is fixed in the specified range, and in the case of Russian projects it is reduced to the minimum value.

6. Conclusions

Overall, our results show that assessing the level of risk of renewable energy projects involves studying not only risk dependence on the types of government support but also the dynamics of the risk during the life-cycle stages of these projects. We found that all RES projects that received non-repayable subsidies are characterized mainly by a high level of risk at the pre-investment stage. However, none of the studied projects showed an increase in risk. Moreover, their risk levels decreased to a minimum. Projects without state support generally did not need additional incentives. Indirect support of the market through the system of "green" pricing allowed them in the overwhelming number of cases to reduce the initial level of risk to a minimum.

Therefore, our analysis revealed the ineffectiveness of government incentives for the RES sector in Russia in terms of providing concessional loans. As a rule, such projects initially have a minimal level of risk and did not require any support. However, at later stages, the risk of such projects increases to a higher level. One can clearly identify the subsidy instrument which does not require repayment showed considerable effectiveness. It can be used in the cases of high risk at the pre-investment stage of the project. On the one hand, among the main reasons for ineffective state support are: i) a small number of applications for RES projects; ii) the lack of effective deterministic risk assessment tools for RES projects; as well as iii) significant impact of external and internal political risks. On the other hand, the specific market conditions contributing to the low efficiency of state influence are: i) lack of a single formalized mechanism for selecting projects for all types of energy markets; ii) lack of a mechanism for signing long-term contracts based on the results of project selection; iii) lack of accounting for replacement generation in isolated power systems; and iv) additional unplanned public expenditures on supporting renewable energy projects without commissioning new capacities.

Surely, our study has its limitations, since the wide applicability of its results is quite limited due to the size of the Russian RES market. In addition, another serious limitation of our study is a small number of assessed projects due to the fact that we did it have access to additional data of RES projects. Nevertheless, we think that our paper provides a valuable insight into the problematique of the impact of state support mechanisms on the distribution of risks in the renewable energy projects.

7. Recommendations and implications

Our results allow to determine promising directions for further research in the field of the state support for RES projects, primarily in terms of methodology. Our findings can be associated with the development of the new deterministic risk assessment tools for the main stages of these projects that take into account the specific character of renewable energy. The new mechanism should help to determine which tools of state support are the most suitable for RES projects, and which projects do not require additional incentives, taking into account the regional affiliation and size of renewable energy facilities.

Funding

The work was supported by GSEM Development Fund (chapters 1–4), by Act 211 of the Government of the Russian Federation, contract No. 02.A03.21.0006 (chapter 4–6).

Declaration of competing interest

He authors declare no conflict of interest.

CRediT authorship contribution statement

Galina Chebotareva: Conceptualization, Methodology, Writing - original draft. **Wadim Strielkowski:** Data curation, Software, Visualization, Validation. **Dalia Streimikiene:** Investigation, Supervision, Writing - review & editing.

References

Abrishambaf, O., Lezama, F., Faria, P., Vale, Z., 2019. Towards transactive energy systems: an analysis on current trends. Energy Strateg. Rev. 26, 100418. https://doi.org/10.1016/j.esr.2019.100418.

Adams, S., Klobodu, E.K.M., Apio, A., 2018. Renewable and non-renewable energy, regime type and economic growth. Renew. Energy 125, 755–767. https://doi.org/10.1016/j.renene.2018.02.135.

Argentiero, A., Bollino, C.A., Micheli, S., Zopounidis, C., 2018. Renewable energy sources policies in a Bayesian DSGE model. Renew. Energy 120, 60–68. https://doi.org/10.1016/j.renene.2017.12.057.

Ascione, F., Bianco, N., De Stasio, C., Mauro, G.M., Vanoli, G.P., 2016. Multi-stage and multi-objective optimization for energy retrofitting a developed hospital reference building: a new approach to assess cost-optimality. Appl. Energy 174, 37–68. https://doi.org/10.1016/j.apenergy.2016.04.078.

AtsEnergo, 2018. The Results of the Projects' Selection. http://www.atsenergo.ru/view/proresults. (Accessed 2 October 2018).

Bai, Y., Song, S.Y., Jiao, J.L., Yang, R.R., 2019. The impacts of government R&D subsidies on green innovation: evidence from Chinese energy-intensive firms. J. Clean. Prod. 233, 819–829. https://doi.org/10.1016/j.jclepro.2019.06.107.

Bohnsack, R., Pinkse, J., Waelpoel, A., 2016. The institutional evolution process of the global solar industry: the role of public and private actors in creating institutional shifts. Environ. Innovation. Soc. Transitions. 20, 16–32. https://doi.org/10.1016/j.eist.2015.10.006.

Borawski, P., Beldycka-Borawska, A., Szymanska, E.J., Jankowski, K.J., Dubis, B., Dunn, J.W., 2019. Development of renewable energy sources market and biofuels in the European Union. J. Clean. Prod. 228, 467–484. https://doi.org/10.1016/j.jclepro.2019.04.242.

Boute, A., 2012. Promoting renewable energy through capacity markets: an analysis of the Russian support scheme. Energy Pol. 46, 68–77. https://doi.org/10.1016/j.enpol.2012.03.026.

Campatelli, G., Benesperi, F., Barbieri, R., Meneghin, A., 2015. New business models for electric mobility. IEEE IEVC 7056136. https://doi.org/10.1109/IEVC.2014.7056136.

Carfora, A., Pansini, R.V., Romano, A.A., Scandurra, G., 2018. Renewable energy development and green public policies complementarities: the case of developed and developing countries. Renew. Energy 115, 741–749. https://doi.org/10.1016/j.renene.2017.09.008.

Chebotareva, G., 2018a. Leading factors of market profitability of the renewable energy companies. Proc. 2nd Int. Conf. Soc. Econ. Acad. Leader. 217, 277–287. https://doi.org/10.2991/icseal-18.2018.39.

Chebotareva, G., 2018b. Risk-oriented approach to competition assessment in the global renewable energy sources market. WIT Trans. Built Environ. 179, 345–355. https://doi.org/10.2495/UG180321.

Chebotareva, G., 2019. Impact of state support mechanisms on the cost of renewable energy projects: the case of developing countries. WIT Trans. Ecol. Environ. 217, 881–891. https://doi.org/10.2495/SDP180741.

Child, M., Kemfert, C., Bogdanov, D., Breyer, C., 2019. Flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe. Renew. Energy 139, 80–101. https://doi.org/10.1016/j.renene.2019.02.077.

Chioncel, C.P., Tirian, G.O., Gillich, N., Hatiegan, C., Spunei, E., 2017. Overview of the wind energy market and renewable energy policy in Romania. IOP Conf. Ser.-Mat. Sci. 163 (1), 012009 https://doi.org/10.1088/1757-899X/163/1/012009.

Deetjen, T.A., Martin, H., Rhodes, J.D., Webber, M.E., 2018. Modeling the optimal mix and location of wind and solar with transmission and carbon pricing considerations. Renew. Energy 120, 35–50. https://doi.org/10.1016/j.renene.2017.12.059.

Dia-Core project, 2016. The Impact of Risks in Renewable Energy Investment and the Role of Smart Policies. http://diacore.eu/results/item/enhancing-res-investments-final-report. (Accessed 17 November 2019).

Dupont, E., Koppelaar, R., Jeanmart, H., 2018. Global available wind energy with physical and energy return on investment constraints. Appl. Energy 209, 322–338. https://doi.org/10.1016/j.apenergy.2017.09.085.

Dyatel, T., 2017. Green energy is eroding [Zelenaya energetika vyvetrivaetsya]. https://www.kommersant.ru/doc/3342654. (Accessed 16 November 2019).

Ebers Broughel, A., 2019. Impact of state policies on generating capacity for production of electricity and combined heat and power from forest biomass in the United States. Renew. Energy 134, 1163–1172. https://doi.org/10.1016/j.renene.2018.09.058.

Ellabban, O., Alassi, A., 2019. Integrated Economic Adoption Model for residential grid-connected photovoltaic systems: an Australian case study. Energy Rep. 5, 310–326. https://doi.org/10.1016/j.egyr.2019.02.004.

Ermolenko, G.V., Tolmacheva, I.S., Ryapin, I.Y., Fetisova, Y.A., Matshura, A.A., Reutiva, A.B., 2016. Handbook on Renewable Energy the European Union [Spravochnik Po Vozobnovlayemoy Energetike Evropeiskogo Souza], first ed. Kanon, Moscow.

Federal Law [Federalnyi Zakon], 2019. On power industry [ob elektroenergetike]. http://www.consultant.ru/document/cons_doc_LAW_41502/. (Accessed 12 April 2019).

Fouquet, D., Johansson, T.B., 2008. European renewable energy policy at crossroads-Focus on electricity support mechanisms. Energy Pol. 36 (11), 4079–4092. https://doi.org/10.1016/j.enpol.2008.06.023.

Gonzalez, A., Riba, J.-R., Esteban, B., Rius, A., 2018. Environmental and cost optimal design of a biomass–Wind–PV electricity generation system. Renew. Energy 126, 420–430. https://doi.org/10.1016/j.renene.2018.03.062.

Govender, I., Thopil, G.A., Inglesi-Lotz, R., 2019. Financial and economic appraisal of a biogas to electricity project. J. Clean. Prod. 214, 154–165. https://doi.org/10.1016/j.jclepro.2018.12.290.

Gui, E.M., MacGill, I., 2018. Typology of future clean energy communities: an exploratory structure, opportunities, and challenges. Energy Res. Soc. Sci. 35, 94–107. https://doi.org/10.1016/j.erss.2017.10.019.

Hu, J., Harmsen, R., Crijns-Graus, W., Worrell, E., 2018. Barriers to investment in utility-scale variable renewable electricity (VRE) generation projects. Renew. Energy 121, 730–744. https://doi.org/10.1016/j.renene.2018.01.092.

Investingcom, 2018. Renewable Energy Projects. https://www.investing.com/search/?q=renewable%20energy&tab=quotes. (Accessed 1 October 2018).

IRENA, 2019. Renewable Energy Statistics. https://www.irena.org/publications/2019/Jul/Renewable-energy-statistics-2019. (Accessed 16 November 2019).

Jenniches, S., 2018. Assessing the regional economic impacts of renewable energy sources-A literature review. Renew. Sustain. Energy Rev. 93, 35–51. https://doi.org/10.1016/j.rser.2018.05.008.

Johnston, S., 2019. Nonrefundable tax credits versus grants: the impact of subsidy form on the effectiveness of subsidies for renewable energy. J. Assoc. Environ. Resour. Econ. 6 (3), 433–460. https://doi.org/10.1086/702736.

Kabir, E., Kumar, P., Kumar, S., Adelodun, A.A., Kim, K.H., 2018. Solar energy: potential and future prospects. Renew. Sustain. Energy Rev. 82, 894–900. https://doi.org/10.1016/j.rser.2017.09.094.

Karimi, F., Komendantova, N., 2017. Understanding experts' views and risk perceptions on carbon capture and storage in three European countries. Geojournal 82, 185–200. https://doi.org/10.1007/s10708-015-9677-8.

Karunathilake, H., Hewage, K., Mérida, W., Sadiq, R., 2019. Renewable energy selection for net-zero energy communities: life cycle based decision making under uncertainty. Renew. Energy 130, 558–573. https://doi.org/10.1016/j.renene.2018.06.086.

Keček, D., Mikulić, D., Lovrinčević, Ž., 2019. Deployment of renewable energy: economic effects on the Croatian economy. Energy Pol. 126, 402–410. https://doi.org/10.1016/j.enpol.2018.11.028.

Khaidarshina, G.A., 2009. Integrated model to assess the risk of bankruptcy. Finance 2, 67–69.

Khuong, P.M., McKenna, R., Fichtner, W., 2019. Analyzing drivers of renewable energy development in Southeast Asia countries with correlation and decomposition methods. J. Clean. Prod. 213, 710–722. https://doi.org/10.1016/j.jclepro.2018.12.192.

Kost, C., Längle, S., 2019. The spatial dimension of the energy transition: European renewable energy sources—local resources and international exchange. In: Gawel, E., Strunz, S., Lehmann, P., Purkus, A. (Eds.), The European Dimension of Germany's Energy Transition. Springer, Cham, pp. 477–490. https://doi.org/10.1007/978-3-030-03374-3_27.

Kozlova, M., Collan, M., 2016. Modeling the effects of the new Russian capacity mechanism on renewable energy investments. Energy Pol. 95, 350–360. https://doi.org/10.1016/j.enpol.2016.05.014.

Kozlova, M., Collan, M., Luuka, P., 2018. Russian mechanism to support renewable energy investments: before and after analysis. In: Diez, P., Neittaanmäki, P., Periaux, J., Tuovinen, T.T., Bräysy, O. (Eds.), Computational Methods and Models for Transport. Springer International Publishing, pp. 243–252. https://doi.org/10.1007/978-3-319-54490-8_15.

Kruger, W., Stritzke, S., Trotter, P.A., 2019. De-risking solar auctions in sub-Saharan Africa – a comparison of site selection strategies in South Africa and Zambia.

Renew. Sustain. Energy Rev. 104, 429–438. https://doi.org/10.1016/j.rser.2019.01.041.
Lai, H., Warner, M., 2015. Transformation of China's energy sector: trends and challenges. Asia. Pac. Bus. Rev. 21 (1), 147–153. https://doi.org/10.1080/13602381.2014.939900.
Lanshina, T.A., Kulakov, A.V., 2017. Development of renewable energy in China: studying the experience and making recommendations for Russia. Therm. Eng. 64 (7), 526–533. https://doi.org/10.1134/S0040601517070035.
Leisen, R., Steffen, B., Weber, C., 2019. Regulatory risk and the resilience of new sustainable business models in the energy sector. J. Clean. Prod. 219, 865–878. https://doi.org/10.1016/j.jclepro.2019.01.330.
Li, W., Adachi, T., 2017. Quantitative estimation of resource nationalism by binary choice logit model for panel data. Resour. Pol. 53, 247–258. https://doi.org/10.1016/j.resourpol.2017.07.002.
Li, Y., Wu, M., Li, Z., 2018. A real options analysis for renewable energy investment decisions under China carbon trading market. Energies 11 (7), 1817. https://doi.org/10.3390/en11071817.
Lin, B., Omoju, O.E., 2017. Focusing on the right targets: economic factors driving non-hydro renewable energy transition. Renew. Energy 113, 52–63. https://doi.org/10.1016/j.renene.2017.05.067.
Lisin, E., Rogalev, A., Strielkowski, W., Komarov, I., 2015. Sustainable modernization of the Russian power utilities industry. Sustainability 7, 11378–11400. https://doi.org/10.3390/su70911378.
Liu, Z., 2018. What is the future of solar energy? Economic and policy barriers. Energy Sources B Energy Econ. Plann. 13 (3), 169–172. https://doi.org/10.1080/15567249.2017.1416704.
Lombardi, P., Schwabe, F., 2017. Sharing economy as a new business model for energy storage systems. Appl. Energy 188, 485–496. https://doi.org/10.1016/j.apenergy.2016.12.016.
Malhotra, A., Battke, B., Beuse, M., Stephan, A., Schmidt, T., 2016. Use cases for stationary battery technologies: a review of the literature and existing projects. Renew. Sustain. Energy Rev. 56, 705–721. https://doi.org/10.1016/j.rser.2015.11.085.
Mignon, I., Bergek, A., 2016. Investments in renewable electricity production: the importance of policy revisited. Renew. Energy 88, 307–316. https://doi.org/10.1016/j.renene.2015.11.045.
Mittlefehldt, S., 2018. From appropriate technology to the clean energy economy: renewable energy and environmental politics since the 1970s. J. Environ. Soc. Sci. 8 (2), 212–219. https://doi.org/10.1007/s13412-018-0471-z.
Mokhov, V.G., Chebotareva, G.S., Khomenko, P.M., 2018. Modelling of "green" investments risks. Bulletin of the South Ural State University, Series: Math. Model Comput. Software 11 (2), 154–159. https://doi.org/10.14529/mmp180213.
Morozov, V., 2016. Energy dialogue and the future of Russia: politics and economics in the struggle for Europe. In: Aalto, P. (Ed.), The EU-Russian Energy Dialogue. Routledge, London, pp. 59–78. https://doi.org/10.4324/9781315558455.
Oppong, R., Talipova, A., Abdul-Latif, B.L., 2016. Technical and legislative risks associated with arctic development case study - Russia and Norway. Arctic Technology Conference 138204. https://doi.org/10.4043/27353-MS.
Panepinto, D., Gitelman, L., Kozhevnikov, M., Magaril, E., Magaril, R., Zanetti, M.C., 2017. Energy from biomass for sustainable cities. IOP C. Ser. Earth. Env. 72 (1) https://doi.org/10.1088/1755-1315/72/1/012021, 012021.
Perlaviciute, G., Steg, L., Contzen, N., Roeser, S., Huijts, N., 2018. Emotional responses to energy projects: insights for responsible decision making in a sustainable energy transition. Sustainability 10 (7), 2526. https://doi.org/10.3390/su10072526.
Pristupa, A.O., Mol, A.P., 2015. Renewable energy in Russia: the take off in solid bioenergy? Renew. Sustain. Energy Rev. 50, 315–324. https://doi.org/10.1016/j.rser.2015.04.183.
Proskuryakova, L.N., Ermolenko, G.V., 2019. The future of Russia's renewable energy sector: trends, scenarios and policies. Renew. Energy 143, 1670–1686. https://doi.org/10.1016/j.renene.2019.05.096.
Resolution of the Russian Government, 2013. On the Mechanism of Stimulation of Using Renewables in the Wholesale Market of Electric Energy and Power. http://base.garant.ru/70388616/. (Accessed 11 January 2019).
Rosales-Asensio, E., Borge-Diez, D., Blanes-Peiró, J.-J., Pérez-Hoyos, A., Comenar-Santos, A., 2019. Review of wind energy technology and associated market and economic conditions in Spain. Renew. Sustain. Energy Rev. 101, 413–427. https://doi.org/10.1016/j.rser.2018.11.029.
Rullo, P., Braccia, L., Luppi, P., Zumoffen, D., Feroldi, D., 2019. Integration of sizing and energy management based on economic predictive control for standalone hybrid renewable energy systems. Renew. Energy 140, 436–451. https://doi.org/10.1016/j.renene.2019.03.074.
Shimbar, A., Ebrahimi, S.B., 2019. Political risk and valuation of renewable energy investments in developing countries. Renew. Energy 145, 1325–1333. https://doi.org/10.1016/j.renene.2019.06.055.
Sisodia, G.S., Soares, I., Ferreira, P., 2016. Modeling business risk: the effect of regulatory revision on renewable energy investment - the Iberian case. Renew. Energy 95, 303–313. https://doi.org/10.1016/j.renene.2016.03.076.5.
Smeets, N., 2018. The green menace: unraveling Russia's elite discourse on enabling and constraining factors of renewable energy policies. Energy Res. Soc. Sci. 40, 244–256. https://doi.org/10.1016/j.erss.2018.02.016.
Sorland, B.F., Rudel, M.G.N., 2015. What Drives Financial Distress Risk and Default Rates of Leveraged Buyout Targets? Empirical Evidence from European Transactions, first ed. Norwegian School of Economics, Oslo.
Strielkowski, W., Volkova, E., Pushkareva, L., Streimikiene, D., 2019. Innovative policies for energy efficiency and the use of renewables in households. Energies 12 (7), 1392. https://doi.org/10.3390/en12071392.
Su, W., Ye, Y., Zhang, S., Baležentis, T., Štreimikienė, D., 2020. Sustainable energy development in the major power-generating countries of the European Union: the Pinch Analysis. J. Clean. Prod. 256, 120696. https://doi.org/10.1016/j.jclepro.2020.120696.
Szulecki, K., Westphal, K., 2018. Taking security seriously in EU energy governance: crimean shock and the energy union. In: Szulecki, K. (Ed.), Energy Security in Europe. Palgrave Macmillan, Cham, pp. 177–202. https://doi.org/10.1007/978-3-319-64964-1_7.
Talipova, A., Parsegov, S., 2018. Evolution of natural gas business model with deregulation, financial instruments, technology solutions, and rising LNG export. Comparative study of projects inside the US and abroad. In: SPE Annual Technical Conference and Exhibition. https://doi.org/10.2118/191532-MS, 143357.
Trinks, A., Scholtens, B., Mulder, M., Dam, L., 2018. Fossil fuel divestment and portfolio performance. Ecol. Econ. 146, 740–748. https://doi.org/10.1016/j.ecolecon.2017.11.036.
Wei, W., Zhao, Y., Wang, J., Song, M., 2019. The environmental benefits and economic impacts of Fit-in-Tariff in China. Renew. Energy 133, 401–410. https://doi.org/10.1016/j.renene.2018.10.064.
Xie, X., Tu, H., Chen, H., Lin, Y., 2018. Modeling the range information inaccuracy risk of battery electric vehicle. CICTP 2017, 4994–5003. https://doi.org/10.1061/9780784480915.515.
Xie, Y., Fu, Z., Xia, D., Lu, W., Huang, G., Wang, H., 2019. Integrated planning for regional electric power system management with risk measure and carbon emission constraints: a case study of the xinjiang uygur autonomous region, China. Energies 12 (4), 601. https://doi.org/10.3390/en12040601.
Zhang, M.M., Wang, Q., Zhou, D., Ding, H., 2019. Evaluating uncertain investment decisions in low-carbon transition toward renewable energy. Appl. Energy 240, 1049–1060. https://doi.org/10.1016/j.apenergy.2019.01.205.

Glossary

CAPEX: Capital Expenditures
CBSS: Capacity-Based Support Scheme
EU: European Union
FIP: Feed-in Premium
FIT: Feed-in Tariff
GWh: Gigawatt Hour
HPP: Hydro Power Plant
IRENA: International Renewable Energy Agency
JSC: Joint-Stock Company
LLC: Limited Liability Company
MPGC: Municipal Power Generating Companies
MW: Megawatt
PD: Probability of Default
P2P Energy Market: Peer-to-Peer Energy Market
PJSC: Public Joint Stock Company
PV: Photovoltaics
RES: Renewable Energy Sources
RHI: Renewable Heat Incentive
RHPP: Renewable Heat Premium Payment
RoA: Return on Assets
RoE: Return on Equity
SPP: Solar Power Plant
WPP: Wind Power Plant