

Development of Leading Approaches for Risk Assessment of the Renewable Energy: Some Recommendations

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Abstract Renewable energy (RE) technologies are gradually taking over the world amid a lack of effective specific risk assessment tools, which is an important element of the strategic development of this sector. Meanwhile, the significant impact of state support on the industry, on the one hand, as well as the refusal of a number of countries to provide incentives to the sector, on the other hand, generate many new specific risks that need to be managed. Therefore, the author was tasked with developing recommendations for the creation of a fundamentally new methodological apparatus aimed at assessing the risks directly threatening RE projects. The article presents the main types of specific risks to renewable energy, and the analysis of the most relevant quantitative assessment approaches. Methodical features of RE risk assessment based on four criteria were systematized: general, project, state influence, individual influence of risks. Qualitative and quantitative restrictions of an assessment were also discussed. Based on the results of the study, recommendations for the development of a specific approach to assessing the risks faced by the sector were given. The obtained results are of practical importance and will be used for creating appropriate tools, and in the future - for assessing the risk effectiveness of the implementation of RE projects under the influence of different economic conditions.

Keywords: *renewable energy, risk assessment, strategic development, leadership, sustainability*

1 Introduction

The practical absence of specific approaches to risk assessment in renewable energy projects affects not only the accuracy and objectivity of the assessment results but also reduces the effectiveness of decision making in the energy market. The current situation is since the global renewable energy market is relatively immature and has not yet accumulated enough experience to develop its own methodological tools for assessing economic/project risks. For example, the Russian energy market where the liberalization of traditional energy began less than 18 years ago has not experienced such a need until recently (Konova et al. 2012; Zlyvko 2014; Gitelman et al. 2017; or Lisin et al. 2018).

Nevertheless, renewable energy is fraught with numerous specific risks (Bloomberg 2016; Panepinto et al. 2017; Strielkowski 2017; Chebotareva 2017; Newbery et al. 2018; Gonzalez et al. 2018; Chebotareva 2019; Brozyna et al. 2020; or Carvalho et al. 2020), including:

- A shortage of qualified personnel in the industry;
- High pace of development of traditional energy;
- Wrong localization of renewable energy facilities;
- Weak financial performance;
- Political risks (changes in the strategy of RE development, schemes of its support);
- Investors' financial dependence on state-sponsored programs;
- Obstacles to the participation of independent electricity producers;
- The absence of an independent regulatory body, etc.

Therefore, there is a complex and urgent task of conducting a theoretical study of how the features of renewable energy determine the specific nature of risk assessment in this sector. The paper summarizes the existing approaches to risk management, methodological features of assessment in the case of renewable energy projects. The outcome of the study is the development of recommendations for the creation of modern risk assessment tools tailored to the RE market, taking into account the project features of the sector, the influence of external economic and political factors of the market, etc. The paper gives priority to quantitative assessment. The results of the study will be used to develop a methodological approach to

assessing RE risks, as well as for studying the impact of instruments of state support for the sector or the denial for such on the effectiveness of projects.

2. A review of the existing approaches to risk assessment

The contemporary *practice of risk management* identifies the following most common quantitative approaches to risk assessment, among which there are both traditional and recently developed models (Echaniz et al. 2019; Blavatsky 2019; Da Silva et al. 2019; Naranjo et al. 2019):

- Logit-modelling of risk;
- Probit- modelling of risk;
- MDA- modelling of risk;
- Assessment of economic capital (risk capital) of projects/companies.

A brief description of the above approaches is presented in Table 1 (Gmurman 1997; Sakaguchi et al. 2013; Chebotareva et al. 2018).

Table 1. Features of risk assessment approaches

Approaches Features	Logit-model	Probit-model	MDA-model	Economic capital
<i>Type</i>	Statistical financial models of risk assessment			Economic model
<i>The main aim of the model</i>	Assessing the probability of default (from 0 to 1)	Assessing the probability of default (0 or 1)	Assessing the probability of default (individual interpretation of each model)	Assessment of the real capital needs of the company / project
<i>Data distribution</i>	Logistic	Normal	Normal	-
<i>Input information for model development</i>	Statistical data (sample) by market / industry			Data from the Basel Committee on Banking Supervision
<i>Input information for calculations</i>	Financial indicators of the company / project			Project and industry indicators

Source: Own results

Currently, there are more than 200 different *statistical models of risk diagnostics*. Improved objectivity and high accuracy of evaluations make such models popular: they are used in 64% of cases (Aziz and Dar 2006). However, in practice, *logit-models* are the most popular for many reasons (Zhdanov and Afanasyeva 2011):

- Logit models make it possible to get the most detailed vision of a default: not only in terms of belonging to a bankrupt group (as in probit and MDA-models), but also to assess the indicator of the probability of default itself;
- In contrast with the *MDA-models*, logit-approaches describe nonlinear relationships between the variables;
- The use of *probit-models* is extremely limited due to strict requirements regarding the normality of the initial data distribution, which is practically impossible under contemporary market conditions.

Assessment of economic capital (risk capital) (Mokhov et al. 2017) is a fundamentally different quantitative approach in risk management, proposed by the world banking community. What makes it peculiar is that it can assess a number of external and internal project indicators, while taking into account the rating of industry companies and calculating the required capital to cover possible risks from the project. Comparison of the required and actual risk-capital allows one to assess the feasibility of the project implementation. Among the main elements of economic capital (Sorland and Rudel 2015; Peter 2006; Gurtler and Heithecker 2005) are:

- *PD (probability of default)* – the project indicator is usually calculated according to the industry *logit-model*;
- *LGD (loss given default)* – external industry indicator;
- *EAD (exposure at default)* – absolute value of the total cost of the project or proportional to the share of participation;
- *M (maturity)* – an effective period during which the risk position is maintained.

In *the energy sector*, the risk management system is only beginning to take shape. Thus, in the Russian practice, there is a gradual transition of corporations to risk-oriented strategies for energy asset management (Deloitte 2015; UNIDO 2017; IRENA 2018; Buera and Kaboski 2012; Kozhevnikov 2019) and industrial safety (PJSC “T Plus” 2015; Techexpert 2017). However, in such cases, the emphasis is on assessing the technical condition of the equipment at energy facilities. The energy sector is lagging behind in terms of developing specific risk assessment tools aimed to economic / project activities of the company. The most popular methods of risk assessment in the industry are still qualitative (expert surveys, interviews, etc.) (Ermolenko et al. 2016; Dia-Core project 2016; KPMG 2011). One of the few examples of quantitative risk assessment in the Russian energy sector is the industry *logit-model* developed by Khaidarshina (Khaidarshina 2009; Mokhov et al. 2018).

3. Methodological features of risk assessment in renewable energy projects

Being a “unconventional” sector, renewable energy has many specific characteristics that form the methodological features of risk assessment of companies and projects in this industry (Heldeweg and Séverine 2020; Cardona-Alzate et al. 2020).

1. *The common features of renewable energy risk assessment* are the following:

- The existence of heterogeneous risks that cannot be assessed by uniform methodological tools. This requires the development of a special integrated approach combining not only quantitative but also qualitative methods of risk assessment;
- Variability of risks (quantitative - by composition; qualitative - probability of risk and level of impact on the effectiveness of projects);
- Simultaneous changes in the quantity and quality of risk make it difficult to estimate the exact value of risk. This requires additional assessment of the “corridor” of fluctuation and migration of risks across the project stages;
- The impact of not only internal but also external, primarily political risks on renewable energy projects.

2. *The peculiarity of project risk assessment of RE* is that such assessment should be pegged to the stages of the project life cycle. The relatively short duration of renewable energy projects (under four years on average) compared to “conventional” energy projects requires reducing the evaluation process to only three main stages: pre-investment, investment and post-investment. The general quantitative assumptions are the following:

- the pre-investment stage covers the first six months if the project period is less than two years, or up to a year of the RE project;
- the post-investment stage includes only the final six months / year of the project under similar conditions;
- the full term of the project is the basis for calculating the average risk for the investment stage.

The qualitative limitations of the project risk assessment of RE are because risk assessment at each stage is different content-wise, so it must be strictly case-specific and depends on the time period and related forecasts. Proceeding from this, the basic requirements for risk assessment at each stage of the industry project have been developed:

- The pre-investment stage is characterized only by forecast information on the project, as well as actual information on the implementation of similar projects. Therefore, at this stage, it is more effective to predominantly use qualitative (expert) risk assessment methods;
- Within the framework of the investment stage, actual specific information on the project being studied and the current state of the energy market is accumulated, preliminary calculations on risks are

updated, etc. This enables a combination of qualitative and quantitative methods with the priority of using mathematical models;

- By the post-investment stage, all actual data on the implementation of the renewable energy project, as well as information on the state of the energy market, has been accumulated. As a result, only quantitative tools need to be developed / applied.

A brief description of the relationship between the characteristics of each stage of RE projects, the initial information, as well as the proposed assessment tools are presented in Table 2 (Chebotareva 2019).

Table 2. The assessment specificity of renewable energy risk by project stage

Stage	Short characteristic	Features of risk assessment		
		Initial information for assessment	Methods for risk assessment	Evaluation of political risk
Pre-investment	Project planning, organization of financing	Only forecast information on the project, including risks, and the market state (data of the business plan); availability of information on the implementation of RE projects with similar characteristics	Preferential use of qualitative (expert) methods of risk assessment	High uncertainty about the possible availability of state support, existence of associated risks
Investment	Construction and commissioning of the RE facility	Actual data on the RES project, the market state; clarification of the calculations on the level of risk before the stage (project reports, contracts)	The combination of qualitative and quantitative methods, the priority of mathematical models in the accumulation of data on current and similar RE projects	High probability of instability / cancelation of state support, the existing of associated risks
Post-investment	The operation of the RE facility	Accurate project data before commissioning of the RE facility	It is possible to use only quantitative tools with enough information on the implementation of the RE project	Reducing the impact of political risks

Source: Own results

Dynamic risk assessment of renewable energy project stages allows one to assess the effectiveness of forecasting and risk management programs at each stage by comparing risk indicators for adjacent stages. The calculated risk at the pre-investment stage is forecast for the investment stage; at the investment stage - for the post-investment stage.

3. *Each stage* of the project is characterized not only by a *strictly individual set of risks*, but also by the *level of influence and probability of risks*. Studies (Addy et al. 2019; Adiyeké et al. 2019; Sim and Kim 2019) have shown that the distribution of specific and common risks across the three stages of renewable energy projects is the following:
 - All stages are influenced by a set of policy risks that are specific to renewable energy (Curtin et al. 2019). A description of the impact of political risks on project stages is given in Table 2.
 - During the project activities, there are general risks caused by the influence of economic factors (as a rule, inflation, credit and, to a lesser extent, currency rates).
 - The greatest number of risks is typical of the post-investment stage during commissioning. It is here that specific risks generated by the energy market begin to have a strong impact.
4. *Active state influence* usually contributes to the emergence of specific risks and drive an increase in the riskiness of renewable energy projects (Mutran et al. 2020). Earlier studies (Ratner et. al 2020; Ermolenko et al. 2016; Chebotareva 2019; Chebotareva 2018; Shimbar and Ebrahimi 2020) quantified the impact of state support mechanisms on the cost and riskiness of RE projects. Thus, in the global renewable energy market there is an increase in the risk closer to the end of projects: the risk hits the highest in the case of subsidies and is at the lowest when there is no state support. The Russian market showed an increase in risk to the end of projects only in the case of government lending, while in the cases of subsidies and the absence of support the risk decreased.

4. Conclusions

The development of specific tools for assessing the risks of renewable energy is a very urgent task. Its implementation will improve the efficiency of projects being implemented in the sector. However, it is important to consider the specific characteristics of renewable energy, as well as the methodological features of the RE risk assessment. Among the results of the study it is important to highlight the following:

- Emphasis should be placed on the development of a quantitative risk assessment method (e.g. The popular logit-model).
- The proposed tools should be refined for each of the three project stages, considering the specified features of each of them.
- In developing the approach, a distinction should be made for the global energy market and for individual regions, as local markets have their own unique character, which will be expressed in a set of specific indicators. In the future, this will allow for a comparative analysis of the risk-effectiveness of different renewable energy markets.

The preliminary study showed that the main indicators of the evaluation of the RE project should include: the volume of public investment; energy shortage in the region; levelized cost of energy (LCOE); the country of purchase of equipment for power generation facilities; the value of environmental costs; the costs of the project region for R&D; intra-financial indicators of the initiator company, etc

However, when using logit-modelling, one of the most important problems is the choice of the dependent variable due to the lack of sufficient negative experience as regards the implementation of RE projects internationally (cases of bankruptcy and non-bankruptcy). A solution may be to choose as such a variable indicator of the economic and/or social efficiency of RE projects.

Nevertheless, integrating the presented recommendations in a uniform mathematical model will enable one to quantify the individual level of risk at each stage of the RE project, the effectiveness of the sector projects in individual countries. From the point of view of methodology, the solution of this task could serve as the basis for the quantitative assessment of risks, including the political risk, which has a major significance for RE, as well as the expediency of state support of a project at each stage.

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References

- Addy MN, Akunyumu S, Simons B (2019) Key risk factors affecting renewable energy independent power producer (IPP) set-up projects in developing countries: The case of Ghana. *Journal of Engineering, Design and Technology* 17(6):1340-1355. doi: 10.1108/JEDT-03-2019-0072
- Adıyeke E, Çanakoğlu E, Ağralı S (2019) Risk averse investment strategies for a private electricity generating company in a carbon constrained environment. *Journal of the Operational Research Society* 70(12):2056-2068. doi: 10.1080/01605682.2018.1535265
- Aziz M, Dar H (2006) Predicting corporate bankruptcy – where we stand. *Corporate Governance Journal* 6(1):18-33. doi: 10.1108/14720700610649436
- Blavatsky P (2019) Future plans and errors. *Mathematical Social Sciences* 102:85-92. doi: 10.1016/j.mathsoesci.2019.08.001
- Bloomberg (2016) Global trends in renewable energy investment. <http://fs-unep-centre.org>. Accessed 12 October 2019
- Brozyna J, Strielkowski W, Fomina A, Nikitina N (2020) Renewable Energy and EU 2020 Target for Energy Efficiency in the Czech Republic and Slovakia. *Energies* 13(4):965. doi: 10.3390/en13040965
- Buera FJ, Kaboski JP (2012) The rise of the service economy. *American Economic Review* 102(6):2540-2569. doi: 10.1257/aer.102.6.2540

- Cardona-Alzate CA, Serna-Loaiza S, Ortiz-Sanchez M (2020) Sustainable biorefineries: What was learned from the design, analysis and implementation. *Journal of Sustainable Development of Energy, Water and Environment Systems* 8(1):88-117. doi: 10.13044/j.sdewes.d7.0268
- Carvalho DB, Pinto BL, Guardia EC, Marangon Lima JW (2020) Economic impact of anticipations or delays in the completion of power generation projects in the Brazilian energy market. *Renewable Energy* 147:1312-1320. doi: 10.1016/j.renene.2019.09.074
- Chebotareva G (2017) Researching the risks of Russian energy companies in the context of renewable energy sources development. *WIT Transactions on Ecology and the Environment* 224:45-56. doi:10.2495/ESUS170051
- Chebotareva G, Khomenko P, Khodorovsky M (2018) Risk management of mergers and acquisitions with borrowed capital in the energy sector. *International Journal of Sustainable Development and Planning* 13(6): 905-916. doi: 10.2495/SDP-V13-N6-905-916
- Chebotareva GS (2019) Risk assessment of renewable energies: Global exposure. *International Journal of Energy Production and Management* 4(2):145-157. doi: 10.2495/EQ-V4-N2-145-157
- Curtin J, McInerney C, Gallachóir B, Hickey C, Deane P, Deeney P (2019) Quantifying stranding risk for fossil fuel assets and implications for renewable energy investment: A review of the literature. *Renewable and Sustainable Energy Reviews* 116:109402. doi: 10.1016/j.rser.2019.109402
- Da Silva MA, Huggins-Manley AC, Mazzon JA, Bazán JL (2019) Bayesian estimation of a flexible bifactor generalized partial credit model to survey data. *Journal of Applied Statistics* 46(13):2372-2387. doi: 10.1080/02664763.2019.1592125
- Deloitte (2015) The future of the global power sector. <https://www.deloitte.com>. Accessed 02 October 2019
- Dia-Core project (2016) The impact of risks in renewable energy investment and the role of smart policies. <http://diacore.eu>. Accessed 10 October 2019
- Echaniz, E, Ho CQ, Rodriguez A, Dell'Olio L (2019) Comparing best-worst and ordered logit approaches for user satisfaction in transit services. *Transportation Research Part A: Policy and Practice* 130:752-769. doi: 10.1016/j.tra.2019.10.012
- Ermolenko GV, Tolmacheva IS, Ryapin IY, Fetisova YA, Matshura AA, Reutiva AB Handbook on renewable energy the European Union, 1st edn. (Moscow: Institute of Energy SRU HSE, Russia, 2016), 96 p.
- Gitelman LD, Gitelman LM, Kozhevnikov MV (2017) Window of Opportunity for Sustainable Energy. *International Journal of Energy Production and Management* 2:173–185. doi: 10.2495/EQ-V2-N2-173-185
- Gmurman V Probability theory and mathematical statistics, 1st edn. (Moscow: Higher School, 1997), 479 p.
- Gonzalez A, Riba JR, Esteban B, Rius A (2018) Environmental and cost optimal design of a biomass–Wind–PV electricity generation system. *Renewable Energy* 126:420-430. doi: 10.1016/j.renene.2018.03.062
- Gurtler M, Heithecker D (2005) Multi-Period defaults and maturity effects on economic capital in a ratings-based default-mode model. *Finanz Wirtschaft* 5:123-134
- Heldeweg MA, Séverine Saintier (2020) Renewable energy communities as ‘socio-legal institutions’: A normative frame for energy decentralization? *Renewable and Sustainable Energy Reviews* 119:109518. doi: 10.1016/j.rser.2019.109518
- IRENA (2018) Global Energy Transformation: A roadmap to 2050. <https://www.irena.org/publications/2018/Apr/Global-Energy-Transition-A-Roadmap-to-2050>. Accessed 12 October 2019
- Khaidarshina GA (2009) Integrated model to assess the risk of bankruptcy. *Finance* 2:67-69
- Konova O, Komarov I, Lisin E (2012) The relevance of power generating capacities based on the combined cycle power plants of high power. *Czech Journal of Social Sciences, Business and Economics* 1(1):101-109. doi: 10.24984/cjssbe.2012.1.1.11
- Kozhevnikov MV (2019) A transition to knowledge-intensive service activities in power industry: A theoretical framework. *WIT Transactions on Ecology and the Environment* 222:13-25. doi: 10.2495/EQ180021
- KPMG (2011) Market risk management – Upravljenie rynochymi riskami. <https://home.kpmg/ru>. Accessed 12 October 2019

- Lisin E, Shuvalova D, Volkova I, Strielkowski W (2018) Sustainable development of regional power systems and the consumption of electric energy. *Sustainability* 10(4):1111. doi:10.3390/su10041111
- Mokhov VG, Chebotareva GS, Demyanenko TS (2017) Complex approach to assessment of investment attractiveness of power generating company. *Bulletin of the South Ural State University. Series "Mathematical Modelling, Programming & Computer Software"* 10(2):150-154. doi:10.14529/mmp170213
- Mokhov VG, Chebotareva GS, Khomenko PM (2018) Modelling of "green" investments risks. *Bulletin of the South Ural State University. Series "Mathematical Modelling, Programming & Computer Software"* 11(2):154-159. doi: 10.14529/mmp180213
- Mutran VM, Ribeiro CO, Nascimento CAO, Chachuat B (2020) Risk-conscious optimization model to support bioenergy investments in the Brazilian sugarcane industry. *Applied Energy* 258:113978. doi: 10.1016/j.apenergy.2019.113978
- Naranjo L, Pérez CJ, Martín J, Mutsvari T, Lesaffre E (2019) A Bayesian approach for misclassified ordinal response data. *Journal of Applied Statistics* 46(12):2198-2215. doi: 10.1080/02664763.2019.1582613
- Newbery D, Pollitt MG, Ritz RA, Strielkowski W (2018) Market design for a high-renewables European electricity system. *Renewable and Sustainable Energy Reviews* 91:695-707. doi: 10.1016/j.rser.2018.04.025
- Panepinto D, Gitelman L, Kozhevnikov M, Magaril E, Magaril R, Zanetti MC (2017) Energy from Biomass for Sustainable Cities. *IOP Conference Series: Earth and Environmental Science* 72(1):012021. doi: 10.1088/1755-1315/72/1/012021
- Peter C (2006) Estimating Loss Given Default – Experiences from Banking Practise. *Springerlink* 2:143-175
- PJSC "T Plus" (2015) <https://www.tplusgroup.ru>. Accessed 12 October 2019
- Ratner SV, Khrustalev EY, Larin SN, Khrustalev OE (2020) Does the development of renewable energy and smart grids pose risks for Russian gas projects? Scenario forecast for partner countries. *International Journal of Energy Economics and Policy* 10(1):286-293. doi: 10.32479/ijee.8627
- Sakaguchi J, Miyauchi H, Misawa T (2013) Risk assessment of power plant investment by three level ordered probit model considering project suspension. *Proceedings of IREP Symposium Bulk Power System Dynamics and Control - IX Optimization, Security and Control of the Emerging Power Grid (IREP)*. doi: 10.1109/IREP.2013.6629398
- Strielkowski W (2017) Social and economic implications for the smart grids of the future. *Economics and Sociology* 10(1):310-318. doi: 10.14254/2071-789X.2017/10-1/22
- IREP Symposium Bulk Power System Dynamics and Control - IX Optimization, Security and Control of the Emerging Power Grid Bulk Power System Dynamics and Control - IX Optimization, Security and Control of the Emerging Power Grid (IREP), 2013 IREP Symposium. 1-5 Aug, 2013
- Shimbar A, Ebrahimi SB (2020) Political risk and valuation of renewable energy investments in developing countries. *Renewable Energy* 145:1325-1333. doi: 10.1016/j.renene.2019.06.055
- Sim J, Kim CS (2019) The value of renewable energy research and development investments with default consideration. *Renewable Energy* 143:530-539. doi: 10.1016/j.renene.2019.04.140
- Sorland BF, Rudel MGN What drives Financial Distress Risk and Default Rates of Leveraged Buyout Targets? Empirical Evidence from European Transactions, 1st edn. (Bergen: Norwegian School of Economics, Norway, 2015), 46 p.
- Techexpert (2017) <http://docs.cntd.ru>. Accessed 12 October 2019
- UNIDO (2017) Accelerating clean energy through Industry 4.0: manufacturing the next revolution. https://www.unido.org/sites/default/files/2017-08/REPORT_Accelerating_clean_energy_through_Industry_4.0.Final_0.pdf. Accessed 12 October 2019
- Zhdanov VY, Afanasyeva OA (2011) Model of bankruptcy risk diagnostics of enterprises of aviation-industrial complex - Model diagnostiki bankrotstva predpriyatii aviacionno-promyshlennogo kompleksa. *Corporate finance Journal – Jurnal Korporativnye financy* 4(20):77-89
- Zlyvko O, Lisin E, Rogalev N, Kurdiukova G (2014) Analysis of the concept of industrial technology platform development in Russia and in the EU. *International Economics Letters* 3(4):124-138. doi: 10.24984/iel.2014.3.4.2