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THE ASSESSMENTS OF FINANCIAL RISK BASED ON RENEWABLE ENERGY INDUSTRY

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ABSTRACT

The potential for renewable energy to spur economic and financial development has long been acknowledged. In particular, renewable energy policies throughout the globe have helped to significantly expand the use of renewable energy sources in the last decade. The subject of Renewable Energy concerns both experts and the general public with increasing interest. Renewable energy technology adoption, especially in poor nations, has received less focus on financial risk management, despite its centrality to mainstream energy and infrastructure projects. The renewable energy industry is pivotal in the global shift towards sustainable energy solutions, yet it faces significant financial risks that can impact its long-term viability. This paper provides an in-depth assessment of these risks, focusing on factors such as price volatility, technological advancements, regulatory changes, and market dynamics. The study's overarching goal is to provide light on the renewable energy sector's financial difficulties by dissecting these factors. Additionally, the paper explores risk mitigation strategies, including diversified investment portfolios, government policies, and technological innovations, to enhance financial stability and encourage continued growth in renewable energy adoption. The results highlight the need for preventative risk management to safeguard investments in renewable energy.

Keywords: Renewable Energy, Financial Risk, Types Of Risk, Project Cost, RE Matrix On Finance.

I. INTRODUCTION

The last ten years have seen a meteoric rise in the use of renewable power. There is a constant search for new and creative methods for countries with more money to put into renewable energy, regardless of their economic status. Renewable energy production is critical for mitigating climate change and achieving energy diversification [1]. Researchers in the field of energy and the environment have recently come to the conclusion that harnessing and using renewable energy sources is an additional viable option for mitigating environmental contamination and the possibility of an energy crisis[2][3]. In addition to having a theoretical endless supply, renewable energy can theoretically provide sustainable power for social operations. When compared to traditional fossil energy, renewable energy significantly lowers carbon emissions, which could effectively mitigate the greenhouse effect and improve environmental quality[4][5]. The cost of using renewable energy will really drop dramatically with the advancement of associated technology; also, due to geographical constraints, conventional fossil fuel sources are unevenly spread around the globe, with the majority being concentrated in a few number of nations. This causes a significant variation in the global energy price as well as a possible danger to the energy supply[6][7].

The renewable energy industry, while offering significant environmental benefits and contributing to global sustainability goals, faces various financial risks that can impact its growth and profitability. These risks include market volatility, fluctuating energy prices, regulatory changes, and technological advancements that can either enhance or disrupt existing business models[8]. Additionally, the industry's reliance on government subsidies and incentives makes it vulnerable to policy shifts, which can alter investment dynamics. Financial risk assessment in this sector is crucial for investors, policymakers, and industry stakeholders to navigate uncertainties, optimize investment strategies, and ensure the long-term viability of renewable energy projects[9][10].

Motivation and contribution of this paper

The objective of this manuscript is to evaluate and examine the several financial hazards linked to the renewable energy sector, including market, credit, operational, liquidity, and political concerns. The motivation behind this study is driven by the increasing global shift towards renewable energy as a critical component of sustainable development and the challenges that accompany this transition. Understanding and managing these financial risks is essential for attracting investment, ensuring the long-term viability of renewable energy projects, and supporting the industry's growth in a volatile and evolving market landscape. This paper contributes as follow:

- The paper develops a comprehensive framework that categorizes and assesses various financial risks specific to the renewable energy industry, providing a structured approach for stakeholders to evaluate these risks.
- It introduces advanced quantitative models to measure the financial risks in renewable energy projects, offering empirical insights that can help investors and policymakers make informed decisions.
- The study analyzes the influence of government policies and regulations on financial risks, highlighting how changes in the regulatory landscape can affect the financial stability of renewable energy investments.
- The paper proposes effective risk mitigation strategies tailored to the renewable energy sector, including financial instruments, insurance options, and diversification approaches, to help stakeholders manage and reduce financial exposure.
- By including case studies of existing renewable energy projects, the paper demonstrates the practical application of the proposed risk assessment framework and strategies, providing valuable lessons for future projects in the industry.

Organization of the paper

The following paper organized as: Section II and III provide Renewable Energy Consumption and Risks with their types, Then Section IV and V discussed the role of Financial Risk Management Based on Renewable Energy and policies, After this Section VI evaluate the RE project cost analysis, next Section VII provide the methodologies as case studies for assessing financial risk with RE. At last Section VIII the related work on this topic with summary. And finally, provide paper conclusion with limitations and future work in Section IX.

II. RENEWABLE ENERGY CONSUMPTION AND RISKS

RE has lately acquired popularity and is making an ever-greater influence on the world's energy sector; its quick adoption is crucial to attaining the sustainable development goals (SDGs). The generation, transmission, and use of energy inside a country are all governed by state-level energy policy. The objective of these laws is to provide a steady supply of power and enhance energy security by encouraging the use of economical and environmentally friendly energy sources. The energy strategy of a nation or area may be significantly influenced by factors such as its economic situation, energy resources, environmental concerns, political aspirations, and the desire to promote substantial investments in renewable energy. Investment climbed by a factor of three between 2000 and 2009, which was mainly driven by projections that the share of global power produced from renewable sources would reach 28% in 2022, up from 19% in 1990. To keep up with regulatory practices and the push for affordable, clean energy on a local, national, and international scale, energy policies must undergo continuous, periodic updates over time to reflect changes in society and technology as well as the emergence of new opportunities and threats. The renewable energy (RE) industry has been growing rapidly due to new energy policies and improvements in energy efficiency. This is all because there is an immediate need to combat climate change and meet sustainable development goals[11], with most nations planning to transition to RE solely between 2030 and 2050[12].Countries can help fight climate change by supporting RE targets and actively transitioning to full RE. The usage of RE and the hazards connected with it are displayed in Figure 1.

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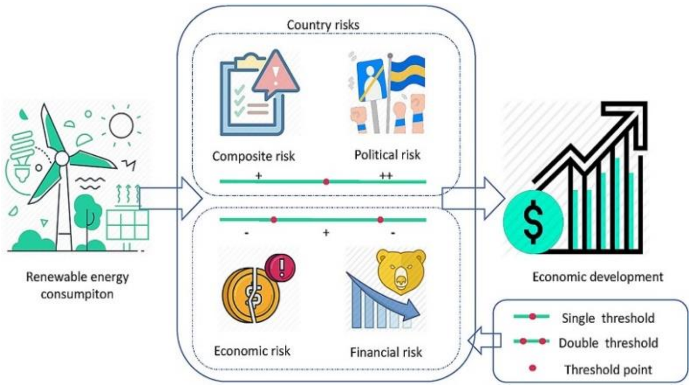

Figure 1. Renewable energy consumption and risks

Alternative energy sources, sometimes known as renewables, are less harmful to the environment than conventional power plants. When every nation is formulating its long-term energy strategy, the renewable energy sector is essential. Funds allocated to renewable energy projects are mostly used for infrastructure development and upkeep, rather than for expensive energy imports. Here, renewable energy offers cutting-edge, cost-effective insurance and risk management solutions for the renewable energy sector, which is helping to tackle the problems that this highly competitive business is facing. Also, experts in risk assessment and insurance broking are in high demand due to a rapid evolution of renewable energy technologies. The renewable energy sector, on the other hand, is attracting more interest than ever before as governments throughout the globe set ambitious targets for the share of renewable energy in total energy production.

III. TYPES OF RISK IN RENEWABLE ENERGY

Market, financial, liquidity, operational, and political risk are the primary types of threat to renewable energy projects and marketplaces. Table 1 provides a summary of the primary causes of each risk category [13].

Table 1. Type of Risk in Finance

Risk Type	Sources of risk
Credit Risk	• Default of renewable energy projects. • Non-performance of renewable energy projects
Market Risk	• Low-capacity factor • Low connection rate • Low dispatch priority
Operational Risk	• Discontinuous electricity output • Volatile electricity output • Outdated operating paradigm of grid
Liquidity Risk	• Non-existence of secondary market • Long payback period
Political Risk	• Unstable renewable energy policy

1) Credit risk

A borrower's potential inability to make timely payments of principle and interest is known as credit risk. It is possible for developers to miss payment deadlines if their renewable energy projects go into default or fail to meet expectations [14].

2) Market risk

Market risk is the possibility of suffering monetary losses as a result of fluctuations in the market. A capacity factor measures how well an organisation performs relative to its potential over time. Compared to traditional energy sources, renewable energy sources might have lower capacity factors due to their intermittent nature and idle capacity [15].

3) Operational Risk

Operational risk, in general, refers to the dangers associated with human, technological, and internal process failures. Concerns related to operations include staff, tools, commissioning, testing, and upkeep. Operational risk has a significant potential to harm society and cause financial loss, as history has shown. Operational risks may also be reduced with the use of a standard, thorough operation risk management approach [16]:

- Assesses and measures potential dangers to operations
- Use suitable risk management frameworks and tools to monitor operational risks.
- Determine the likely sources of both anticipated and unforeseen loss occurrences
- The operational risks should be examined for patterns, correlations, and trends.
- Determine the effect on investment and revenue as well as the possible losses caused by operational risk.

4) Funding liquidity risk

Both finance and asset liquidity risk are significant concerns in the renewable energy industry's growth and market. The capacity of a company to get funds and other forms of capital in order to pay its bills is known as funding liquidity risk, while the ability of a company to sell or otherwise realise its assets on the current market at their fair value is known as asset liquidity risk. Investing in renewable energy often requires a lengthy time frame [17][18].

IV. ROLE OF FINANCIAL RISK MANAGEMENT BASED ON RENEWABLE ENERGY

Lenders and investors are understandably wary of projects with a history of unanticipated negative cash flow changes. One of the most basic requirements for securing funding is reducing the likelihood of events that might have a negative financial effect on the project via risk management. The purpose of this research is to identify various financial risk instruments that may assist in shifting some risks from project backers and lenders to underwriters and managers with more expertise in this area. Various approaches to risk management are now under investigation, including alternative risk transfer, credit improvement products, contingent capital, insurance/reinsurance, risk finance, and a host of others. Consequently, commercial lenders seldom even consider big agreements in potentially problematic countries, much less small-scale RE initiatives[19]. The different types of funding and their respective benefits in the context of RE projects are considered in Table 2.

Table 2. Forms of finance with relative merits in the context of RE[20]

Type of finance	Description	Merits in RE context
Private Finance	Private funding via individual savings accounts or secured bank loans.	Frequently become the only source of funding for modest-scale activities.
Grants	A common purpose of public sector grants is to assist project developers in spreading the expense of preliminary development.	Vital to the commercialisation of certain RETs, including wind, wave, and tidal.
Risk Capital	Investors like private equity firms, venture capitalists, and strategic investors (such equipment makers) provide risk money in the form of equity.	Risk capital is often the only source of funding for real estate developments, apart from the developer's own equity and other forms of private financing.
Mezzanine Finance	Many different types of structures make up mezzanine financing, ranging from high-risk, high-reward equity positions to low-risk, fixed-return loan positions.	Public and private financing opportunities are good. The developing world is now focussing on a variety of RE mezzanine funds.
Corporate Finance	Financial institutions lend money to established businesses via corporate finance, with the promise of future profits secured by "on-balance sheet" assets. A corporate sponsor must be willing to fully embrace the risks and possible rewards of a project.	Reserved mostly for established businesses with solid financing capacity, internal cash flows, and asset bases. Development potential is provided by structured financing in partnership with the public sector. Examples are

		provided by IFC deals.
Project Finance	Project finance refers to the practice of banks' lending money to separate, purpose-built businesses with the assurance that they would make a profit thanks to credit-worthy off-take agreements. Power Purchase Agreements (PPAs) are the usual framework for such initiatives including renewable energy sources.	Non-recourse financing is made possible for suitable tenors by long-term off-take agreements. PPAs often provide steep discounts, which lowers the value for developers. Lenders' desire for such non-recourse financing is sometimes diminished when regulatory risk is disregarded. The scope of off-grid RE initiatives is limited.
Participation Finance	Project financing and participation finance are conceptually similar; however, with participation finance, a cooperative wind fund or other group of investors acts as the "lender" and often receives financial and tax advantages.	Potentially ready to provide primary funding, which eliminates the need for long-term PPAs, especially in situations where risks may be hedged and handled proactively.
Risk Finance/Insurance Structures	Risk Finance/Insurance In order to "smooth" income flows and have commercial insurers or other parties effectively underwrite risk exposures, structures are employed to control or transfer certain risks.	Promising potential for creating innovative financing strategies for RE in nations with active insurance markets.
Consumer Finance	Consumer financing is often necessary for rural consumers in order to make contemporary energy services affordable. The portfolio cannot be considered an asset or used as collateral for funding until the client's creditworthiness has been shown.	The solar home system market, for instance, is now seeing the implementation of many microcredit programs, many of which include risk-sharing at the institutional and local levels.
Third-party Finance	Third-party financing, in which a separate entity provides funding for a number of different energy systems. This encompasses a wide range of consumer financing options, including hire-purchase, fee-for-service, and leasing plans.	There may be tax advantages to asset backed financing in addition to the flexibility it provides over more conventional project financing models.

V. FINANCIAL RISK IN RENEWABLE ENERGY POLICY

The danger of an investment losing value due to changes in government policies or the structure of institutions is known as political risk. Political risk may be broadly classified into two types: those at the macro and local levels. One kind of project-specific risk is policy risk, which is a subset of micro-level political risk. Potential investment losses in a nation as a result of policy shifts towards renewable energy sources is known as renewable energy policy financial risk. There are two ways to categorise the risks associated with renewable energy policies: prospective and retroactive. The regulatory framework's general volatility and unpredictability provide a danger to new project planning, known as prospective policy risk, and to the financial soundness of ongoing projects, known as retroactive policy risk. Because they undermine the developers', financiers', and investors' assumptions and predictions, retroactive alterations pose a greater threat to policy than the other kind of risk [21]. RE policy risk affects the three main players in a renewable energy project in various ways at different points in time. From the vantage points of developers, financiers, and investors, Figure 3 depicts a typical timetable of a RE project.

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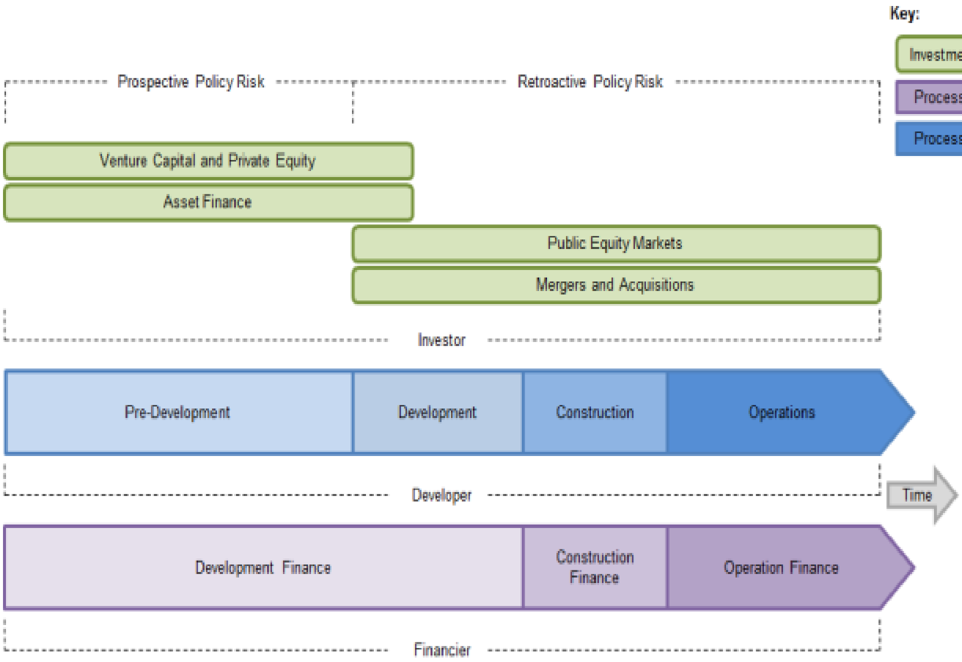

Figure 2. A typical renewable energy project timeline for developer, financier and investor[13]

1) Developer Perspective

Developers evaluate market conditions that could impact the building and operation of renewable energy projects. Developers make the most progress after analyzing the project.

- Renewable energy projects begin with a thorough examination of the planning, building, and operating environments by developers who take into account potential market factors. In order to capitalise on prospects, they zero down on a certain set of renewable resources or technology. The next step is for developers to evaluate each project and advance only the most promising ones to the next round. Major obstacles that hinder the project's execution are often identified at this phase via technical and financial research. When evaluating a renewable energy project, developers use their own risk tolerance and expert judgement to do a customised pro forma study. Less time and money are required to implement RE policies, decreasing the associated risk.
- During the second phase, the developer must devote a much larger amount of time and expense. This is due to the fact that at this stage, all project paperwork must be ready for project finance and completion. To assess the potential dangers of the renewable energy project, decision-makers could use a framework for project development known as SROPTTC. Due to the large amounts of time and money needed, renewable energy strategy carries the greatest risk.
- Phase three involves developers beginning the building process. Developers' compliance with contract obligations regarding service delivery and renewable energy project operation is of paramount importance. This is a period of significant policy risk. The project's assumptions and estimates are susceptible to changes in renewable energy legislation, and it is difficult to reverse the initiative. But the production of assets has reduced many of the dangers.
- In the last stage, the focus moves from building to operating. A new renewable energy plant is now up and running. According to the developers, they have created a renewable energy project that can meet all of the contract's operational criteria. Once the contract is in place, the onus for operating and maintaining the renewable energy plant shifts to the developers. There will be less of an impact from changing policies as the project nears the conclusion of its planned horizon. Consequently, the policy risk is reduced over time.

2) Financier's Perspective

Development finance, building finance, and operation finance are the three main areas from the financier's point of view.

- In the first phase, it stands for the most speculative stage. Investors run the danger of losing all their money if a transaction falls through. Debt is typically unavailable at this era because to the high level of speculation.

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Developers and other equity investors provide the bulk of the funding for development financing. The same holds true for renewable energy policy: investors run the danger of seeing their whole investment evaporate if lawmakers adopt changes that make it harder to close the transaction. Therefore, this is the most precarious time for renewable energy policy.

- In the second phase, it stands for the whole investment required to launch a renewable energy initiative. Equity and loan funding are often extended throughout the building phase due to the fact that a lot of the risks have been reduced via the production of assets. The backup of assets reduces the high policy risk, but it is still there.
- In the final stage, it represents the operational funding of a renewable energy project. The once-fragile project is now a solid asset, shielded from the ups and downs of development and building. Policy risk and the impact of policy changes diminish with time.

3) Investments throughout the process

Investments go into one of four broad types as shown in figure 3: venture capital, private equity, asset financing, public stock markets, or mergers and acquisitions[22]. Renewable energy investment in its early stages is facilitated by venture finance and private equity. The approach for the investments is illiquid and aimed at the long term. The primary distinction between private equity and venture capital is that the former mostly backs established businesses while the latter backs new ventures. As a result, venture capital often carries a greater level of risk and a projected higher return compared to private equity. Standard industry valuation methods, net asset value, discounted cash flows, discounted earnings, and earnings multiple are among the most common ways to estimate a company's value[23].

VI. RENEWABLE ENERGY PROJECT COST ANALYSIS

Renewable energy's power prices have dropped dramatically over the last decade, thanks to a confluence of factors including technological advancements, economies of scale, more competitive supply chains, and more developer expertise. Technology for producing electricity from renewable sources has therefore emerged as the most cost-effective means of adding capacity in almost every region of the globe. Deployment is starting to catch up with this new reality; in 2019, renewables made over 72% of all global new capacity additions. From 2010 to 2019, the worldwide weighted-average levelized cost of electricity (LCOE) for utility-scale solar PV dropped by 82%, according to the most current cost statistics from the IRENA. The LCOE fell by 47% for concentrated solar power (CSP), 39% for onshore wind, and 29% for offshore wind, as shown in Table 2.

Table 3. Total cost, Capacity factor and LCOE

	Total installed costs			Capacity factor			Levelised cost of electricity		
	(2020 USD/kW)			(%)			(2020 USD/kWh)		
	2010	2020	Percent change	2010	2020	Percent change	2010	2020	Percent change
Bioenergy	2 619	2 543	-3%	72	70	-2%	0.076	0.076	0%
Geothermal	2 620	4 468	71%	87	83	-5%	0.049	0.071	45%
Hydropower	1 269	1 870	47%	44	46	4%	0.038	0.044	18%
Solar PV	4 731	883	-81%	14	16	17%	0.381	0.057	-85%
CSP	9 095	4 581	-50%	30	42	40%	0.340	0.108	-68%
Onshore wind	1 971	1 355	-31%	27	36	31%	0.089	0.039	-56%
Offshore wind	4 706	3 185	-32%	38	40	6%	0.162	0.084	-48%

Renewable energy technology performance and cost data has been collected and reported by the cost analysis set over the previous many decades. For the future of renewable energy mix development, current, trustworthy cost and performance data is of the utmost significance. Table 4 shows how the installation costs of various energy sources are rapidly declining, which directly contributes to the threefold increase in investment in this industry. The corresponding cost savings imply that information from merely a year or two ago may be very inaccurate. In fact, data as old as six months may greatly inflate prices in some markets when it comes to solar PV.

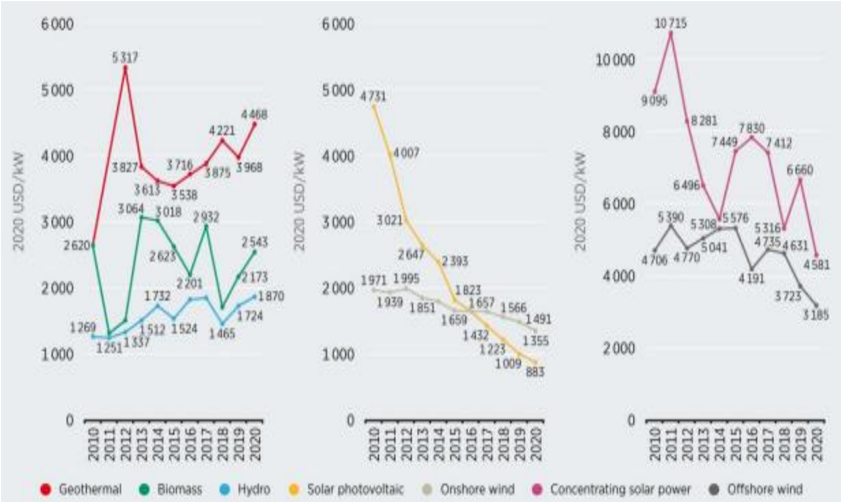

Figure 3. Analysis of cost for different renewable energy

The figure 4 compares renewable energy sources' global LCOE from 2010 to 2020. Three graphs show the data: Variable LCOE trends for geothermal, biomass, and hydro power sources. The price of geothermal energy peaked at $5,317 per megawatt-hour (MWh) in 2011 and subsequently stabilized about $4,000 by 2020. Most biomass and hydro trends are constant, reaching $1,700/MWh and $1,500/MWh, respectively. The center graph shows solar photovoltaic (PV) technology's much lower levelized cost of electricity (LCOE) from $4,731 per megawatt-hour (MWh) in 2010 to $883 in 2020. Onshore, offshore, and concentrated solar power LCOE trends are shown in the right graph. Onshore wind power costs go down from $1,981 per MWh in 2010 to $1,355 in 2020. Offshore wind prices fluctuated throughout 2020, settling at $3,185 per MWh. In 2011, concentrating solar power costs $10,715 per megawatt-hour, then drops to $4,651 by 2020.

VII. METHODOLOGIES FOR ASSESSING FINANCIAL RISK

Assessing financial risk in renewable energy involves a combination of quantitative and qualitative methods. While scenario analysis and expert judgement are qualitative techniques that provide light on the effects of various risk variables, quantitative techniques like Value at Risk (VAR) and Monte Carlo simulations give numerical estimates of possible losses.

Quantitative Methods

Quantitative research approaches measure data for statistical, mathematical, or computational analysis. Economics, finance, psychology, sociology, and many natural sciences use these methodologies.

Monte-Carlo Simulation Approach

Monte Carlo simulation appeared around 1944. This approach has evolved and developed through different interpretations and definitions. The method's initial challenge was generating huge random numbers. First, pseudo-random numbers were utilized, but computer technology removed this hurdle. Paul F. Dienemann authored a fascinating book on the Monte Carlo method for investment project selection in 1966 for the U.S. military called Cost Estimating Uncertainty Using Monte Carlo Techniques. The book was published by the RAND Corporation. This study discussed cost-based project selection. The author stressed that stochastic variables like average, standard deviation, asymmetry, and others are needed to make the best project selection decision. The method's low computational cost in relation to the severity of the problems makes it useful for addressing many of them with little computer work. In the Monte Carlo method, synthetic probabilistic variable values are generated using a uniformly distributed random number generator on the interval [0, 1] and the cumulative distribution function. Decision adaptation, control, and pricing policy are just a few examples of the many processes that might benefit from economic decision simulation. Decision optimisation is different from simulation. Interactive algorithms and well specified procedures are essential for problem-solving in simulation. In most cases, variables created by random number generators serve as the input data. Five interactive steps demonstrate the algorithm.

- **Step 1:** Creating a parametric model, y = f (x1, x2, ..., xq);
- **Step 2:** Generation of random input set of data, xi1, xi2, ..., xiq;

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- **Step 3:** Effective calculations and memorizing results as yi;
- **Step 4:** Repeating steps 2 and 3 for i = 1 ton (n⍰ 5000);
- **Step 5:** Examining outcomes via the use of various statistical indicators derived from the simulation, such as confidence intervals, histograms, etc.

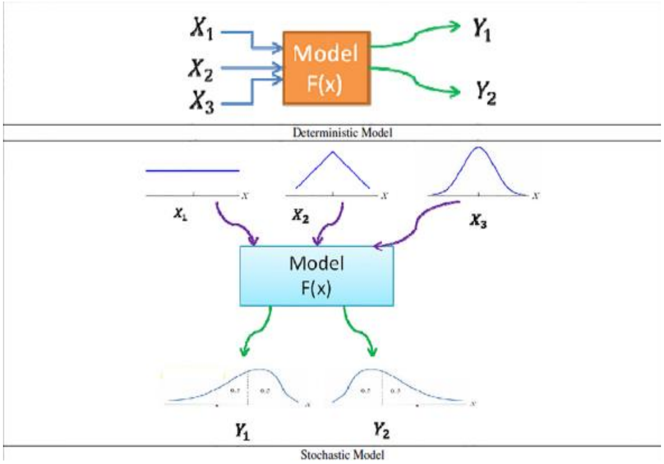

Figure 4. Deterministic and stochastic models

The figure 5 shows the main difference between stochastic and deterministic models[24]. Variables that are fed into the parametric deterministic model are reported as outcome variables. A key tenet of the stochastic model of uncertainty propagation is the assumption of normally distributed random variables for both inputs and outputs. The fundamental idea behind Monte Carlo simulation is that.

Value at Risk (VAR)

The VAR of a financial asset or portfolio is the most that might fall in value over a given time frame with a certain level of certainty. The desired outcome is to demonstrate the possible loss in the face of certain severe circumstances. The very unlikely loss variable's quantile is VAR. Therefore, the possibility of the loss exceeding this amount is quite remote. Furthermore, practitioners may evaluate the correctness of the underlying loss model by back testing this metric, due to the statistical character of VAR. Here is the precise definition of VAR:

$$\mathbf{P(L > VaR) \leq 1 - c} \ldots\ldots (1)$$

"P" is the possibility that the real decline in asset value will exceed the worst-case scenario, "L" is the monetary worth of an investment that is expected to decline during a certain period of time, and "c" is the degree of certainty according to equation (1). If the loss does not exceed the VAR value in a subsequent holding period, then c is the likelihood, as shown in Equation (1). VAR's definition emphasizes holding period and confidence level. In addition, the VAR model includes asset price distribution features. varied probability distribution models give financial assets varied VAR values. The VAR approach uses financial asset historical data to predict the future using a probability distribution. Estimating the volatility of financial assets is crucial to the VAR value calculation, which analyses historical data to predict the probability distribution of return or value of financial assets.

Qualitative Methods

Qualitative methods study phenomena using non-numerical data including words, behaviors, and images. The social sciences, humanities, and fields that need understanding context, experiences, and meanings use these methodologies.

Scenario Analysis

Conducting a scenario analysis allows one to examine the potential effects of future events on the system's performance by considering a number of various outcomes, or scenarios. This allows one to propose several courses for future growth, each with its own unique set of consequences. In a scenario analysis, the expected value of a performance indicator is forecasted in an uncertain setting by taking into account a time frame, a number of events, and the corresponding changes in the values of system parameters. Scenario analysis may be used to theoretical best-case (optimistic) or worst-case (pessimistic) scenarios in order to study changes in system performance and forecast how the system would behave in the event of an unexpected occurrence.

When developing a strategy plan based on the findings of a scenario analysis, it is important to take into account both the likelihood of an event occurring and its potential effects[25].

Expert Judgement

It is a qualitative method used in decision-making, risk assessment, and problem-solving. It entails extracting insights, assessments, or forecasts from the knowledge and experience of subject matter experts. This approach is frequently employed in situations where there is a dearth of empirical data, the data is intricate or ambiguous, and expert opinions can provide crucial context or bridge gaps in knowledge. Experts are chosen for their extensive knowledge in specialized fields, and their evaluations are vital in guiding decisions in areas such as project management, risk analysis, and strategy development. While expert assessment might be valuable, it is inevitably subjective and vulnerable to individual biases. To enhance reliability, it is customary to solicit feedback from diverse specialists and utilize techniques like the Delphi method to collect and refine their perspectives.

VIII. LITERATURE REVIEW

Despite numerous studies conducted to explore the challenges and potential of expanding renewable energy in finance risk sector.

In, Karamoozian et al., (2022), explores renewable energy and sustainability are related to risk assessments. The goal here is to raise consciousness among the business sector. Sustainable financial management, Islamic financing, green financing, and financial risk management are some of the financial facets that get the most attention in the research. The article includes three case studies that deal with renewable energy source decision-making and risk management[26].

In, Adaiem, (2022) performed a panel data analysis using the least-squares approach on financial ratios derived from 2017–2021 company financial statements. The financial statements of the corporations, Yahoo Finance, and the Wall Street Journal Market database were the sources of the data. For the purpose of analysing the financial structure, the model contained financing ratios and financial costs coverage ratios. Organisational financial risk was evaluated using a model that included total assets, financial leverage, and financial risk ratio. According to the results, financial risk ratio, capital structure, financing costs, and loan repayment capabilities were the criteria that determined whether alternative energy businesses were successful[27].

In Delapedra-Silva et al., (2022), RES project financial evaluations include a wide variety of approaches. It is critical to comprehend if and how these strategies have evolved, as well as what factors may have prompted fresh ideas. A thorough literature review and discussion of financial assessment of RES projects from 2011–2020 are included in this paper. Usual criteria including net present value, internal rate of return, payback period, levelized cost of energy, return on investment technique, and real alternatives analysis were used to assess RES projects. The research shows that most RES projects still use traditional financial assessment approaches[28].

In Apak, Atay and Tuncer, (2011), to research the renewable energy industry's increasing financial risk management tools in Turkey and the European Union. In this light, renewable energy offers a renewable energy risk management and insurance program that is both creative and cost-effective, which is assisting this highly competitive sector in meeting its problems.Experts in risk assessment and insurance broking are in high demand due to the rapid evolution of renewable energy technologies. The renewable energy industry, however, is receiving unprecedented attention as governments worldwide set ambitious goals for the proportion of energy to be generated from renewable sources[29].

In Lee and Zhong, (2015), presents a hybrid bond for energy projects that use renewable sources. Energy projects that use renewable sources are part of the hybrid bond set. It handles the risks associated with investments in renewable energy and funds the initial capital expenses. Critical risks related to the market, credit, liquidity, operations, and politics are recognised and managed. Hybrid bonds may manage big risks and fund a considerable amount of renewable energy projects' initial capital expenditures, according to the suggested structure[30].

In Xiao et al., (2021), presents the several physical and financial tools that are used to mitigate hazards associated with power generation, such as energy conversion devices, forward contracts, demand response programs, and FTR. Power market price risk management tools including virtual bidding, forward contracts, and electricity derivatives are also covered. Stochastic optimisation, robust optimisation, and optimisation based on information gap decision theory (IGDT) are three often used risk-aware optimisation methods that are then shown in detail. The summary concludes with the findings and suggestions for further study on the subject[31].

The related works collectively explore the intersection of financial risk management and the renewable energy sector, emphasizing the importance of sustainable financial practices and innovative risk management tools. The studies highlight various methodologies and approaches for evaluating financial risks and the performance of renewable energy companies, including panel data analysis, traditional financial metrics, and the introduction of hybrid bonds. These works also discuss the evolving financial instruments and optimization techniques used to manage price and production risks in power markets, as well as the need for specialized risk advice and insurance services to support the rapidly changing renewable energy landscape. The results highlight the importance of financial risk management in making sure renewable energy projects can withstand changes in regulations and stay competitive with new technologies.

Table 3 provides an overview of the key aspects of each study, including their methodologies, achievements, limitations, and areas for future research.

Table 4. Summary of related work

Ref.	Methods	Achievements	Drawbacks	Future Enhancements
[26]	Case studies, literature review	Raised awareness of risk assessments in renewable energy; highlighted sustainable financial management and green financing.	Focuses mainly on financial facets, which might not cover all operational risks.	Expand to include operational and environmental risks; incorporate more case studies from diverse regions.
[27]	Panel data analysis using least-squares approach; financial ratios from company statements	Identified key financial ratios influencing success of alternative energy businesses; assessed impact of financial structure and risk ratios.	Limited to data from financial statements and may not fully capture dynamic market conditions.	Incorporate real-time data and dynamic market factors; explore additional financial metrics.
[28]	Literature review; quantitative analysis of financial assessment methods	Reviewed various financial assessment methods for RES projects; identified predominant use of traditional approaches.	Traditional methods may not fully reflect modern market dynamics.	Investigate emerging financial assessment methods; consider integrating technological advancements.
[29]	Research on financial risk management tools; case studies	Highlighted innovative risk management and insurance programs; addressed sector-specific challenges.	Focus on Turkey and the EU may limit applicability to other regions.	Broaden research to include other regions; explore new risk management tools and strategies.
[30]	Hybrid bond structure for energy projects; risk management	Proposed a hybrid bond structure to manage risks and fund initial capital expenditures for renewable projects.	May not address all types of risks (e.g., long-term operational risks).	Develop more comprehensive bond structures; explore integration with other financial instruments.
[31]	Review of risk management tools; stochastic and robust	Provided a summary of physical and financial tools; detailed	May not cover all practical applications of the tools; limited	Include more practical case studies; explore advancements in

	optimisation methods	optimisation methods for risk management.	case studies.	optimisation techniques.

IX. CONCLUSION

Disruptive innovations in energy have arisen in the form of alternative energy models in the last few years. In conclusion, the financial risks associated with the renewable energy industry are complex and multifaceted, requiring a strategic approach to ensure sustainable growth. This paper has highlighted key risk factors, including price volatility, regulatory changes, and technological uncertainties, which can significantly influence investment outcomes. Effective risk management strategies, such as diversification, robust policy frameworks, and continuous innovation, are essential to mitigate these challenges. By addressing these risks, stakeholders in the renewable energy sector can better navigate the uncertainties and capitalize on the opportunities presented by the global shift towards sustainable energy. Ultimately, the successful management of financial risks will be crucial in achieving long-term energy security and environmental sustainability.

This paper primarily focuses on the financial risks within the renewable energy industry, with an emphasis on market dynamics, regulatory changes, and technological uncertainties. However, the analysis is limited by the availability of historical data and the rapidly evolving nature of the industry, which may lead to gaps in forecasting long-term risks. Additionally, the study does not extensively explore the regional variations in financial risks, which could offer more localized insights. Future work should aim to incorporate real-time data analytics and machine learning models to predict financial risks more accurately. Expanding the scope to include regional analyses and examining the impact of emerging technologies, such as energy storage and smart grids, will also be essential in providing a more comprehensive understanding of the financial landscape in the renewable energy sector.

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