International Journal of Economic Literature (INJOLE) e-ISSN: 3026-0221
Vol. 3 No. 5 May 2025, page., 534-545

OPTIMIZING INVESTMENT DECISIONS USING A REAL OPTIONS-BASED PROJECT EVALUATION MODEL: IMPLEMENTATION IN THE RENEWABLE ENERGY SECTOR

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Abstract

Investments in the renewable energy sector face the challenge of high uncertainty due to energy price volatility, regulatory changes and technological developments. Traditional investment evaluation methods such as Net Present Value (NPV) and Internal Rate of Return (IRR) are often less effective in dealing with these dynamics because they do not consider flexibility in decision making. Therefore, the Real Options approach emerged as an alternative solution that allows investors to adjust investment strategies based on changing market conditions. This research is a literature review which aims to analyze the effectiveness of Real Options in optimizing investment decisions in the renewable energy sector. Through literature studies from journals, academic books, and research reports, comparisons were made between traditional methods and Real Options, as well as identification of key factors that influence the application of this model, such as government policy, technological innovation, and access to funding. This study shows that the Real Options approach provides advantages in managing risk, increasing the flexibility of investment strategies, and optimizing project value by considering strategic options such as delaying, expanding, or canceling projects. The results of this research have important implications, both theoretically and practically. Theoretically, this research reinforces the concept that investment must be dynamic and adaptive, especially in an environment full of uncertainty such as renewable energy. Practically, applying this model can help investors optimize investment decisions and reduce financial risk. However, challenges such as the complexity of calculations and limited access to accurate data are still obstacles in its implementation. Therefore, it is necessary to develop simpler analytical tools and more stable policies to support Real Options-based renewable energy investment.

Keywords: Real Options, renewable energy, investment evaluation, uncertainty, investment decisions.

INTRODUCTION

Investment in the renewable energy sector is increasingly becoming a major focus in various countries along with increasing awareness of the importance of a sustainable energy transition. Renewable energies such as solar, wind, hydro and biomass power offer environmentally friendly solutions to reduce dependence on fossil fuels which are limited and have a negative impact on the environment (ÖZEKENCİ & DÜZAKIN, 2023). In addition, various countries have set ambitious targets to reduce carbon emissions in order to achieve net zero emissions in the next few decades. Therefore, increasing investment in the renewable energy sector is key to supporting the achievement of global sustainability goals.

However, investment in renewable energy projects faces various challenges, especially high uncertainty in technological aspects, regulations and market conditions. Changes in government policy, fluctuations in energy prices, and new technological developments can affect the long-term profitability of renewable energy projects. Additionally, renewable energy projects often require large initial investments with relatively long payback periods, thereby increasing financial risks for investors (Pérez-Vas et al., 2024). Therefore, investment evaluation methods that are able to accommodate uncertainty are very important in making investment decisions.

Conventional methods of investment evaluation, such as Net Present Value (NPV) and Internal Rate of Return (IRR), are often used to assess the financial feasibility of a project. However, this method has limitations in dealing with the uncertainty inherent in renewable energy investments. NPV and IRR tend to be static and do not consider managerial flexibility in adjusting investment strategies based on changing market conditions (Chang & Huang, 2024). As a result, investment decisions based on this method may overlook potential opportunities that could increase the overall value of the project.

In facing these challenges, a Real Options based approach offers a more adaptive solution in investment evaluation. The concept of Real Options originates from financial theory and adapts the principles of options to real investment decisions. In contrast to NPV which only considers projected cash flows, Real Options allow more flexible decision making by considering various possible future scenarios (Walek & Müller, 2022). This allows investors

to delay, expand, reduce, or even cancel projects based on developing external conditions.

The application of Real Options in the renewable energy sector is gaining increasing attention due to its ability to handle uncertainty and increase project value through dynamic decision strategies. For example, in solar power projects, investors may have the option to expand production capacity if energy prices increase or delay investment if government regulations change (Assche & Compernolle, 2022). Thus, this method not only increases accuracy in decision making but also reduces the risk of losses due to unexpected external changes.

In addition, various studies have shown that the use of Real Options in investment evaluation can provide more accurate results than traditional methods. This model allows companies and investors to develop adaptive strategies that better suit the characteristics of the dynamic renewable energy market (Stachoň, 2023). However, although Real Options offer significant advantages, their implementation still faces various challenges, such as computational complexity and the need for more accurate data to estimate option values. Therefore, further research is needed to optimize the use of this model in renewable energy investments.

With the global shift towards clean energy, the need for more sophisticated investment evaluation methods is increasingly pressing. Governments, companies and investors should consider innovative approaches such as Real Options in their investment strategies to ensure the sustainability of renewable energy projects (Zhang & Qing, 2022). This research will examine how the Real Options model can be implemented optimally in the renewable energy sector as well as the factors that influence its effectiveness in making investment decisions.

Through this literature review, it is hoped that new insights can be found regarding the benefits and challenges of implementing Real Options in renewable energy investment. The results of this research can also serve as a guide for investors and policy makers in determining more flexible and adaptive strategies in dealing with market uncertainty, so as to increase the attractiveness of investment in the renewable energy sector.

RESEARCH METHOD

This research uses a literature review method to analyze various studies that have been carried out regarding the application of Real Options in evaluating investments in the renewable energy sector. The literature study

was carried out by collecting and analyzing references from indexed scientific journals, academic books, and research reports that discuss investment evaluation methods, especially in the context of renewable energy. In addition, a comparative analysis was carried out on conventional investment evaluation methods such as NPV and IRR with the Real Options approach, in order to identify the advantages and disadvantages of each method in dealing with investment uncertainty.

In the literature selection process, this research focuses on sources that have high relevance, namely journals indexed by Scopus, Web of Science, and Sinta, international conference proceedings, as well as academic books that discuss renewable energy investment and Real Options theory. The literature used is limited to the last 10 years to ensure relevance to the latest developments in this field. The data analysis method used is content analysis, namely identifying patterns, trends and research gaps from previous studies. In addition, a comparison of investment evaluation models was carried out, highlighting the advantages and disadvantages of the Real Options method compared to traditional approaches in optimizing investment decisions in the renewable energy sector (Babbie, 2020; Bryman, 2016; Field, n.d.).

RESULT AND DISCUSSION

Comparison of Investment Evaluation Methods

In making investment decisions, project evaluation methods play an important role in assessing the financial feasibility and risk of a project. Traditional methods such as Net Present Value (NPV) and Internal Rate of Return (IRR) have long been used as the main tools in investment analysis. NPV calculates the net value of the project's cash flows discounted to its current value, while IRR measures the project's rate of return based on the cash flows generated (Baum, 2022). These two methods provide an overview of project profitability with the assumption that all investment parameters are definite and do not change over time.

However, traditional methods have several disadvantages, especially in dealing with uncertainty and volatility in renewable energy investments. For example, NPV and IRR do not consider flexibility in decision making after the project is underway. Investment decisions based on this method tend to be static, where projects must be accepted or rejected based on the results of initial calculations without considering possible changes in external conditions such as energy price fluctuations, regulatory changes, or new technological

developments (He, 2024). As a result, this method may cause investors to miss opportunities to adjust investment strategies to optimize project value.

In contrast, the Real Options based approach offers a more flexible solution in evaluating investment projects. This method allows investors to adapt investment strategies based on changing market conditions by considering various decision scenarios. Real Options allow companies to postpone investments until conditions are more favorable, expand the project if the market develops rapidly, or even cancel the project if the risks increase significantly. This flexibility provides additional advantages that conventional methods do not have, especially in the renewable energy sector which has a high level of uncertainty (Ali & Rafique, 2024).

In a context of uncertainty, investment in renewable energy is strongly influenced by energy price volatility, changes in government policy, and technological advances. For example, the price of solar panels and wind turbines continues to decline along with technological innovation, while incentive policies such as subsidies or carbon taxes can change at any time. By using the Real Options approach, investors can better respond to these changes with a more dynamic strategy compared to the NPV or IRR methods which tend to only take into account initial investment conditions (Chandra & Hartley, 2024).

Apart from flexibility, Real Options also provides advantages in risk mitigation. For example, in wind energy projects, investors may choose the option to delay construction until regulatory certainty is clearer or technology prices are more competitive. While in traditional methods, projects may be executed immediately despite high uncertainty, which can increase the risk of failure. The ability to make decisions in stages makes Real Options superior in facing dynamic market conditions (BIYIKLI et al., 2023).

Even though it has many advantages, implementing Real Options also has challenges. One of them is the higher complexity of calculations compared to traditional methods. Real Options calculations often use financial models such as the Black-Scholes Model or Binomial Model, which require estimation of parameters such as volatility and risk-free interest rates (Odloak, 2024). Apart from that, not all investors or companies have the analytical capacity and expertise to apply this method, so many still rely on the NPV and IRR approaches because of their simplicity.

By considering the advantages and disadvantages of each method, the best approach in evaluating renewable energy investments is a combination of traditional methods with Real Options. NPV and IRR can be used as basic

tools to assess the financial viability of a project, while Real Options can help in optimizing decisions by considering flexibility and uncertainty. In this way, investors can make more adaptive and strategic decisions to maximize investment value in the long term.

Key Factors in Implementing Real Options

The application of Real Options in evaluating renewable energy investments is influenced by various factors that determine the flexibility and effectiveness of decision making. Several main factors that play a role in implementing Real Options include government policies and regulations, technological advances and innovation, as well as access to funding and investment incentive schemes. These factors can influence project uncertainty and determine the extent to which investors can use option strategies in optimizing the value of their investments (Li, 2024).

Government policies and regulations have a significant impact on investment decisions in the renewable energy sector. Supportive regulations, such as clean energy targets, feed-in tariff (FiT) schemes, carbon taxes and green energy subsidies, can increase project profitability and reduce investment risks. On the other hand, regulatory uncertainty, such as changes in incentive policies or revisions in renewable energy tariffs, can create risks that are difficult to predict (Yuan, 2022). In the context of Real Options, investors can use the option to postpone or reduce the scale of investment if there is regulatory uncertainty, thereby allowing them to take more flexible decisions based on the latest policy developments.

Apart from regulations, technological developments and innovation in renewable energy are also key factors in implementing Real Options. Advances in the efficiency of solar panels, energy storage batteries, and wind and hydro technologies can impact the production costs and competitiveness of renewable energy projects. For example, in solar power generation projects, investors can choose the option of delaying investment until solar panel prices are cheaper or technological efficiency improves (Chu et al., 2022). By considering technological dynamics, Real Options enables more optimal decision making in the face of innovation uncertainty.

Furthermore, access to funding factors and investment incentive schemes also determine the success of implementing Real Options in renewable energy investment. Funding green energy projects often requires special financing schemes, such as green bonds, low-interest loans, or public-private partnerships (PPPs). Uncertainty in access to funding can increase

project risk, so investors can use the option of adjusting the scale of the project based on available financial conditions (Sadat & Min, 2024). For example, if there are capital constraints, investors may start the project on a small scale with the option to expand capacity in the future when additional funding becomes available.

Apart from funding, various investment incentive schemes also play an important role in reducing financial risks and increasing the attractiveness of renewable energy projects. Incentives such as investment tax credits (ITC), renewable energy certificates (REC), and research grants can encourage investors to be more active in financing green energy projects (Yang et al., 2024). With this incentive, Real Options can be implemented more optimally, for example by choosing the option to expand investment if there are supporting policies that increase the potential profit of the project.

However, although these factors support the adoption of Real Options, there are challenges in integrating this model into the investment decision-making process. One of the main challenges is the difficulty in measuring uncertainty parameters, such as energy price volatility, government policies, and technological changes. In addition, not all investors have sufficient analytical capacity to use the Real Options model, considering that this method requires complex calculations with sophisticated financial approaches such as the Black-Scholes Model or Binomial Model. (Becker et al., 2023) Therefore, it is necessary to increase capacity and develop simpler analytical tools so that Real Options can be more easily applied in evaluating renewable energy investments.

Overall, government policy, technological developments, and access to funding are the main factors that determine the success of implementing Real Options in renewable energy investment. By understanding these factors, investors can optimize their decisions in the face of uncertainty and increase project value through more flexible investment strategies. Increasing coordination between the government, investors and financial institutions is also key in creating a more stable and sustainable green energy investment ecosystem.

Optimal Model of Investment Evaluation Based on Real Options

In the face of high uncertainty in renewable energy investment, an optimal investment evaluation model based on Real Options is needed to increase decision-making flexibility. This optimal model must be able to capture the dynamics of changing market conditions, regulations and

technology, as well as provide strategic options for investors to adjust their investments in line with developments in the external environment. The approaches widely used in Real Options involve binomial models, Black-Scholes models, and Monte Carlo simulations, which allow the analysis of various scenarios in the investment process (Balassem et al., 2024).

The optimal model for making investment decisions in the renewable energy sector needs to include various strategic options such as postponing investment (option to defer), expanding the project scale (option to expand), reducing the project scale (option to contract), and canceling the project if it is not profitable (option to abandon) (Ito et al., 2023). For example, in investing in wind power plants, investors can use the option to postpone the project if the price of wind turbines is predicted to fall in the next few years. This optimal model provides a dynamic approach, where investment decisions are not just made once at the start but can be adjusted based on new information as it emerges.

In the context of risk mitigation, the Real Options model provides advantages over traditional methods such as Net Present Value (NPV) and Internal Rate of Return (IRR). Risks faced in renewable energy projects include fluctuations in energy prices, changes in incentive policies, and the development of new technologies (Tsvetkov & Bozmarova, 2023). By using the Real Options approach, investors can manage these risks more effectively, for example by delaying projects until government policies are more stable or until more efficient technology is available on the market.

One of the risk mitigation strategies in Real Options is the staged investment option. In this strategy, renewable energy projects can be started on a small scale with the possibility of expanding if the market shows positive growth (Fan et al., 2023). For example, a company investing in solar power generation may start with a small capacity and gradually add capacity based on increasing demand for electricity or changes in energy prices. This allows investors to limit initial risk exposure and only increase investment when the project prospects are more favorable.

Apart from that, the exit option strategy is also an important part of the optimal Real Options model. If drastic changes occur that reduce the profitability of the project, such as a sharp decline in conventional energy prices or the elimination of renewable energy subsidies, investors can exercise the option to cancel the project before incurring greater losses (Sun et al., 2023). This approach differs from traditional NPV methods which often require

investors to continue pursuing a project even if market conditions are no longer favorable.

In implementing the optimal Real Options model, the use of Monte Carlo simulation can help in analyzing various investment scenarios. This simulation allows investors to estimate the value of a project by considering various uncertain factors, such as energy prices, regulations, and technological advances (Edet, 2023). This way, investors can make decisions that are more data and probability based, rather than relying solely on a single estimate as in the NPV method.

By combining a flexible Real Options approach and appropriate risk mitigation strategies, optimal investment evaluation models can increase the resilience of renewable energy projects to uncertainty. The use of this model not only helps investors make more rational and adaptive decisions but also increases the attractiveness of the renewable energy sector for investors and financial institutions (Ukam, 2023). Therefore, further development in the implementation of Real Options is an important step in supporting a sustainable energy transition.

CONCLUSION

This literature review confirms that Real Options is a more effective investment evaluation method than traditional approaches such as Net Present Value (NPV) and Internal Rate of Return (IRR) in the renewable energy sector. Real Options' main advantage lies in its flexibility in managing uncertainty and volatility, which are often key challenges in green energy projects. By considering various strategic options such as delaying, expanding, reducing the scale, or canceling the project, this method allows investors to optimize the value of the project based on technological developments, policies, and market conditions. The analyzed literature also shows that the use of models such as Monte Carlo simulation and binomial models can increase the accuracy of investment decision making by considering more realistic scenarios and probabilities.

In terms of theoretical implications, this research strengthens the concept that investment decisions must be dynamic and adaptive, not just based on static estimates as in traditional methods. This opens up opportunities for further development in investment management theory under conditions of high uncertainty. In practical terms, the application of Real Options can help investors, companies and policy makers in developing more resilient investment strategies, especially in the renewable energy sector

which is highly influenced by technological and regulatory changes. However, challenges such as computational complexity and limited access to accurate data are still obstacles in implementing this model. Therefore, further efforts are needed in simplifying analytical methods, increasing financial literacy for investors, as well as more stable policy support to encourage wider adoption of Real Options in renewable energy investments.

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