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Decision-Making Under Uncertainty: Lessons from Renewable Energy Sector Professionals

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A B S T R A C T

This study aims to explore the decision-making processes of professionals in the renewable energy sector under conditions of uncertainty. Through semi-structured interviews, the research investigates the types of uncertainties encountered, decision-making frameworks utilized, risk management strategies employed, external influences considered, and insights gained from both successful and failed projects. Twenty professionals from diverse roles within the renewable energy sector participated in semi-structured interviews. The interviews were conducted to gather qualitative data on participants' experiences, perspectives, and strategies related to decision-making under uncertainty. Theoretical saturation was achieved through iterative data analysis using NVivo software, focusing on identifying recurring themes and patterns in participants' responses. The study identified five main themes: types of uncertainties (policy, market, technological, environmental, financial), decision-making frameworks (risk assessment, scenario planning, stakeholder consultation, cost-benefit analysis, strategic planning, adaptive management), risk management strategies (diversification, insurance, hedging, collaboration, redundancy), external influences (policy and regulations, economic conditions, technological advances, social and cultural factors, environmental considerations), and success and failure stories. These findings highlight the complexity of decision-making in the renewable energy sector and underscore the importance of adaptive strategies and stakeholder engagement. Professionals in the renewable energy sector face multifaceted uncertainties that require robust decision-making frameworks and proactive risk management strategies. By understanding and effectively navigating these uncertainties, practitioners can enhance project outcomes and contribute to sustainable energy transitions. The study emphasizes the need for continuous adaptation, innovation, and strategic planning to address evolving challenges in the renewable energy landscape.

Keywords: *Renewable energy, decision-making, uncertainty, risk management.*

1. Introduction

Renewable energy sources, such as solar, wind, and biomass, offer substantial benefits, including energy security, economic development, and job creation, alongside environmental sustainability (Dajah & Alshora, 2022; Halhoul Merabet, 2021; Ibrahim et al., 2021; Kratschmann & Dütschke, 2021; Lin, 2023; Mohylevska et al., 2023; Pourdarbani, 2020). The urgency to transition to renewable energy is further driven by global climate commitments like the Paris Agreement, which aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels (Li et al., 2018; Liargovas & Apostolopoulos, 2016). However, the path to achieving these benefits is riddled with uncertainties that professionals in the sector must navigate.

Uncertainties in the renewable energy sector can be broadly categorized into policy, market, technological, environmental, and financial uncertainties. Policy uncertainty, involving regulatory changes and inconsistent regulations, significantly impacts project planning and execution. Assereto and Byrne (2020) highlight how fluctuating policies deter investment in solar photovoltaic projects, emphasizing the need for stable and consistent policy frameworks to encourage long-term investment (Assereto & Byrne, 2020). Market uncertainties include price volatility and shifting demand dynamics, as Rehman (2023) discusses the effects of global uncertainties and market interconnectedness on renewable energy indices (Rehman, 2023). Technological uncertainties encompass advancements and integration issues, with Jasiński et al. (2023) noting the challenges in ensuring the reliability and compatibility of new technologies. Environmental uncertainties, such as weather variability and natural disasters, are significant concerns (Jasiński et al., 2023), as highlighted by Ezbakhe and Foguet (2021). Financial uncertainties, involving funding availability and investment risks, are critical as well, with Victor-Gallardo (2024) emphasizing the economic evaluation of decarbonizing the electricity sector (Ezbakhe & Foguet, 2021; Victor-Gallardo, 2024).

To manage these uncertainties, professionals in the renewable energy sector employ various decision-making frameworks, including risk assessment, scenario planning, stakeholder consultation, cost-benefit analysis, strategic planning, and adaptive management. Risk assessment is essential for identifying and mitigating potential risks (Soroudi & Amraee, 2013). Scenario planning helps prepare for multiple possible futures, providing flexible and robust strategies (Ezbakhe & Foguet, 2021). Stakeholder consultation ensures that diverse perspectives are considered, addressing potential issues early on (Meijer et al., 2007). Cost-benefit analysis balances financial, social, and environmental considerations (Li et al., 2018). Strategic planning involves setting long-term goals and aligning short-term objectives with these goals, as highlighted by Gil-García et al. (2021). Adaptive management emphasizes flexibility and continuous improvement, allowing professionals to refine strategies based on real-time feedback and changing conditions (Gil-García et al., 2021).

Risk management strategies such as diversification, insurance, hedging, collaboration, and redundancy are crucial for mitigating risks and increasing resilience. Rehman (2023) underscores the importance of financial and contractual hedging to protect against market uncertainties (Rehman, 2023). Collaboration and redundancy are critical for pooling resources and ensuring operational continuity (Salehi, 2023).

External factors such as policy and regulations, economic conditions, technological advances, social and cultural factors, and environmental considerations significantly influence decision-making processes. Assereto and Byrne (2020) discuss the role of government incentives and regulatory frameworks (Assereto & Byrne, 2020), while Ifelebuegu et al. (2017) highlight the impact of Brexit on UK energy policy and security (Ifelebuegu et al., 2017). The importance of technological advances in maintaining competitiveness and driving innovation is previously noted (Jasiński et al., 2023). Social and cultural factors, including public perception and community engagement, are essential for project acceptance and success (Wang et al., 2021). Environmental considerations, such as climate change impacts and resource availability, shape decision-making processes (Reynolds, 2024).

Examining both successful projects and failures provides valuable insights into effective practices and lessons learned. Victor-Gallardo (2024) and Rehman (2023) highlight the importance of effective communication, strong leadership, and robust project management in achieving project success (Rehman, 2023; Victor-Gallardo, 2024). Innovations in practice, such as implementing new technologies and creative problem-solving, drive continuous advancement in the renewable energy sector (Sitorus, 2020). The reflections of professionals on their decision-making processes, career growth, and team dynamics provide a personal perspective on the challenges and opportunities in the sector (Reynolds, 2024).

This study provides a comprehensive examination of the decision-making processes of professionals in the renewable energy sector under conditions of uncertainty. By understanding and effectively navigating these uncertainties, practitioners can enhance project outcomes and contribute to sustainable energy transitions. Overall, this study aims to explore the decision-making processes of professionals in the renewable energy sector under conditions of uncertainty, providing insights from semi-structured interviews with industry experts.

2. Methods and Materials

2.1. Study Design and Participants

This study employs a qualitative research design to explore the decision-making processes of professionals in the renewable energy sector under conditions of uncertainty. The primary method of data collection is semi-structured interviews, which allow for in-depth exploration of participants' experiences and insights. This approach is particularly suited for capturing the complexities and nuances of decision-making in a rapidly evolving industry like renewable energy.

The sampling strategy used in this study is purposive sampling, aimed at selecting participants who have significant experience and expertise in the renewable energy sector. The participants include professionals from various roles such as project managers, policy makers, engineers, and financial analysts. The inclusion criteria ensured that all participants had a minimum of five years of experience in the renewable energy sector, providing a rich basis for understanding their decision-making processes.

Theoretical saturation was used to determine the sample size. Interviews continued until no new themes or insights emerged from the data, indicating that additional interviews would not contribute significantly to the findings. This approach ensures that the data collected is both comprehensive and rich in detail, providing a robust basis for understanding decision-making under uncertainty.

2.2. Measures

2.2.1. Semi-Structured Interview

Data was collected through semi-structured interviews, which provided a flexible yet structured way to gather detailed information. An interview guide was developed, covering key topics such as:

- Types of uncertainties encountered in their work.
- Strategies and frameworks used for decision-making.
- The role of risk assessment and management.
- Influence of external factors such as policy changes and market dynamics.
- Personal experiences of success and failure in decision-making.

Each interview lasted between 60 and 90 minutes and was conducted either in person or via video conferencing, depending on the participants' availability and preferences. Interviews were audio-recorded with the consent of the participants and subsequently transcribed verbatim for analysis.

2.3. Data Analysis

The data analysis process began with transcription of the interviews, followed by an iterative process of coding and theme development. NVivo software was utilized to manage and analyze the qualitative data. Thematic analysis was conducted to identify common patterns and themes across the interviews. This involved several stages:

Familiarization: Reading and re-reading the transcripts to become deeply familiar with the content.

Initial Coding: Generating initial codes from the data, capturing interesting features.

Searching for Themes: Collating codes into potential themes, gathering all data relevant to each potential theme.

Reviewing Themes: Refining themes to ensure they accurately reflect the data.

Defining and Naming Themes: Defining each theme clearly and giving it a concise name.

3. Findings and Results

The study included 20 participants, each bringing a wealth of experience and diverse perspectives from the renewable energy sector. The participants were evenly split by gender, with 10 males and 10 females, ensuring a balanced representation. The age range of the participants varied significantly, with the youngest participant being 28 years old and the oldest 58 years old. Most participants (12 out of 20) were in the 35-45 age range, indicating a concentration of mid-career professionals.

In terms of professional roles, the sample included 6 project managers, 4 policy makers, 4 engineers, 3 financial analysts, and 3 environmental consultants. This diversity in roles provided a comprehensive view of decision-making processes across different functions within the sector. The

majority of participants (15 out of 20) had over 10 years of experience in the renewable energy industry, with the remaining 5 having between 5 and 10 years of experience. This level of expertise ensured that the insights gathered were deeply informed by extensive practical experience.

Geographically, participants were from various regions, with 8 from North America, 6 from Europe, 4 from Asia, and 2 from Australia, reflecting a global perspective on renewable energy challenges and strategies. This diverse demographic profile enriched the data, offering a wide range of viewpoints and experiences related to decision-making under uncertainty in the renewable energy sector.

Table 1

The Results of Qualitative Analysis

Category	Subcategory	Concepts
1. Types of Uncertainties	Policy Uncertainty	Regulatory changes, Policy delays, Inconsistent regulations
	Market Uncertainty	Price volatility, Market demand shifts, Competitor actions
	Technological Uncertainty	Technological advancements, Equipment reliability, Integration issues
	Environmental Uncertainty	Weather variability, Natural disasters, Environmental regulations
	Financial Uncertainty	Funding availability, Investment risks, Cost fluctuations
2. Decision-Making Frameworks	Risk Assessment	Risk identification, Risk evaluation, Mitigation strategies
	Scenario Planning	Best-case scenarios, Worst-case scenarios, Contingency plans
	Stakeholder Consultation	Stakeholder meetings, Public consultations, Expert panels
	Cost-Benefit Analysis	Financial analysis, Social impact assessment, Environmental impact
	Strategic Planning	Long-term goals, Short-term objectives, Resource allocation
	Adaptive Management	Feedback loops, Flexibility in plans, Continuous improvement
3. Risk Management Strategies	Diversification	Portfolio diversification, Technology diversification, Geographic spread
	Insurance	Insurance coverage, Risk transfer, Liability management
	Hedging	Financial hedging, Contractual hedging, Price guarantees
	Collaboration	Partnerships, Joint ventures, Knowledge sharing
	Redundancy	Backup systems, Redundant resources, Contingency resources
4. External Influences	Policy and Regulations	Government incentives, Regulatory compliance, Policy advocacy
	Economic Conditions	Economic cycles, Inflation rates, Currency fluctuations
	Technological Advances	Innovation adoption, R&D investment, Patent acquisition
	Social and Cultural Factors	Public perception, Cultural attitudes, Community engagement
	Environmental Factors	Climate change impact, Resource availability, Environmental activism
5. Success and Failure Stories	Successful Projects	Project milestones, Stakeholder satisfaction, Financial success
	Lessons from Failures	Project delays, Budget overruns, Technological failures
	Best Practices	Effective communication, Strong leadership, Robust project management
	Innovations in Practice	New technology implementation, Creative problem-solving, Process improvements
	Personal Experiences	Decision-making reflections, Career growth, Team dynamics

3.1. Types of Uncertainties

Professionals in the renewable energy sector face various types of uncertainties that influence their decision-making processes. Policy Uncertainty is a significant concern, with frequent regulatory changes, policy delays, and inconsistent regulations affecting project planning and execution. One participant noted, "Policy shifts are our biggest headache; we plan for one scenario, and a new regulation turns everything upside down."

Market Uncertainty includes price volatility, shifts in market demand, and actions by competitors. These factors can unpredictably alter project viability. As one interviewee mentioned, "Market prices fluctuate so much that it's like trying to hit a moving target."

Technological Uncertainty encompasses advancements in technology, equipment reliability, and integration issues. "We often invest in new technologies, not knowing if they'll be reliable or how well they'll integrate with existing systems," a participant explained.

Environmental Uncertainty is related to weather variability, natural disasters, and environmental regulations. "Weather patterns are increasingly erratic, making it hard to predict energy outputs," said one respondent.

Financial Uncertainty involves funding availability, investment risks, and cost fluctuations. A professional

shared, "Securing consistent funding is a challenge, with costs often exceeding initial estimates."

3.2. *Decision-Making Frameworks*

To navigate uncertainties, professionals employ various decision-making frameworks. Risk Assessment involves identifying, evaluating, and mitigating risks. "We systematically assess risks to minimize potential impacts," explained one project manager.

Scenario Planning includes developing best-case and worst-case scenarios, along with contingency plans. "We plan for multiple outcomes to ensure we're prepared for any eventuality," stated an engineer.

Stakeholder Consultation entails meetings with stakeholders, public consultations, and expert panels. "Engaging stakeholders early on helps us foresee and address potential issues," remarked a policy maker.

Cost-Benefit Analysis involves financial analysis, social impact assessment, and environmental impact evaluation. "We weigh costs against benefits to make informed decisions," said a financial analyst.

Strategic Planning covers setting long-term goals, short-term objectives, and resource allocation. "Strategic planning is crucial for aligning our projects with overarching goals," noted a senior manager.

Adaptive Management includes feedback loops, flexibility in plans, and continuous improvement. "Being adaptable allows us to refine our approach based on real-time feedback," shared a project lead.

3.3. *Risk Management Strategies*

Various strategies are used to manage risks effectively. Diversification includes portfolio diversification, technology diversification, and geographic spread. "Diversifying our investments helps us spread risk and increase resilience," explained a respondent.

Insurance involves obtaining insurance coverage, transferring risk, and managing liabilities. "Insurance is a key part of our risk management strategy," said a project manager.

Hedging includes financial hedging, contractual hedging, and price guarantees. "We hedge our bets to protect against financial uncertainties," noted a financial officer.

Collaboration involves partnerships, joint ventures, and knowledge sharing. "Collaborating with others allows us to pool resources and expertise," remarked a senior engineer.

Redundancy includes backup systems, redundant resources, and contingency resources. "Having redundancies in place ensures we can maintain operations despite disruptions," explained a technical lead.

3.4. *External Influences*

External factors significantly impact decision-making. Policy and Regulations include government incentives, regulatory compliance, and policy advocacy. "Government incentives can make or break a project," said one interviewee.

Economic Conditions cover economic cycles, inflation rates, and currency fluctuations. "Economic downturns affect our ability to secure funding," noted a participant.

Technological Advances involve innovation adoption, R&D investment, and patent acquisition. "Staying ahead with new technologies is crucial for competitiveness," remarked a research director.

Social and Cultural Factors include public perception, cultural attitudes, and community engagement. "Community support is essential for the success of our projects," said a community liaison.

Environmental Factors encompass climate change impact, resource availability, and environmental activism. "Environmental concerns are increasingly shaping our strategies," explained an environmental analyst.

3.5. *Success and Failure Stories*

The experiences of success and failure provide valuable insights. Successful Projects highlight project milestones, stakeholder satisfaction, and financial success. "Our latest project exceeded expectations, thanks to meticulous planning and stakeholder collaboration," shared a project manager.

Lessons from Failures include project delays, budget overruns, and technological failures. "We've learned hard lessons from projects that didn't go as planned," admitted a senior engineer.

Best Practices involve effective communication, strong leadership, and robust project management. "Clear communication and strong leadership are vital for project success," noted a team lead.

Innovations in Practice cover new technology implementation, creative problem-solving, and process improvements. "Innovation is at the heart of our approach, driving continuous improvement," stated a chief technologist.

Personal Experiences include reflections on decision-making, career growth, and team dynamics. "Personal experiences shape our approach to decision-making and professional development," remarked a senior executive.

4. Discussion and Conclusion

The study investigated the decision-making processes of professionals in the renewable energy sector under conditions of uncertainty through semi-structured interviews with 20 industry experts. The results highlighted five main themes: types of uncertainties, decision-making frameworks, risk management strategies, external influences, and success and failure stories.

The types of uncertainties faced by professionals included policy, market, technological, environmental, and financial uncertainties. Policy uncertainty, for instance, involved regulatory changes and inconsistent regulations, which significantly impacted project planning and execution. Market uncertainties encompassed price volatility and changing demand dynamics, while technological uncertainties involved advancements and integration issues. Environmental uncertainties related to weather variability and natural disasters, and financial uncertainties were connected to funding availability and cost fluctuations.

In terms of decision-making frameworks, professionals used various methods such as risk assessment, scenario planning, stakeholder consultation, cost-benefit analysis, strategic planning, and adaptive management. Risk assessment was crucial for identifying and mitigating potential risks, while scenario planning helped prepare for various possible futures. Stakeholder consultation ensured that diverse perspectives were considered, and cost-benefit analysis provided a balanced view of financial, social, and environmental factors. Strategic planning and adaptive management allowed for flexibility and continuous improvement.

Risk management strategies employed by professionals included diversification, insurance, hedging, collaboration, and redundancy. These strategies helped mitigate risks and increase resilience. External influences such as policy and regulations, economic conditions, technological advances, social and cultural factors, and environmental considerations played a significant role in shaping decision-making processes. Lastly, examining both successful projects and failures provided valuable insights into effective practices and lessons learned.

The results of this study align with and are supported by previous research on decision-making under uncertainty in the renewable energy sector. The impact of policy uncertainty on investment decisions is well-documented. Assereto and Byrne (2020) highlighted how frequent policy changes deter investments in solar photovoltaic projects, emphasizing the need for stable policy frameworks to encourage long-term investment (Assereto & Byrne, 2020). Similarly, Meijer et al. (2007) found that perceived uncertainty in emerging renewable energy technologies, such as biomass gasification, significantly influenced entrepreneurial actions (Meijer et al., 2007).

Market uncertainties, including price volatility and changing demand dynamics, were also highlighted in previous studies. Rehman (2023) discussed how global uncertainties and market interconnectedness affect renewable energy indices, reflecting the complex market-driven risks identified in this study (Rehman, 2023). The importance of market dynamics in shaping renewable energy investments is further supported by Li et al. (2018), who used real options analysis to examine investment decisions under China's carbon trading market (Li et al., 2018).

Technological uncertainties, particularly the challenges of integrating new technologies, were consistent with findings by Jasiński et al. (2023), who reviewed mathematical optimization approaches for planning energy hubs under uncertainty. These technological challenges necessitate robust decision-making frameworks to ensure compatibility and reliability (Jasiński et al., 2023).

Environmental uncertainties, such as weather variability and natural disasters, were also a significant concern. Ezbakhe and Foguet (2021) underscored the impact of environmental factors on renewable energy planning, highlighting the need for adaptive management strategies to mitigate these risks (Ezbakhe & Foguet, 2021). The role of financial uncertainties, including funding availability and investment risks, aligns with the findings of Victor-Gallardo (2024), who emphasized the economic evaluation of decarbonizing the electricity sector in the Dominican Republic (Victor-Gallardo, 2024).

The decision-making frameworks identified in this study, such as risk assessment and scenario planning, are crucial for navigating uncertainties. Soroudi and Amraee (2013) noted the importance of decision-making under uncertainty in energy systems, advocating for comprehensive risk assessments and scenario planning to manage risks effectively (Soroudi & Amraee, 2013). The role of stakeholder consultation in ensuring diverse perspectives

and addressing potential issues early on is previously supported (Meijer et al., 2007).

Risk management strategies, such as diversification and insurance, are essential for mitigating risks. The importance of these strategies is echoed by Rehman (2023), who discussed the need for financial hedging and contractual hedging to protect against market uncertainties (Rehman, 2023). Collaboration and redundancy were also identified as critical strategies for increasing resilience, aligning with findings by Salehi (2023) on stochastic optimal transactive energy management using artificial neural networks (Salehi, 2023).

External influences, including policy and regulations, economic conditions, and technological advances, significantly impact decision-making processes. Assereto and Byrne (2020) highlighted the influence of government incentives and regulatory frameworks (Assereto & Byrne, 2020), while Ifelebuegu et al. (2017) discussed the implications of Brexit on UK energy policy and security (Ifelebuegu et al., 2017). The role of technological advances in maintaining competitiveness and driving innovation is also supported (Jasiński et al., 2023).

The success and failure stories provided valuable insights into effective practices and lessons learned. The importance of effective communication, strong leadership, and robust project management in achieving project success is consistent with prior findings (Rehman, 2023; Victor-Gallardo, 2024). Innovations in practice, such as new technology implementation and creative problem-solving, were also critical for continuous advancement in the renewable energy sector, aligning with previous findings (Sitorus, 2020).

While this study provides valuable insights into the decision-making processes of professionals in the renewable energy sector, it is not without limitations. The qualitative nature of the research, based on semi-structured interviews with a relatively small sample size of 20 participants, may limit the generalizability of the findings. The purposive sampling strategy, although effective in selecting experienced professionals, may introduce selection bias. Additionally, the study focuses on professionals from various regions, but it does not account for specific regional differences in policy, market conditions, and technological advancements that might influence decision-making processes. Future research could address these limitations by including a larger, more diverse sample and exploring regional variations in greater detail.

Future research should consider expanding the scope of this study to include a larger and more diverse sample of professionals from different regions and sectors within the renewable energy industry. This would enhance the generalizability of the findings and provide a more comprehensive understanding of decision-making processes under uncertainty. Longitudinal studies could also be conducted to examine how decision-making strategies evolve over time in response to changing uncertainties. Additionally, quantitative research methods, such as surveys and statistical analysis, could complement the qualitative insights and provide a more robust analysis of the factors influencing decision-making. Exploring the impact of specific regional policies and market conditions on decision-making processes would further enrich the understanding of how contextual factors shape strategies in the renewable energy sector.

For practitioners in the renewable energy sector, the findings of this study highlight the importance of adopting comprehensive decision-making frameworks and robust risk management strategies. Emphasizing adaptive management and continuous improvement can help professionals navigate the uncertainties inherent in this sector. Engaging stakeholders early and incorporating their perspectives into the decision-making process can mitigate potential issues and enhance project outcomes. Practitioners should also prioritize diversification, both in terms of technology and geographic spread, to manage risks effectively. Finally, maintaining flexibility and being open to innovation can drive continuous advancement and ensure the long-term success of renewable energy projects.

In conclusion, this study provides a detailed examination of the decision-making processes of professionals in the renewable energy sector under conditions of uncertainty. The insights gained from this research contribute to the broader understanding of how uncertainties are managed and how effective decision-making frameworks are developed. As the world continues to transition towards sustainable energy systems, these findings will be crucial for achieving long-term environmental, economic, and social goals.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were considered.

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