

## Renewable Energy Sources Development Risk Analysis and Evaluation: the Case of Azerbaijan

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### Abstract

Steady increase in renewable energy production and supply allows gradually substitute environmentally harmful traditional energy systems. Developers of the renewable projects encounter various types of risks, inherent to these projects, and all these risks should be studied in advance and ways of their mitigation developed. In the paper risks related to the development of renewables in Azerbaijan are analyzed and assessed based on experts' opinion study. Typical for the projects on renewable energy, nine risks and risk components likelihood and their impacts have been evaluated by experts and, based on their opinion, risk levels are calculated, and a risk profile is constructed. In general, risks are sufficiently different. However, energy policy-related, grid access and financial risks are significantly influential and require more attention.

**Keywords:** renewable energy, risk analysis, risk likelihood, risk impact, risk level

### Introduction

During the last decades, we are witnessing stable growth of renewable energy sources (Ritchie & Roser, 2019) and, as a result of this tendency, renewables share in energy production is increasing from year to year. For example, at present, it accounts for a third of the world electricity production (International Renewable Energy Agency. Renewable Capacity Statistics, 2018). Peculiarity of this tendency is that not only countries with limited energy resources are paying special attention to this issue, but also leading oil-producing countries significantly increased consumption of the renewables (wind, solar, geothermal, biomass etc) during the last decade. For example, the USA increased renewables consumption by 3.8 times, Canada - 4, Brazil - 5, Mexico - 2.3, and China – 30 times.

Taking into consideration that any oil and gas resources are limited, development of the renewables-based energy systems is of interest for Azerbaijan as well, especially development of the solar and wind-based systems. According to statistical reports (Ioannou, Angus & Brennan, 2017), wind and solar photovoltaics (PV) accounted for an approximately 77% of new capacity in 2016. In such circumstances, it is not unusual that in 2018, 10% of electricity produced in Azerbaijan was generated by renewables and it is expected that during the next decade this number will be approximately 35% (Yusifov, 2018).

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It is necessary to mention that despite the rich lessons learned and know-how accumulated, renewables projects developed in various countries encounter serious financial, technological, organizational, juridical and many other risks, and these risks in the most cases are region and country-specific.

As it is shown in Noothout et al (2016), European Union member countries till now have quite different risk profiles, and this is a common case for other regions as well (Jhij-HaoLina, Wu & Lin, 2016).

There is no general agreement upon the classification of renewables-related risks. Researchers, based on own experience, country-specific information, decision-making objectives, and applications, have been working with various categories of risks. In view of these specifics of the development of renewables, it would be useful to overview renewables-related risks and their identification and assessment.

To our best knowledge, the case of Azerbaijan has been outside of the mainstream of researches on renewable energy risk management. In this regard, we advance previous research works by scrutinizing risk factors in an oil-rich country having peculiar characteristics. Our findings will enhance our understanding of investment risk management in renewable energy projects and suggest effective policies for achieving sustainable energy development that would contribute to economic progress of Azerbaijan.

The remainder of the article is set out as follows. Section 2 provides a detailed literature review, identifies and classifies risks. Section 3 describes questionnaire and survey based on the risks. Section 4 defines risk assessment methodology and presents empirical results. Finally, section 5 provides conclusion and policy implications.

### **Risks identification and classification**

Market risk, credit risk, liquidity risk, operational risk and political risk have been denoted in Wing and Jin (2015) as the main categories of risks, adversely affecting financial and technical indicators of the renewables related projects.

In Ioannou, Angus, & Brennan (2017), six risk categories were analyzed: political, economic, technological, legal, social and environmental.

Referring to the lack of the standardized classification of risks associated with renewable energy and wind parks in particular, the following classification of risks is proposed in The MITRE Corporation, Risk Impact Assessment and Prioritization (2015): Strategic / business risks, Transport / construction / completion, Operation / maintenance, Liability / legal risk, Market / sales risks, Counterparty risk, Policy / regulatory risks.

Franklin (2019) assumes that in the case of India major risks associated with renewable energy developments and marketing are market, credit, operational, liquidity and political risks.

In the last decades, achievements in the development of renewables and renewables-related risk management laid down a foundation for the applied research in this field (Ritchie & Roser, 2019; IRENA, 2018; Ioannou, Angus, & Brennan, 2017; Noothout et al, 2016; Jhij-HaoLina, Wu & Lin, 2016; Wing & Jin, 2015; Franklin, 2019; Rostami, 2016). From this point of view, study of risks inherent to Azerbaijan, as a potential region for development of renewables, is of particular interest.

Development of renewable energy system is a typical example of the project and before immersion into details of the renewables-related risk assessment, it would be useful to specify risk concept. There are many various definitions of the risk. In our research, we are utilizing definitions of risk given in Aven (2012) and PMBOK guide by Rose (2013).

Hancock (2015) analyses risk assessment and prioritization practices that have been commonly used for Enterprise Risk Management (ERM). Key considerations of risk assessment process such as risk assessment dimensions, scales used for likelihood and impacts quantification, ranking procedures are illustrated by examples.

Noothout et al., (2016) identifies nine country-related risks for the EU. Some of the risks embrace all three phases of the renewables project development process (planning, construction, and operations) and others are inherent only for the one or two phases.

Classification of risks associated with risk management of renewable energy projects in case of onshore and offshore wind parks (Gatzert and Kosub, 2016, July) includes seven key risks: strategic / business; transport /construction / completion;

operation / maintenance; liability / legal; market / sales; counterparty; political, policy, regulatory and associated sub-risks, and these risks are comparable with risks identified in Noothout et al., (2016).

Waissbein et al., (2013), based on risk environment, investment barriers and risk driver analysis, identify nine risk categories: power market; permits; social acceptance; resource and technology; grid/transmission; counterparty; financial sector; political; currency/macroeconomic risks.

Risk factors evaluated by investors of the renewable energy and presented in Ragwitz et al., (2007) include three key risk categories (political, technological and market risks), subdivided into more detailed categories like financial change of support system; conditions on access to the grid; planning and permit risk; financial risks; non-financial change of the support system; complexity of the support scheme; other administrative risks; risk of resource availability; risks on the regular market.

In general, absolute or relative severity of the economic, social, political, legal, technological, and environmental forces, creating risk and driving changes predetermines enterprise-level, region or country-specific project risk categories.

Complexity and uncertainty inherent to large scale RES projects require a well-grounded combination of the various approaches and tools. Country-level solution of such issue is given in Santoyo-Castelazo, & Azapagic (2014). A framework for analysis, based on life cycle approach and integration of the environmental, economic and social dimensions of sustainable development, is created. The framework includes scenario analysis, life cycle assessment, life cycle costing, social sustainability assessment, and multi-criteria decision analysis, which are used to assess and identify the most sustainable energy options. The application of the framework is illustrated in the example of future electricity supply in Mexico.

Energy is a basis of sustainable economic development and at present RES are becoming an inseparable part of this basis in many developed and emerging countries. Risks are a major barrier to financing RES projects and require various risk management mechanisms and tools. Guerrero-Liquet et al., (2016) discusses risk management tools in solar facilities. Within the PMBOK Guide framework, a combination of different decision-making methodologies has been carried out. The methodologies allow acquiring the knowledge by experts, revealing relationships between causes and effects, and making the best decision. For acquisition of the required information, Delphi and Checklist techniques, cause and effect diagrams, SWOT analysis are applied. Analytic Hierarchy Process (AHP) is used for the categorization and prioritization of risks. As case study, a real case in the Dominican Republic is presented.

A qualitative assessment of the critical risks of an offshore wind project in Persian Gulf in Iran has been made by Mirkheshti & Feshari (2017). Using the AHP method and six main decision-making criteria, the authors have prioritized the risks, namely "lack of capital, verification processes, network connectivity, technology constraints, design and quality of the foundation, demand changes, price fluctuations, and natural hazards" (Mirkheshti & Feshari, 2017). As a source of information experts' interview and literature review are used.

From the risk assessment standpoint, key notions are uncertainty, likelihood (probabilities), impact (consequences). Depending on nature of uncertainties and information available various qualitative and quantitative or semi-quantitative methods can be used for the risks description and assessment (Karmen et al., 2019; Haimes & Sage, 2015; Simmons et al., 2017).

Qualitative methods are based on expert judgment and are used for the purpose of the exploratory research or when risk components have a very large degree of uncertainty and are not quantifiable. According to several surveys results, qualitative risk assessment methods are used most frequently. A proper application of the qualitative approach to the project risk management (Anna Korombel, Piotr Tworek, 2011) requires the knowledge of advantages and disadvantages of specific methods and techniques that are applicable in the subject area. Strength and weaknesses of some chosen techniques are given.

Ioannou, Angus, & Brennan (2017), used quantitative and semi-quantitative methods to model risks and uncertainties in energy system planning, feasibility studies, and development of optimal energy technology portfolios. According to the authors, "quantitative methods measure risks mainly by means of the variance or probability density distributions of technical and economic parameters; while semi-quantitative methods such as scenario analysis and multi-criteria decision

analysis (MCDA) can also address non-statistical parameters such as socio-economic factors (e.g. macro-economic trends, lack of public acceptance)".

Segal (2011) views the ERM as a cyclical process including risk identification (risk categorization and risk definition, qualitative risk assessment, emerging risk identification), risk quantification, risk decision making, and risk messaging. Segal (2011) pays special attention to the qualitative risk assessment as a kernel component of risk identification.

Approaches used for risks management in traditional energy systems, as it is accentuated in Michelez et al., (2011), are transferable for the risks management of RES. There are generic six steps that project risk management cyclical process includes project definition and requirements, risk identification, risk evaluation, risk control, risk follow-up revision and risk feedback. Risk identification step is based on brainstorming, Delphi method, experts interview, checklist, hazard and operability analysis, database, cause and effect diagrams. The output of the step is the risk register. All risks are subdivided into four categories: political, economic, social, and technical.

Questionnaire-based study of risks inherent in bioenergy projects (Bature et al, 2018) categorizes technical, political and regulatory, financial, social, and environmental risks. According to the survey, financial, policy and regulations, and the environmental risks are the most important.

Drivers and determinants of policy and regulatory risks associated with renewable energy investments in developed countries with a focus on Europe have been studied in Gatzert & Kosub (2016). Key drivers and determinants for policy and regulatory risk are categorized as economic stress situation, costs of grid management, technology and technological progress, type and size of financial support scheme, control mechanism, national targets, ideological change, socio-political uncertainty, moral hazard, acceptance risks, and institutional determinants.

As it is shown in Gatzert & Vogl (2016, August), policy risks play an important role in renewable energy projects and should be closely monitored and assessed. A model framework for assessing policy risks using fuzzy set theory, which also takes into account energy price risk, inflation risk, and resource risk, is presented. Research result shows that policy risk can have a serious impact on an investor's risk-return profile.

It is necessary to mention that during last decades methods based on fuzzy logics have been used for the risk assessment and management as a combination of the quantitative and semi-quantitative approaches (Shapiro & Kossi, 2015). However, in comparison with qualitative and semi-quantitative methods, probabilistic and fuzzy approaches are more time consuming from data collection standpoint and, at the same time, they are computational and knowledge-intensive in terms of problem solution, results interpretation, decision-making and implementation.

### **Questionnaire and survey**

Taking into consideration renewables risk-related statistical data limitation, experts' opinion survey approach was chosen as an information collection tool. A group of experts was composed of the twelve specialists in fields of economics, business administration and energy systems. The experts were selected based on their experience and competencies.

Following Ragwitz et al. (2007), Michelez et al., (2011), and Nothout et al., (2016), our survey questionnaire evaluates nine multidimensional key risks. We analyze thirty one sub-risks associated with the development of renewable energy: country-related potential risk (political stability, economic development, legal issues, corruption, volatility of the exchange rate); social acceptability risk (local communities discontent with the environmental issues, opposition caused by the expected increase of the energy costs, risks caused by the lack of the knowledge about positive aspects of renewables); administrative risk (lack of transparent rules and procedures, corruption-related, delays in getting permissions and approvals); financial risks (insufficient investments, limited experience in the development of renewables, strict bank regulations); technical and management (likelihood of incurring losses due to deficiency of the operational experience and knowledge, local specialists knowledge and experience deficiency, misestimation of the resources, lack of the relevant industry, infrastructure limitation); grid access risk (legal, technical, generated by the insufficient experience, grid infrastructure and renewables mismatch); energy policy related risk (lack of support for the renewables); market and regulation risks (uncertainty of the governmental energy policy, legal issues, lack of the independent regulation, lack of independent producers and sellers, lack of an independent regulatory body); sudden change of the RES policy (strategy change, support change).

**Table 1 Questionnaire fragment**

N	Potential risks	Evaluate risk occurrence probability and risk impact (severity)									
		Probability of the risk occurrence					Severity of the risk				
		Very High	High	Medium	Low	Very Low	Very High	High	Medium	Low	Very Low
1	Country-related potential risks										
1.1	Political stability related										
1.2	Economic development related										
1.3	Legal issues										
1.4	Corruption related risk										
1.5	Volatility of the exchange rate risk										
.	.....	.	.	.	.	.	.	.	.	.	.
9	Disruptive change of the Renewable Energy Sources Development policy										
9.1	Change of the strategy										
9.2	Change of the support policy										

The key point in any survey is a survey data processing and interpretation. Question framing predetermines and limits risk metrics and descriptions available. So, before formulating the survey questions and collecting data, we present data processing technique, describe risks and metrics that we are going to use.

**Risk assessment methodology**

Risk analysis and evaluation in application areas are mainly based on domain experts' opinion studies. When it comes to evaluation of the various indicators and variables based on experts' opinion, there is a temptation to assume that experts are operating with perfect and exhaustive information and that they are able to provide exact numbers. Unfortunately, in the most cases, subject area information is incomplete, imprecise and vague by nature. Based on knowledge and experience, experts operate with linguistic terms and, even though they provide numbers, these numbers are subjective estimates and approximations. Linguistic information provided by the experts, in order to be useful for a decision-making process, needs some preliminary interpretation, processing and formalization.

For the risk assessment, different number of levels can be chosen (Hancock, 2015), but in the most cases researchers prefer to use five levels scale as a scale having sufficient descriptive and discrimination efficiency.

According to the questionnaire, experts evaluate probabilities and severity (seriousness) of potential risks on five level linguistic terms scale: **Very High, High, Medium, Low and Very Low**.

Qualitative and quantitative information, acquired in the survey, can be integrated based on approaches used in Rose (2013, PMBOK guide) and Risk Assessment and Prioritization guide by MITRE Corporation (2014).

In case of symmetrical distribution and equal intervals, probability of the risk occurrence can be described by the intervals or as a midpoint of the intervals.

In some cases, researchers increase the number of intervals. For example, MITRE corporation has been using 11 intervals (The MITRE Corporation. Risk Impact Assessment and Prioritization, 2014), but in this case more statistical data should be provided to the decision maker and experts. Moreover, discrimination ability of the people is limited by the nine chunks of information that people are able to process simultaneously.

Risk impact severity can be evaluated on various scales. Based on experience and requirements, each organization determines risk scales and permissible levels of the risks for the system (PMBOK guide). If high and very high levels of the risk severity are not admissible, non-linear scale is preferable for the evaluation of the risk impact severity.

Non-linear scale can be constructed based on the following exponential function:

$$Y_i = \alpha * \beta^{i-1},$$

where  $\alpha$  is value of the risk impact severity for the term “**Very Low**” and in the most cases, it is assumed that  $\alpha = 0.05$ ;  $\beta$  is a base of the exponential function and value of the base shows how many times adjacent linguistic variables’ severity degrees differ;  $i=1,2,3 \dots k$  – are indexes of the linguistic variables describing severity of the risks, linguistic variables indexes ranked from the lower to higher severity- degree “**Very Low**” has index equal to 1, “**Very High**” degree has index equal to  $k$ . In the most cases  $k=5$ . This number is based on the number of the linguistic terms that people are able to soundly differentiate and justify. According to [Wing & Jin \(2015\)](#), most people are able to keep and process  $7 \pm 2$  chunks of the information simultaneously in their operative memories. Taking this into consideration, experts, as a rule, answer a questionnaire for a short time, and therefore, lower boundary of the interval is more reliable.

Choosing appropriate values for the  $\alpha$ ,  $\beta$  and  $k$ , we can determine minimum value of the degree, number of the degrees, and ratio of the adjacent degrees. If we choose  $\alpha=0.05$ ,  $\beta=2$  and  $k=5$ , then non-linear scale of the risk severity will be:

Very High	0.60
High	0.40
Medium	0.20
Low	0.10
Very Low	0.05

If the number of the experts equals  $Q$  and indexes  $q=1,2,\dots,Q$  assigned to the experts, then risk factor for the  $r$  component of the risk  $i$ , according to an opinion of the  $q$ -th expert, can be calculated as:

$$RF_{qir} = P_{qir} * CD_{qir},$$

here  $P_{qir}$  is a probability of the risk component,  $CD_{qir}$  is the numerical value of the risk factor severity.

If the risk components from the standpoint of the influence are significantly different, then weight  $W_{ir}$  can be assigned to the each component and risk factor  $RF_{qi}$  for the  $i$ -th risk can be calculated as a weighted average of the components:

$$RF_{qi} = \sum_{r=1}^{m_i} W_{ir} * P_{qir} * CD_{qir}$$

Weights should satisfy the following constraints:

$$0 < w_{ir} < 1, \quad \sum_r w_{ir} = 1$$

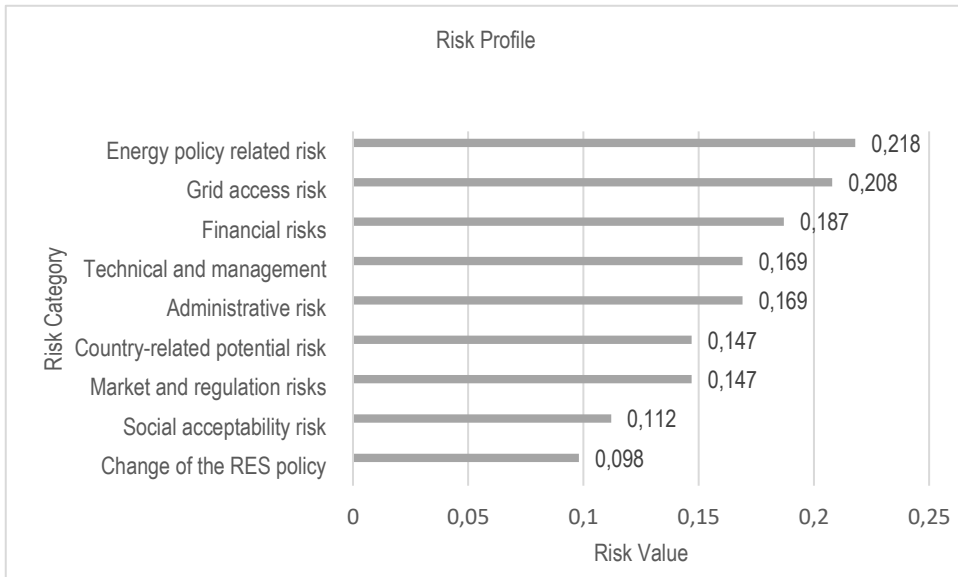
Some other scales can be used as well, but in this case, weights should be normalized before calculations.

Based on experts’ opinions, risk factor for each risk is calculated in accordance with the following expression:

$$RF_i = \sum_q^Q RF_{qi}$$

If a panel of experts decides that it is necessary to take into consideration differences between experts in knowledge level and competencies, then weights can be assigned to the experts as well, and in this case risk factor will be calculated as a weighted average.

**Figure 1 Risk values calculated based on experts' opinion**



According to the risk profile, there are sufficiently large differences between various types of risks. Most influential and significant are energy policy, grid access and financial risks according to the Kendall's concordance coefficient ( $W=0.402$ ).

**Conclusion**

Environmentally friendly renewable energy sources are becoming the mainstream in the energy projects development. But, development of renewables, as any other business and technological innovations and undertakings, encounters serious country-specific, legal, administrative, technological, financial, and many other issues and these issues-related risks. Risks directly influence the objectives of energy projects and outcomes and should be analyzed and assessed in advance.

The case of Azerbaijan was studied in detail. Taking into consideration limitedness of the country experience in the development of renewables and lack of appropriate historical statistical data, an opinion study of experts was chosen to acquire the relevant information.

Survey questionnaire evaluated nine risks and thirty-one sub-risks, risk probability and risk impacts. Based on these indicators, risk value for each risk category was calculated and risk profile for the renewable energy systems in Azerbaijan was constructed. According to experts' opinion, most influential are energy policy, grid access and financial risks. According to the derived Kendall's concordance coefficient ( $W=0.402$ ), there is medium level agreement among experts on the evaluation of expected risks in the development of renewables in Azerbaijan. The results of this research enhance understanding of investment risks in renewable energy projects and contribute to risk management policies on achieving sustainable energy development in Azerbaijan.

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