



Interpretive and Structured Development of Comprehensive Risk Management for Investing in Renewable Energy

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ABSTRACT

The aim of the present study was to develop interpretive and structured comprehensive risk management for investing in renewable energy. The research methodology is mixed and is categorized as developmental research. In this study, interviews are used to collect data in the qualitative part, and matrix checklists based on paired comparisons are used in the quantitative part. The statistical population of the study consisted of 14 experts and university professors and members of the risk committees of companies in 1403, who were selected based on the purposive sampling method with a snowball approach. The results of the present study in the qualitative section showed 2 overarching themes, 8 organizing themes, and 33 basic themes. Then, aimed at assessing the reliability of the identified organizing themes, Delphi analysis was used. Based on the average evaluation of the first and second phases of Delphi, it was determined that all dimensions were approved, and the possibility of measuring them through interpretative and structured analysis was provided. based on the fourth research question, an attempt was made to determine the most effective themes of the comprehensive risk management model for investing in renewable energies. industry-related risks (B) were the most effective theme of the comprehensive risk management model for investing in renewable energies. A comprehensive risk management framework for renewable energy investment can be seen as a key element for improvement. These measures not only contribute to financial and economic efficiency, but contribute to environmental protection and sustainable energy supply

Keywords: Comprehensive risk management, Industry related risks, Investment, Renewable energy



1. Introduction

Renewable energy¹ refers to resources produced by natural processes or production technology that can be used indefinitely and are considered clean energies that reduce negative impacts on the environment. For example, solar energy, wind, hydropower, and marine energy are considered renewable energies. These sources have a significant impact on providing green energy due to the reluctance and concerns about storing harmful waste (Jiskani, 2022). Also, ensuring energy sustainability² leads to independence from unsustainable energy sources. On the other hand, investing in renewable energy means allocating financial resources to projects that use these resources to produce energy. This investment can be done in two ways: directly or indirectly (Ke, 2022). Investing in renewable energy plays an important role in the development and productivity of this industry and also helps to achieve the Sustainable Development Goals (SDGs)³. A comprehensive risk management framework is needed to successfully implement renewable energy investments. Risk management refers to a research and dynamic approach that finds appropriate answers to the ifs and buts that arise in various projects. In other words, the ifs and buts that arise in all areas of the project are identified by project management, and then the impacts of events, incidents, and contingencies are examined. Ultimately, risk management finds an appropriate and appropriate response to the ifs and creates a positive impact on the achievement of project objectives. There are unpredictable events in every project called risks and they occur over time. It is clear that these unforeseen events will cause damage to the project; therefore, the theory of risk management is proposed as a technique for identifying and controlling unpredictable events. Many countries have supported solar power plants

through legislation, which has led to the growth of the solar power market. This situation has led to the rapid growth of the solar energy industry (Abba et al., 2022). Many countries have realized the important role of renewable energy due to the increasing global concern about the depletion of fossil energy reserves and the growing protection of the environment and climate change, which is mainly caused by greenhouse gas emissions (Zeng, F et al., 2019, Liu et al., 2017). Investment in renewable energy, which plays an important role in promoting the utilization of renewable energy, has four main characteristics. First, the investment is partially or completely irreversible. Second, the investment costs of renewable power generation projects are often higher than those of fossil fuel power generation projects due to the immature technology in this field. Third, investment in renewable energy faces many uncertainties, including market development, technological progress, and support policies.

Investment has four main characteristics in the field of renewable energy, which plays an important role in promoting the use of renewable energy. First, the investment is partially or completely irreversible. Second, the investment costs of renewable power generation projects are often higher than those of fossil fuel power generation projects due to the lack of maturity of technology in this field. Third, investment in the field of renewable energy faces many uncertain factors, including market development, technological progress, and support policies. Fourth, the timing of investment in renewable energy projects is optional (Sami'e-Nasab, 2024); therefore, investments in renewable energy face various types of risks, including market, credit, and operational risks. Market risks include price fluctuations, demand changes, and changes in regulatory and policy environments that can significantly affect revenue streams (Cornwall et al., 2023). If the return on a renewable energy project is comparable to the risk it takes or the investment can be postponed to gain more risk-related knowledge, profit-seeking investors can make this investment. Therefore, investing in renewable energy is one of the most important factors in preserving the environment and reducing the effects of climate change (Ibahar, 2022).

Iran is facing many problems and challenges in using renewable energies. Some of the most important obstacles to achieving new energies at this time

¹ Renewable energy (or green energy) is energy from renewable natural resources that are replenished on a human timescale.

² Energy sustainability is defined by the present author as the provision of energy services at present and in the future, for all people, in a manner that is sustainable, that is, sufficient to provide basic necessities, not overly detrimental to the environment, affordable by all people, and acceptable to people and ...

³ The Sustainable Development Goals (SDGs) are a collection of 17 global objectives established by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development.

include the lack of sufficient awareness of the people and officials about the vital issue of energy, the lack of proper knowledge of renewable energy sources and their benefits, as well as the lack of economic justification and the existence of rich fossil resources in the country are the reasons for the lack of success in developing renewables, but it is difficult for the government to optimally allocate these financial incentives, because the results obtained will not be desirable if these resources are not allocated appropriately, and in practice the government will lose part of its capital, albeit temporarily.

This study was conducted with the aim of providing a comprehensive framework for understanding and addressing various risks related to investment in renewable energies; therefore, the issue raised in this context is the use of a comprehensive and localized risk management framework appropriate to the country's conditions. As mentioned, in this study, first, with an analytical approach in the content analysis section, based on the Attride-Stirling (2001) approach, during the coding stages, the themes are identified through open coding of the research, and then through selective coding, the overarching, organizing, and basic themes related to localized comprehensive risk management based on the Cuzco (2004) model for investment in renewable energies are determined; therefore, the main issue of the present study is what is the appropriate model for comprehensive risk management for investment in renewable energies? And what are the most effective themes of comprehensive risk management for investment in renewable energies? This study is one of the few research topics conducted in Iran that presents a comprehensive risk management model for investing in renewable energies based on the COSO model and in an empirical manner and considering the specific characteristics of Iran in all stages of the work. It is very useful to have a process perspective in identifying the risks of investing in renewable energies and providing appropriate classification for the types of risks, and ultimately formulating the appropriate decision to deal with each of the presented categories that best suits its conditions. Finally, the risks identified in investing in renewable energies are numerous, and the nature of risk assessment, which is external degree centrality and betweenness centrality, therefore, providing a comprehensive risk management model is considered another innovation of this

research due to the conditions of risk management in investing in renewable energies. Also, innovation in risk analysis and comprehensive risk management framework for renewable energy investment can be considered as a key element for improvement and efficiency in this industry and this innovation in risk analysis and comprehensive risk management framework for renewable energy investment can help to improve the performance of the renewable energy industry and reduce risks. These measures not only contribute to financial and economic efficiency, but also help to preserve the environment and provide sustainable energy. Improving risk analysis and creating innovative approaches can help to develop sustainable and essential renewable energy projects in the world.

Theoretical framework of the research

Governments should now plan to better manage the capital used in energy development projects as the private sector welcomes investment in this area. Currently, most energy development projects are directly managed by governments, and this is an opportunity to maximize the use of private sector resources to achieve the goals of economic development based on reducing environmental pollutants (Yüksel et al., 2024). However, the main problem is to create a desire in private sector investors to move along the path planned by governments. It should be noted that governments have always sought to create the necessary infrastructure to provide energy from renewable sources, and the next priority is to pay attention to the profitability of the private sector (Ming, 2014). In other words, achieving the goals of the governments is more important to public sector managers than the risks that exist for private sector investors in entering various sectors of renewable energy development. This has led to a decrease in the amount of investments in countries that do not have appropriate economic infrastructures and the private sector is not sure of its future profitability (Sami'e Nasab, 1403). The concepts related to comprehensive risk management for investing in renewable energies are discussed below.

The importance of investment risk management

Investment is considered one of the key tools for increasing wealth and achieving long-term financial goals, because investors can earn higher returns than

bank deposits by accepting risk through investing in financial markets, such as the stock market or direct investment in companies. Despite all these benefits, there are always threatening factors that increase investment risk. Assessing the level of investment risk is important for both managers and shareholders. Businesses that do not consider the areas of potential risks for themselves and do not plan to deal with them are like countries that have no idea what to do in times of crisis. In this situation, shareholders are the first to suffer (Serebryakova et al., 2020). Investment risks have various sources that are divided into two general categories: internal and external. Some of them are the result of external conditions, and others are the results of decisions, actions and internal structures of the company. Just as ordinary life in the world entails risks, even in its most peaceful places, investing in an economic enterprise will also entail its own risks; therefore, one should not be unnecessarily afraid of economic activity; rather, one should take the desired actions by gaining the necessary knowledge (Dvorský et al., 2020).

Types of investment risk

Investments are faced with various types of risks, the identification and proper management of which plays a significant role in the investor's success. The following introduces the most important of these factors: Systematic risk or market risk: This type of risk refers to the risk resulting from the effect of general market factors that simultaneously affect the prices of securities in the financial market. Factors such as economic, political and social developments (such as exchange rate changes, business cycles, inflation, monetary and fiscal policies of governments) create systematic risk in financial and economic systems (Yüksel et al., 2024).

Unsystematic risk or company risk: This risk is related to the performance or specific circumstances of a company. Careful research and study of the company and industry can help reduce this type of investment risk (Ige et al., 2024).

Country risk⁴: This risk arises from political, economic, or social factors in a country. It can be beneficial to have geographical diversification in your

investment portfolio to manage this investment risk (Abbas et al., 2023).

Liquidity risk: Liquidity investment risk occurs when an asset cannot be converted into cash quickly and without a decline in price. Having some cash or liquid assets can be helpful in managing this risk (Canabarro, 2024, Kou et al., 2023, Wing & Jin, 2014).

Exchange rate risk: This risk occurs in international investments and the use of derivative instruments such as forwards can help manage this investment risk. The diagram related to the types of investment risk is shown in Figure (1):

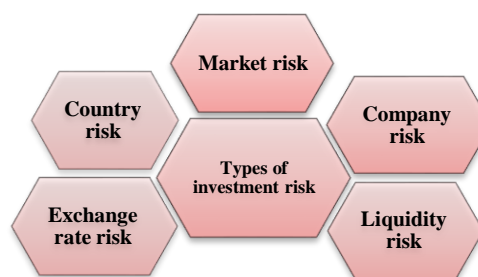


Figure (1): Types of investment risk (Yüksel et al., 2024).

COSO Risk Management

COSO originally created an enterprise risk management (ERM) model in 1992, which was structured in the form of a pyramid, and focused on assessing existing controls. This was updated in 2013 to the COSO Cube, which focused on the design and implementation of a risk management framework. Cossow's Integrated Risk Management Framework (2004) incorporates the "Internal Control - An Integrated Framework", previously published by the Integrated Framework (the COSO Framework) was developed by the Committee of Sponsoring Organizations (COSO) of the Treadway Commission, which believes that by expanding the scope of internal control, it provides a broader and more robust focus on the subject of risk management.

This framework defines Enterprise risk management (ERM) as: "A process influenced by an enterprise's board of directors, management and other employees, used in strategy formulation and throughout the entity, designed to identify potential events that could affect the enterprise, manage risk

⁴ Country risk refers to the economic, social, and political conditions and events in a foreign country that may adversely affect a financial institution's operations.

within the enterprise's risk appetite and provide reasonable assurance regarding the achievement of the enterprise's objectives." Key concepts included in this definition include:

- Enterprise risk management (ERM) is a process, not just an event.
- There is a direct relationship between enterprise risk management and strategy development.
- It is applied throughout the enterprise.
- It is in line with achieving the enterprise's objectives.

The COSO framework for ERM identifies eight components: 1. Internal environment, 2. Objective setting, 3. event identification 4. Risk assessment 5. Risk response 6. Control activities 7. Information and communication 8. Monitoring (Harjoni et al., 2024). According to COSO, almost any component can affect another element. COSO's Enterprise Risk Management Cube Model (Figure below) aims to show the relationships between these components, the organization's objectives, and the organization's structure. As such, the model is particularly powerful in portraying the full end-point of the enterprise risk management picture. The three dimensions of this cube reflect and relate to the elements of risk management, the organization's business objectives, and its organizational structure, and paint a complete picture. Also, the three-dimensional structure of the COSO cube facilitates attention to the parts of the framework during implementation (Yuni et al., 2024).



Figure (2): COSO Enterprise Risk Management Cube model (Yuni et al., 2024).

Research background

The background of research undertaken inside and outside the country on the research topic and their results will be briefly described in the following section:

According to the results of Zeng, F., & Wu, (2024), Brazil is accelerating its power transition in its position as a major energy producer in Latin America. In addition to being the largest economy in South America, Brazil is also the country in which China has invested the most. In addition, Brazil is increasing its efforts to develop wind power, photovoltaics and other renewable energy sources in response to the high demand for renewable energy sources. Brazil's renewable energy sector offers great potential for investment based on a solid foundation for cooperation between China and Brazil. The gray forecasting model was used for this research to forecast Brazil's installed renewable energy generation capacity and the results indicate a positive trend in Brazil's renewable energy generation. They also concluded that there is a rapid growth in wind and photovoltaic power generation over the next 5 years, with growth rates reaching 50.39% and 182.99%, respectively, indicating that there is potential for a wide range of development. Their research used factor analysis to assess investment risks related to Brazil's renewable energy sector from 2000 to 2020. According to their study, Chinese power companies investing in Brazil's renewable energy sector face the highest political risk, while other risks gradually decrease. Zhao et al. (2024) concluded that improving energy efficiency and investing in renewables are key influencing factors that may lead to sustainable outcomes from climate change policies. Their study examined the impact of green financing, oil price volatility, and geopolitical risk on renewable energy investment using data from Chinese listed companies. Their study confirmed the importance of green financing and environmental taxes in encouraging investment in renewable energy.

According to Heckman's Two-Step Selection model with endogenous effects on the Chinese economy, geopolitical risk has a significant impact on green investment in the short and long term. Furthermore, the analysis strengthened the link between green finance and renewable energy investment, while confirming the moderating function of green regulations. They concluded that China should prioritize the growth of environmentally

friendly businesses to make investment in renewable energy sources mainstream. Kou et al. (2023) concluded that there are risks such as legal, technological and financial issues in renewable energy investments. Hence, appropriate measures should be taken to minimize these risks. However, each of the measures that must be taken to manage risks creates new costs for businesses; therefore, measures should be taken for the most important risks in the first stage to ensure the financial sustainability of the projects. It is necessary to conduct a priority analysis for the risks facing renewable energy projects due to this situation in order to increase the effectiveness of risk management. Accordingly, they have investigated the risks and benefits of sustainable investment decisions for renewable energy projects. In this area, a new model was generated by integrating different techniques. Another important point of their study was that a new technique called neural decision-making was also developed. In this technique, the facial expressions of experts who evaluate which technological changes are most important were taken into account. In addition, government incentives were identified as the most essential reward for improving sustainable investments in renewable energy; therefore, appropriate measures should be taken to effectively manage these risks. Ilbahar et al. (2022) concluded in a study that major investments have been made in this field by most countries that intend to replace traditional energy sources with renewable energy sources. Assessing investment risks is very important for making the best investment decisions because renewable energies require high investment costs. However, the lack of decision-making and cognitive bias of experts should be eliminated because the risk assessment process is based on expert judgments. Renewable energy investment risks were prioritized by overcoming experts' indecision and cognitive bias based on their proposed risk assessment approach. Van Tassel et al. (2014) used non-radiographic data overlay analysis to measure the efficiency of public sector energy and environmental investments in European countries during the years 2001–2008. The study is divided into two sub-periods: in the period 2001–2006, all crops are covered by government financial support, and in the second period from 2007–2008, a new financial support scheme is implemented separately. The results of this study show

that energy efficiency in countries such as Germany, Sweden, and Australia, is above standard levels.

Wang et al. (2012) used various data overlay analysis models from 2000 to 2009 in 30 regions of China to produce a framework that expresses the desired and undesirable outputs of investment, as well as to separate energy and non-energy inputs. In this study, energy efficiency measurement and pollution emission rate are considered integrally. Also, two approaches for undesirable emissions are proposed and then compared with each other, as in the first approach energy is considered only, and in the second approach it is considered integrally with pollution emission. Sami'e-Nasab (1403) examined the country's renewable energy financing strategies in line with the law on removing production barriers and concluded that many challenges and risks have hindered the development of renewable energies in the country, including "the risk of not paying producers' demands on time", "the risk of violating obligations regarding electricity purchases", "the risk of difficulty in importing power plant components", "the risk resulting from low price competitiveness between renewable and thermal energies" and "the lack of an effective and efficient financing model". It can be effective in developing these energy sources to use the capacities of the law on removing obstacles to the development of the electricity industry, which requires industries and companies to supply at least one percent of their electricity needs through renewable energies or through the green electricity exchange board. In addition, adopting the following solutions can be effective in developing renewable energies: 1) reforming the structure of the circulation of fuel revenues saved in the subsidy targeting organization, 2) issuing government guarantees to reduce the risk of foreign investment, 3) increasing the willingness to invest in renewable power plants by amending the price of fuel delivered to thermal power plants, and 4) providing legal and infrastructural support for the construction of renewable power plants by major industries.

Mousavi et al. (1401) examined the feasibility of financing renewable energy projects through public-private partnerships in the Iranian economy. The aim of their study was to investigate the feasibility of financing renewable energy projects through public-private partnerships in Iran. To achieve this goal, an attempt is made to provide suggestions to increase the

status of public-private partnerships in renewable energy investments in Iran by using a comparative study focusing on public-private partnerships in financing renewable energy infrastructure in developing countries that have been successful in implementing such projects (Mexico, Brazil, South Africa, Pakistan, and India) and examining the laws, experiences, policies, and requirements for private sector investment in renewable energy. According to the research findings, the most important influencing factors are: (1) trust and special attention to the private sector (2) lifting economic sanctions (3) reducing the degree of political and economic risk (4) implementing reforms in the institutional framework. Yeganagi and Qasem Lu (2014) concluded in a study that it is necessary to transition to renewable energies on a large scale in order to mitigate climate change. It is inevitable to create a competitive environment and private sector participation in the field of renewable energies exploitation due to the rapid growth of the market demand and energy consumption. Rahmani and Keramati (1400) in a study titled "Providing a comprehensive model of risk management and cost reduction in capital banks" concluded that human resources risk, banking regulations risk, liquidity risk, credit risk, operational risk, market risk, information technology risk, interest rate risk, and relationship risk and power risk have a significant impact on risk management in capital banks and the establishment of corporate governance in the bank, supervision of the bank's management and board of directors, bank security controls, and reputation and legal risk management are proposed as management approaches to dealing with risk in capital banks, on the other hand, the reserve ratio, the interbank interest rate, mergers with banks and credit financial institutions, the interest paid by the central bank on legal deposits, branch location optimization, the development of electronic banking and facility insurance has a significant impact on reducing costs in capital banks.

Research questions

The aim of the present research process is to find answers to the following questions:

Qualitative Section Questions

- 1) What are the basic themes of comprehensive risk management for renewable energy investments?
- 2) What are the organizing themes of comprehensive risk management for renewable energy investments?
- 3) What are the global themes of comprehensive risk management for renewable energy investments?

Quantitative section question

What are the most influential themes of comprehensive risk management for investing in renewable energy?

As mentioned earlier, the first three questions of this study seek to determine the dimensions of a comprehensive risk management framework for renewable energy investment through content analysis, and the fourth question of this study attempts to examine the most influential factors identified for comprehensive risk management for renewable energy investment through structural-interpretive analysis.

Research Method

The methodological nature of this study is considered to be a developmental study in terms of its results, because no previous study has attempted to provide a framework for a comprehensive risk management model for renewable energy investment, and conducting this study can help to provide conceptual integration of the phenomenon under study. Also, this study is considered as an exploratory study in terms of the objective, which seeks to determine the basic, organizing, and global themes in line with a comprehensive risk management model for renewable energy investment according to expert interviews and three-stage coding. From the perspective of the nature of data collection, it should be stated that this study uses qualitative analysis methods. Based on the intersection of voluntarism in the philosophy of the world with structuralism in the philosophy of science, the philosophy of the present study is considered basic; therefore, the nature of the basic philosophy in the research is a combination of the inductive-deductive approach. In-depth semi-structured interviews were used to collect data, and the snowball technique, which is one of the purposive sampling methods, was used to

identify experts. Semi-structured interviews were used because, in addition to the possibility of exchanging ideas and thoughts, the discussion and topic of the interview can be guided towards achieving the research objectives. Also, during the interview process, it is possible to observe the feelings and reach the beliefs and convictions of the interviewees about the research topic.

Data collection methods and tools

Data for this stage was collected in the following two ways:

A) Review of texts: First, 11 texts were selected using a library method to review theoretical literature and analysis, and were numbered.

B) Interview: A semi-structured interview tool was used in this stage, and interviews were conducted with experienced professionals and experts in the field of capital markets and members of the companies' risk committees, and were numbered.

The final analysis of the data of the present study was carried out through interviews with experts with professional experience in the field of capital markets and members of the risk committees of companies in 2024. Therefore, the population includes experts and professors with professional experience in the field of capital markets and members of the risk committees of companies. The sampling method is a combination of purposive and snowball sampling methods. For this purpose, in the first step, three people from the statistical population who were known as experts based on published articles in fields related to the research topic or scientific and executive backgrounds in the field of accounting and financial reporting were purposefully selected. In the second step, people from the statistical population who were introduced to the researcher by the interviewees based on the snowball method and had the opportunity to be interviewed were added to the statistical sample, and the theoretical saturation point is the criterion for reaching the end of data collection. The logic of purposive sampling is to select cases that are rich in information about the research topic and provide the possibility of in-depth research (Burns & Grove, 2006). The process of introducing the next participants and conducting interviews continued until theoretical saturation 1 of 14 people was reached. Theoretical saturation is determined based on the subjective judgment of the researcher, and reaching theoretical saturation

indicates the adequacy of data collection (Lopez, 2010). In the quantitative part, the same statistical population as the qualitative part was present for interpretive structural modeling. As the research of Plant et al. (2017); Northcutt & McCoy (2004) stated that the optimal limit of the statistical population in this study is 12 to 25 people, in terms of sample size, 14 people are approved as a sample in this study.

Research validity: The triangulation method⁵ was used in the qualitative study in this section with the aim of assessing the validity of the coding. In fact, triangulation, derived from the knowledge of geometry, assesses the reliability in qualitative research through at least three sources to determine that the codes created have sufficient validity and trust, and this study does not suffer from the so-called "inherent bias"; therefore, validation was carried out in the qualitative section in this study to achieve this in 4 dimensions after observing the opinions of experts after the end of coding.

However, Delphi analysis was used to assess validity in the quantitative section. In fact, Delphi analysis was conducted to examine the extent of application of concepts in the target population in order to obtain theoretical adequacy in the target population regarding the identified dimensions and components. The results of this section are presented in the form of Table (4) in the second part of the analysis of research findings.

⁵ Triangulation refers to the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena (Patton, 1999).

Table (2): Validation of triangulation of identified dimensions

Description	Triangulation dimensions
The aim of this dimension is to assess the theoretical fit or conceptual alignment of organizational themes with scientific sources in past research; therefore, given that organizational themes were extracted from previous studies in this study, the validity of the data of the identified codes was confirmed based on the nature of the analysis. Because, the alignment of the theme with the identified concepts was carried out in the previous study.	Data Source Triangulation
The aim of this dimension is to assess the data collection process in the interview and coding. In fact, the participants' subjective interpretations of the coding and question design during the interview were the basis for validation. Several researchers participated in this study, and while the interpretation of the codes was close to each other, the interview style and any deviations in the codes were discussed.	Investigator Triangulation
The purpose of the data collection method in this dimension is qualitative study. For example, how to reach the theoretical satisfaction point in the interview is considered; therefore, due to the use of open (deep) and semi-open interviews to reach theoretical satisfaction during the interview, it can be said that the data collection method is not one-sided, and it can help validate the study by using a combination of interview methods and initial coding at the interview site.	Method Triangulation
The aim of this dimension, which has a gray border with resource triangulation in terms of implementation, is to connect organizational themes and comprehensive themes from the central and selective coding stage; therefore, given that the process of organizing themes was to organize theoretical names based on related theories in other interdisciplinary sciences such as management, the identified codes are confirmed from the triangulation theory.	Theory Triangulation

Research findings

The necessary analyses for data localization are carried out using thematic analysis method after data collection through interviews. Information related to

basic, organizing, and global themes is shown in Table (3).

Table (3) - Identification and extraction of global, organizing, and basic themes

Source	Basic themes	Organizing themes	Global themes
Interview Yüksel, D. et al. (2024) Zeng, F, et al. (2024) Canabaro (2024) Cornwall et al. (2023) Abba et al (2022)	The risk of a lack of common understanding regarding the development of risky investment in renewable energies	Strategic risks	Structural Risk Management
Interview Yüksel et al. (2024) Zeng, F et al. (2024) Abba et al (2022)	Creating appropriate geographical distribution		
Interview Abba et al (2022)	Risk related to the appropriate structure of the parent entity or the main investor of renewable energy risk-averse capital funds		
Interview	Risk planning and development of a spatial map for the appropriate deployment of risk averse investment institutions	Industry-related risks	
Interview	High volume of capital attraction in the industry		
Interview Zeng, F et al (2024)	The risk of large industrial holdings entering this industry		
Interview	The risk of the timely departure of the government from risk-averse investment institutions	Internal environmental risks	
Interview Yüksel et al. (2024) Zeng, F et al. (2024) Canabaro) (2024)	Risks in transmission lines and the nationwide network		
Interview	Domestic Financing Risks		

Source	Basic themes	Organizing themes	Global themes
Yüksel et al. (2024) Zeng, F et al. (2024) Abba et al.(2022)			Institutional Risk Management
Interview Kornwell et al. (2023) Abba et al(2022)	Foreign Financing Risks		
Interview	Uncertainty about interest rate changes		
Interview Yüksel et al. (2024) Zeng, F et al. (2024) Abba et al. (2022)	Restrictions on purchasing equipment and supplying parts	Operational risks	
Interview	Damage to equipment during transportation to the construction site or during installation		
Interview Yüksel et al. (2024) Zeng, F et al. (2024) Canabaro (2024) Kornwell et al. (2023) Abba et al. (2022)	Lack of access to skilled and specialized labor		
Interview	Use of low-quality and cheap technologies	Technological and technical risks	
Interview	Existence and access to service and maintenance facilities in the country		
Interview	Technical advances in this field and alternative technologies		
Interview	Maturity of the technology used		
Interview	Lack of stability in laws, regulations, and directives related to renewable power plants	Political and legal risks	
Interview	Complex regulations and excessive administrative bureaucracy		
Interview	Political and economic sanctions		
Interview	Lack of a specialized authority to resolve disputes between risk-averse capital institutions and entrepreneurs in the risk-averse Capital Association		
Interview	Lack of long-term and in-depth plans for this industry		
Interview	Lack of stability in public policies for the formation of risk-averse capital	Environmental risks	
Interview	Destructive ecosystem effects		
Interview	Risk of climate change in the region		
Interview Zeng, F et al(2024)	Adverse biological and physical effects on living organisms		
Interview	Occurrence of natural disasters		
Interview	Changes in inflation rate	Economic risks	
Interview	The country's economic conditions and its future prospects		
Interview	The deviation of the actual costs of constructing and operating these power plants from the amounts predicted in the feasibility phase (such as the cost of purchasing and installing equipment, salaries and wages, insurance, repairs)		
Interview	The deviation of the cost of constructing the reachability road from the amounts predicted in the feasibility phase		
Interview	The deviation of the actual costs of constructing the substation and cabling for connecting to the network from the amounts predicted in the feasibility phase		

Delphi analysis findings

Delphi analysis is considered as a link between qualitative and quantitative analysis, because it makes

it possible to explain the model components in the form of the desired research tools in the target population in the quantitative part by assessing the reliability of the designed model dimensions. In this

study, Delphi analysis was used to assess the reliability of the presented model contents. This analysis is based on two criteria: agreement coefficient and mean. In order to carry out this assessment, the research components were first arranged in the form of a seven-option questionnaire to be distributed among the panel members and the level of reliability of the research components was assessed based on several rounds of questionnaire return.

According to the two criteria of mean and agreement coefficient, all the main themes related to the comprehensive risk management model for investing in renewable energies are approved. In other words, it can be stated that all the themes identified in the qualitative section were approved, because the mean of the main components was 5 and above, and on the other hand, because the agreement coefficient obtained is more than 0.5. Therefore, structural-interpretive analysis should be used to determine the most influential themes identified.

Table (4) - Delphi analysis of identified themes

Result	Second round of Delphi		First round of Delphi		Organizing themes	Global themes	
	contingency coefficient	Mean	contingency coefficient	Mean		Structural Risk Management	Comprehensive Risk Management Model for Investing in Renewable Energy
Confirmed	0.82	5.71	0.69	5.43	Strategic risks		
Confirmed	0.90	5.69	0.78	5.40	Industry-related risks		
Confirmed	0.81	5.50	0.65	5.30	Internal environment risks		
Confirmed	0.84	5.74	0.82	6.01	Operational risks		
Confirmed	0.70	5.40	0.65	5.30	Technological and technical risks		
Confirmed	0.84	5.98	0.88	6.03	Political and legal risks	Institutional Risk Management	
Confirmed	0.80	6.03	0.90	5.44	Environmental risks		
Confirmed	0.79	5.71	0.69	5.86	Economic risks		

Findings of interpretive structural analysis

A structural interpretive analysis is conducted after identifying and confirming the main research components with the aim of selecting the most effective component of comprehensive risk management for investing in renewable energies. First, the components need to be coded in the format of the table below.

According to the coding of Table (5), the components confirmed based on Delphi analysis have been determined based on the defined signs and symbols to create a structural self-interaction matrix.

The “mode” index has been used for pairwise comparison to form this matrix, so that among the four possible relationships between the indicators, the relationship that has the highest frequency according to the participants has been included in the final table. This matrix is a matrix of dimensions of confirmed statements that is compiled based on the pairwise comparison of statements. This self-interaction matrix is formed in the form of a checklist questionnaire and based on the discussion and opinions of the expert group. However, the defined symbols O, A, X and V are used based on the definitions in the table below to determine the score.

Table (5) - Codes related to comprehensive risk management components for investing in renewable energies

Abbreviation	Component
A	Strategic risks
B	Industry-related risks
C	Internal environment risks
D	Operational risks
E	Technological and technical risks
F	Political and legal risks
G	Environmental risks
H	Economic risks

Table (6) - Conceptual relationships in the formation of the structural self-interaction matrix

Defined abbreviations				
O	X	A	V	
$i \not\leftrightarrow j$	$i \leftrightarrow j$	$i \leftarrow j$	$i \Rightarrow j$	Mathematical explanation
No row-column effect	Row-column interaction)Two-way Relationship(Direct row-column effect)inverse relationship(Direct row-column effect)one-way relationship(Explanatory explanation

Then, the participants' opinions are selected based on the "mode" index, considering the highest frequency among the conceptual relationships V; A; X and O. The following table shows the results of the self-interaction matrix, which is presented in coded form:

At this stage, the Reachability matrix (RM) can be formed by converting the structural matrix relationship symbols to the numbers two, one, zero, and negative one according to the table below. The reachability matrix is obtained by transforming the structural self-interaction matrix into a two-valued matrix of zero and one. Instead of the symbols X of the number 2 and V of the number

one, A of the number -1 and O of the number zero are used to extract the reachability matrix in each row of the self-interaction matrix. The obtained matrix is called the initial reachability matrix. The elements of the main diagonal are set to one. In fact, this step is known as obtaining the structural matrix of internal relations of variables (SSIM). Now, in order to separate the results obtained from the research experts, it should be done according to Table (8):

In this section, a reachability matrix is formed to determine the comparison of row "i" and column "j" based on these concepts.

Table (7) - Formation of self-interaction matrix

H	G	F	E	D	C	B	A		Codes created
X	V	V	O	V	V	V	-	A	Strategic risks
V	O	V	V	O	O	-	A	B	Industry-related risks
A	O	X	V	V	-	O	A	C	Internal environment risks
V	V	A	V	-	A	O	A	D	Operational risks
O	V	O	-	A	A	A	O	E	Technological and technical risks
O	V	-	O	V	X	A	A	F	Political and legal risks
O	-	A	A	A	O	O	A	G	Environmental risks
-	O	O	O	A	V	A	X	H	Economic risks

Table (8) - Abbreviation symbol conversion process

Converting conceptual symbols into quantitative numbers		
The cell corresponding to this pair is placed in the reachability matrix with the number 1 and its symmetrical cell is the number -1.	V	Conceptual symbol
The cell corresponding to this pair is placed in the reachability matrix with the number -1 and its symmetrical cell is the number 1.	A	
The cell corresponding to this pair is placed in the reachability matrix with the number 2 and its symmetrical cell is the number 2.	X	
The cell corresponding to this pair is placed in the reachability matrix with the number 0 and its symmetrical cell is the number 0.	O	

Table (9) - Determining the panel members' scores in the form of an initial matrix

H	G	F	E	D	C	B	A		Codes created
2	1	1	0	1	1	1	-	A	Strategic risks
1	0	1	1	0	0	-	-1	B	Industry-related risks
-1	0	2	1	1	-	0	-1	C	Internal environment risks
1	1	-1	1	-	-1	0	-1	D	Operational risks
0	1	0	-	-1	-1	-1	0	E	Technological and technical risks
0	1	-	0	1	2	-1	-1	F	Political and legal risks
0	-	-1	-1	-1	0	0	-1	G	Environmental risks
-	0	0	0	-1	1	-1	2	H	Economic risks

According to the above table, the conceptual symbols assigned based on the mode index have been converted to scores of 0 and 1 according to the definition of conceptual relationships to numbers according to the previous table. Again, indirect relationships should be specified as “*1” in order to form the final matrix. In other words, the reachability matrix is developed using the self-interaction structural matrix and this matrix is checked for its coherence. Coherence is a content relationship and a basic assumption in interpretive structural modeling. Coherence means that if variable “A” is related to variable “B” and variable “B” is also related to variable “C”, then variable “A” is also related to variable “C”. The final reachability matrix is obtained for the criteria by considering the coherence relationship to adapt the initial reachability matrix. For this purpose, the initial matrix must be raised to the power of k+1, so that the steady state is established " $M^k = M^{k+1}$ ". Thus, some zero elements will also be converted to 1, which is shown as "*1". After constructing the relationship matrix or initial reachability matrix, the final reachability matrix should be obtained using the following equation:

$$M = D + I$$

$$M^* = M^k = M^{k+1}, k > 1$$

In large and complex systems, it is assumed that each component is reachable by itself. Hence, all the principal diagonal elements of the final matrix of the system are always 1. For this purpose, the identity matrix "I" is added to the initial reachability matrix to obtain the final matrix. The properties of the final matrix are:

$$M^2 = M$$

For this purpose, the final matrix obtained is raised to the power until the above condition occurs, and the resulting matrix will be the final matrix. The number of 1s in the first row indicates the lines or effects that result from the first criterion. The number of 1s in the first column indicates the effects that are made on the first criterion. The component that affects all components of the system, and no component affects it, is called the source. As mentioned, the final reachability matrix is determined.

According to the results obtained in Table (10), which shows the final reachability matrix, in Table (11) the driving power (score 1 obtained from the row) and the dependence power (score 1 obtained from the column) are determined.

Table (10) - Determining panel member scores in the final access matrix format

H	G	F	E	D	C	B	A		Codes created
1	1	1	*1	1	1	1	1	A	Strategic risks
1	*1	1	1	*1	*1	1	*1	B	Industry-related risks
*1	*1	1	1	1	1	0	0	C	Internal environment risks
1	1	0	1	1	*1	0	*1	D	Operational risks
0	1	0	1	0	0	0	0	E	Technological and technical risks
*1	1	1	*1	1	1	0	0	F	Political and legal risks
0	1	0	0	0	0	0	0	G	Environmental risks
1	*1	*1	*1	*1	1	*1	1	H	Economic risks

Table (11) - Separation of forces of driving and dependence

Dependence power	Driving power	Abbreviation	Index
4	8	A	Strategic risks
3	8	B	Industry-related risks
6	6	C	Internal environment risks
6	6	D	Operational risks
7	2	E	Technological and technical risks
5	6	F	Political and legal risks
8	1	G	Environmental risks
6	8	H	Economic risks

The output set and input set for each criterion must be extracted from the received matrix to determine the relationships and leveling of the criteria in the interpretive structural model (ISM). The output set includes the criterion itself and the criteria that are affected by it. The input set includes the criterion itself and the criteria that affect it. Then the set of two-way relationships of the criteria is determined. The first row where the commonality of the two sets is equal to the reachable set (inputs), the first level of priority will be determined. In this section, the output set, input set, and common elements must first be identified in order to determine the relationships between the variables. The score for leveling and prioritizing variables, the reachability set, and the AnteceVen set are determined for each variable. The reachability set of each variable includes the variables that can be reached through this variable and the AnteceVen set includes the variables according to which this variable can be reached. Then, the commonalities of the reachability and AnteceVen sets of all factors are determined, and if they are the same, the reachability set with the common set of that factor(s) is considered as the priority level. Level refers to the designed layers of the final model. Previous levels must be removed from the matrix to obtain other levels, and the process is repeated. In other words, ranking criteria is done after determining the reachability set and the prior set for each of the criteria and determining the common set. The common set is obtained by taking the common set of two reachability and prior sets. Criteria whose common set is the same as their reachability set are assigned the first priority level. The levels of other criteria are also determined by eliminating these criteria and repeating this process for the other criteria.

At this stage, the research model is presented according to the levels of variables and the final access matrix. The factors are placed at different levels in this study, where the two components of environmental risks (G) and technological and technical risks (E) are placed at the highest level, and then political and legal risks (F), operational risks (D), internal environment risks (C) and economic risks (H) are placed at the next level, and after that strategic risks (A) are placed at the lowest level, and the most effective components are industry-related risks (B). It should be noted that factors at higher levels have less influence, and are

more influenced by factors at lower levels. In fact, lower-level factors are considered as the infrastructure and fundamental foundation of comprehensive risk management for investing in renewable energy.

The nodes and links of each research component are analyzed in the form of a MICMAC analysis chart according to the determination of the driving power and dependence power; therefore, the components are placed based on the driving power and dependence power by combining the symmetry of the components based on the 4 graphical dimensions of this analysis, the results of which are presented in Figure (2):

According to the results, in the first quadrant, i.e. autonomy, it was determined that no component was included (factors at this level are those that have a low position in terms of importance among the research components, because they do not play an influential role due to their low level of dependence and driving power). On the other hand, in the dependent quadrant, it was determined that there are two components of environmental risks (G) and technological and technical risks (E), which, although they have a lower influence than desired, have a strong dependence power; therefore, the two components of environmental risks (G) and technological and technical risks (E) are affected by the variables of the independent quadrant. It was found that the components of political and legal risks (F), operational risks (D), internal environment risks (C) and economic risks (H) are located in the linked quadrant, which has a higher influence than the dependent quadrant, and finally, it was found that in the independent quadrant, it was found that the components of strategic risks (A) and industry-related risks (B) are located, which have a very high influence in comprehensive risk management for investing in renewable energies, and the variable of industry-related risks (B) as the most influential component of comprehensive risk management for investing in renewable energies has a higher influence compared to other cases.

Chart (2) - Ranking of research components based on driving and dependency

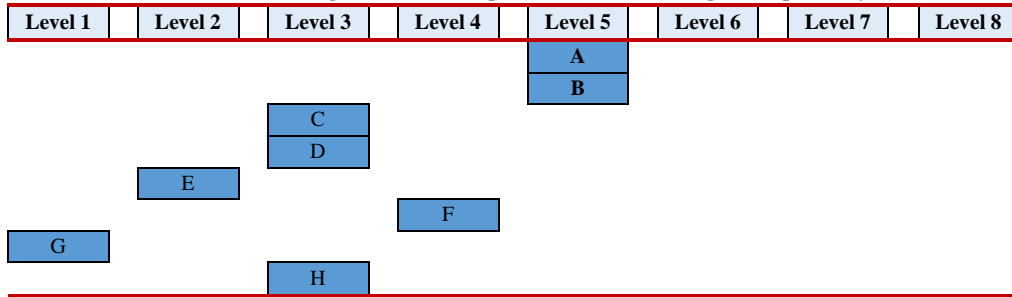


Chart (2) -(MICMAC) Ranking of research components based on the driving power and dependence power

Independent quarter				Linked quarter				
driving power		B	A			H		8
								7
					F	D C		6
								5
								4
								3
							E	2
								G
	1	2	3	4	5	6	7	8
Quarter of autonomy				Dependent quarter				
dependence power								

Discussion and Conclusion

Risk management in renewable energy investments, as a systematic and structured process, plays a vital role in reducing uncertainties and enhancing the financial and environmental returns of these projects. Renewable energies, including solar, wind, hydro, and biomass, despite their high potential to reduce greenhouse gas emissions and provide sustainable energy sources, face numerous challenges and risks, including technical risks (such as technology failures and uncertainty in system performance), financial risks (such as price fluctuations, high initial investment costs, and limited access to financial resources), political and legal risks (such as changes in government support policies and environmental regulations), market risks (such as competition with fossil fuels and demand fluctuations), and environmental risks (such as climate change and

ecological impacts). To manage these risks, various approaches are recommended, including quantitative and qualitative risk assessments, the use of financial instruments like insurance and derivatives, portfolio diversification, participation in public-private partnerships, and the application of advanced technologies for risk monitoring and prediction. Furthermore, establishing transparent and stable legal frameworks, strengthening international cooperation, and raising stakeholders' awareness of the risks and opportunities associated with renewable energy are key strategies for reducing risk and increasing investment attractiveness in this sector. Effective risk management not only contributes to the financial sustainability of renewable energy projects but also plays a significant role in accelerating the transition towards sustainable and low-carbon energy systems. Investing in renewable energy faces risks like any other investment, which need to be identified and

analyzed carefully to ensure a proper return on investment. This study was conducted with the aim of developing an interpretative and structured approach to comprehensive risk management for investing in renewable energy. Qualitative analysis was used in this research due to the argumentative support of the methodology and based on the type of data collection. The results of the present study indicated 2 global themes (structural risk management and institutional risk management), 8 organizing themes (strategic risks, industry-related risks, internal environment risks, operational risks, technological and technical risks, political and legal risks, environmental risks, and economic risks), and 33 basic themes. Next, Delphi analysis was used to explain it in the context of the comprehensive risk management process for investing in renewable energies with the aim of measuring the reliability of the identified organizing themes, and the results of the average evaluation of the first and second phases of Delphi showed that all dimensions are confirmed, and it was possible to measure it through interpretative and structured analysis in this way; therefore, an attempt was made to determine the most effective themes of the comprehensive risk management model for investing in renewable energies with the help of the fourth research question. In order to analyze the obtained result, it should be stated that, as specified in the model, risks related to industry (B) were considered as the most effective theme of the comprehensive risk management model for investing in renewable energies.

Identifying structural and institutional risks as overarching themes indicates that risk management in this domain cannot focus solely on one dimension but requires a comprehensive and multi-dimensional approach considering the complex interactions between various factors. This finding is logically justified, as renewable energy, being an emerging industry, is subject to rapid technological advancements, market volatility, and policy shifts. Therefore, risk management in this field must be capable of addressing these complexities. Ultimately, this research, by presenting a structured and evidence-based model, not only provides a deeper understanding of the challenges of risk management in renewable energy but also offers practical guidance for policymakers, investors, and managers in designing efficient and sustainable risk management strategies. These findings can serve as a foundation for future

research aimed at improving risk management models and developing innovative risk analysis methods in emerging industries.

In this study, in addition to reviewing the literature, experts in this field were also surveyed due to the different investment conditions in Iran (such as relevant laws and regulations, macroeconomic conditions, etc.) to identify the risks posed to Iran. Because, some of the risks raised in the literature may be of little importance in Iran or other risks in this area may be relevant to our country, which the results obtained from the interpretive structural technique also confirm. The risk management model enables investors to reduce the financial risks associated with investing in renewable energies, which includes managing the risks associated with changes in energy prices, exchange rates, and market fluctuations. Investors can avoid financial losses by carefully analyzing these risks and applying appropriate risk management strategies. Therefore, one should seek normative guiding principles; principles that indicate the appropriate direction of movement, and are based more on the accumulation of knowledge and the study of the experiences of other countries based on the country's domestic conditions; therefore, one should not expect to fully implement in Iran or any other country the policies that American or European governments have adopted (and have been effective in forming a successful risk-averse capital industry in these countries) and achieve a similar result, but rather, appropriate policies should be designed to promote risk-averse capital in the country, taking into account the experiences of other countries and the conceptual models presented, and with full awareness and understanding of the conditions of the Iranian innovation system. Unfortunately, the position of policy-making in this field is very new, unprofessional, and weak. For example, it is not yet clear which institution or ministry is responsible for policy-making on risk-averse capital and even policy-making in the field of technology in the country. Various components in the country's innovation system claim policymaking, and each pursues related matters in its own subordinate institutions separately, according to its power and support. It seems to be an inevitable necessity to create a kind of centrality in the policy-making of the innovation system (in general) and the policy-making of risk-averse investment (in particular). As long as such a centrality is not formed

in risk-averse investment, it will be very far from being possible to develop intelligent and targeted risk-averse investment in the country. The concept of comprehensive risk management of renewable energy investments is defined by a developed structure and a developed function. The developed structure of the industry can be created by the indicator of industry privatization, and this can be shown in the following way: the high volume of capital absorption in the industry, as well as the entry of large industrial holdings into this industry, has led to the complete transfer of state research and technology funds to the private sector, and even the government will have a timely exit from mature risk-taking investment institutions, which can demonstrate an aspect of the developed structure. Also, access to actors and a professional environment is another indicator of the developed structure, which can be created by the following: Creating appropriate geographical distribution, creating a common understanding regarding the development of this industry in the country, along with creating an appropriate structure for active institutions, planning and compiling a spatial map, appropriate establishment of new venture capital institutions, appropriate interaction and networking of industry players, employing experts and elites in the industry, training managers with professional qualifications specific to these institutions, etc., but the developed performance for this industry is manifested by developing its internal performance through a balance in the supply and demand of the industry, as well as defining an appropriate index for it, the successful exit of innovative enterprises that have benefited from the resources of this industry, for example, in the stock market, strengthening the financial power and empowerment of research and technology funds by the Innovation and Prosperity Fund, etc., and the development of external performance is manifested by the brilliance of this industry among the global indicators. Improving Iran's position in the global competitiveness index and the sub-index of financial development, global monitoring, ease of doing business, etc. are considered as one of the methods of achieving development in each sector by overcoming its challenges and bottlenecks. Of course, many of these challenges cannot be easily overcome by policymakers and activists, and require solving obstacles at the macro level of the country. We are facing many challenges

and weaknesses in economic and sometimes even political issues in the country, and some of them exist as systematic risks, and it is out of reach to plan for their improvement, but in some issues, we can move towards the development of this industry with planning and targeted management. Yüksel et al. (2024) conducted a comprehensive risk analysis and decision-making model for investing in hydroelectric energy and concluded that the most important risk is environmental risk with the highest weight value of 0.2478. The results of Zeng, F., & Wu, (2024) study showed that Chinese power companies investing in Brazil's renewable energy sector face the highest political risk, while other risks gradually decrease. Also, Kou et al. (2023) stated that there are risks such as legal, technological and financial issues in renewable energy investments. Hence, appropriate measures should be taken to minimize these risks. However, each of the measures that need to be taken to manage risks creates new costs for businesses. The results of this study are consistent with the findings of the studies of Yüksel et al. (2024), Zeng, F., & Wu (2024), Kou et al. (2023), Zeng, F., et al. (2024), Canabarro (2024), Cornwell et al. (2023) and Abba et al. (2022). These researchers also showed that political-legal risks, environmental risks, and technological risks are important dimensions of comprehensive risk management for investing in renewable energy in the markets. The following suggestions are made based on the research findings: The results of this research can be used by various stakeholders in this field. The identified risks will provide the necessary awareness to individuals who intend to invest in renewable energies, and will help them make better decisions. On the other hand, it will help policymakers to adopt appropriate support policies to encourage and persuade individuals to invest in renewable energies and to control investment risks in this field. In this way, the adverse effects of risks will be reduced, and the probability of investment success will increase. Prioritizing risks will also significantly contribute to the risk management process. Because analyzing all risks is time-consuming and will not be efficient in the risk management process. Therefore, industry-related risks with the greatest impact on the investment should be identified and prioritized.

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