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Analysis of renewable energy investment in Iran using real options approach

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Abstract

Many nations' quick development and progress during the last century may be directly attributed to the widespread use of fossil fuels. Particularly during the twentieth century, oil has stood out as a defining feature of human civilization. However, the increasing use of fossil fuels like oil and coal has led to severe problems for the world's ecosystems, national security, and economic prosperity. This article uses the real options technique to examine the interplay between the volatility of diesel prices, electricity prices, and the externality of consuming oil in determining the optimal time to invest in renewable energy. Employing the real options approach, it offers a nuanced analysis that underscores the value of flexibility in investment decisions under uncertainty. The methodology facilitates a comprehensive evaluation of various actual option strategies for discretion assessment, contrasting them with traditional decision-making frameworks that often overlook the element of uncertainty. Different actual choice approaches for discretion assessment are addressed and compared, as well as the usage of devolution for decision-making. Finally, Monte Carlo simulations compare these techniques to conventional approaches. The findings show that investments in renewable energy have a positive net present value. The timelessness of investing choices is emphasized by the real options method. Under the present energy system in Iran, switching to renewable energy sources is preferable to maintaining reliance on oil to provide power. Policies should encourage investment in renewable energy sources by increasing the cost of using oil or reducing the cost of electricity.

Highlights

- Providing a framework in which the advantage of using the real option theory in evaluating new energy projects in various ways.
- devolution is used to make decisions, and different methods of real pricing options are used to evaluate the discretion,
- The results show that there is a significant difference between the conventional methods and the real options method

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1. Introduction

Renewable energies comprise a diverse range of sources that are derived from natural and readily available energy sources. Although imperfect, their use can reduce petroleum product consumption, employment, and environmental pollution (Salvador & Ribeiro, 2023).

Unfortunately, attention to developing new energy sources in Iran has been focused on other countries' activities and research in recent decades. However, in the past few years, significant progress has been made in improving renewable energy by utilizing solar power plants and wind turbines. Rationalizing the cost of energy carriers can further facilitate the adoption of these technologies (Mollahosseini et al., 2017).

Like many other developed nations, implementing renewable energy in Iran is very important. The government has already made the necessary plans to develop these energies in the Fifth Development Plan in line with global policies to tackle various issues and create job opportunities. Studies have shown that developing new energy sources can significantly enhance the energy system's security in the country (Razmjoo et al., 2021).

This article introduces various examples of renewable energy sources, including wind, solar, biomass, geothermal, and tidal energy from the moon. The aim is to examine the country's current usage of these energies and their impact on economic and social dimensions. Additionally, this article will explore the country's development of modern renewable technologies and strategies for future growth.

Based on available data about renewable energies in Iran, an appropriate strategic plan framework can be developed to facilitate effective measures towards sustainable development. Due to increasing global demand for renewable resources and greater attention to indicators of sustainable energy consumption worldwide, countries are investing more heavily in new and innovative power generation sources. In 2008 alone, over $120 billion was invested globally into constructing power plants that use new clean-energy methods or developing new ways to increase capacity through renewables.

By 2010, end-of-year figures showed that 3.8% of electricity production worldwide came from renewables - not accounting for hydropower, which accounts for a further 15%. More than 14% of people worldwide now use some form of new energy source in their daily lives. However, despite all this global progress towards cleaner fuels, many countries remain where government policy needs to pay more attention to transitioning away from non-renewable fuels - such as our own country (Rodrik, 2014).

Today, countries' economic and political support heavily relies on their productivity from fossil resources. The depletion of these resources or even the desire to move away from them not only threatens the economies of those countries but also causes significant concerns for other nations' economic systems (Adebayo, 2023).

Creating policies that support investors and technology transfer to developing countries is necessary for renewable energy development in all countries. The new energy industry is now at a crossroads - it has the technical capability to provide sustainable solutions and be economically competitive in many parts of our country. After the depletion of oil and gas resources and global warming, advancing the benefits will help developed nations tremendously. These industries can invest in each country's markets while promoting energy recycling technologies.

There are three main factors in expanding market attraction towards renewable energy; the first is security in national-level energy fields. Reports show that oil utilization is increasing rapidly and will soon surpass high domestic production levels, making developed nations increasingly dependent on oil markets. This dependence may lead to vulnerability when interruptions to oil imports, which could significantly affect Western economies.

The rapid growth of emerging nations will further exacerbate this issue as they, too, become reliant on global oil markets over time. However, switching to renewable sources can help Western nations depend more on domestic sources for their energy needs instead of relying solely on petroleum products, thereby reducing consumption growth rates over time while mitigating environmental impact concerns.

The primary concern regarding renewable energy is its link to climate change. Sustainable power can address the energy problem and reduce greenhouse gas emissions, such as carbon dioxide and methane, accumulating in the Earth's atmosphere and gradually increasing global temperatures. Unfortunately, rising temperatures have negative and potentially catastrophic consequences. Carbon-free renewable energy must be used as one of several strategies to prevent this issue. However, Iran has been slower in adopting new energy policies than other countries. Fortunately, wind turbines and solar power plants have been established in recent years despite the high costs of these technologies. A codified strategic plan is necessary for using different methods of new energies according to current conditions while achieving a suitable portion of the energy supply within a set timeframe. Therefore, this study considers using working-class currency as an event that brings flexibility to management decisions when exercising their right to invest capital budgeting methods like discounting work within the same time frame. Studies show that volatility at 5% of current exchange rates is more appropriate because an increase in current currency value causes an increase in overall currency value.

Net present value (NPV) analysis is used for investment projects. Developers, financial organizations, and government agencies employ this method when cash is owed. NPV undervalues investment prospects and is unsuitable for appraising RE projects in underdeveloped countries due to variable energy costs and evolving RE technology (Kim et al., 2017). The real options approach (ROA) solves this issue by combining risks and uncertainties with flexibility in investment scheduling as a possible component that adds value to the project Brach (2003). Recent studies use ROA renewable energy investment, particularly for wind, solar photovoltaic (PV), hydropower, concentrated solar power (CSP), and hybrid RE with uncertainties in non-RE cost, certified emission reduction (CER), feed-in tariff (FIT), energy production, operations and maintenance (O&M) cost, research and development (R&D) grants, production tax credit (PTC), RE credit (REC), and others.

This study introduces a ROA framework for building country RE project analysis. This research uses ROA to assess if investing in RE is better than utilizing diesel for electricity production, considering uncertainties in diesel fuel price, local power pricing, and diesel externality tax. Finally, this proposes government initiatives to address environmental, supply chain, and energy security issues.

2. Literature review

Compared to other investment approaches, the real options approach combines three crucial factors of an investment decision - uncertainty about future incomes from the venture, irreversibility of investment, and flexibility in timing (Gupta, 2021; Trigeorgis, 1995).

Lezord estimated the unit cost of energy for a photovoltaic system in 1997 at 25 cents per kilowatt-hour, which is higher than the conventional electricity generation cost of 10 cents per kilowatt-hour (Lesourd, 2001). However, due to technological advancements and rising global fuel prices, solar electricity costs are predicted to be reduced by half in the short term. In a study on investing in photovoltaic panels in Flanders, Belien et al. suggest that governments should support incentive policies to invest in manufacturing industries and use photovoltaic panels while minimizing taxes on investors investing in renewable energy sources and increasing electricity prices (Beliën et al., 2013). These policies would make solar panels more affordable than other household options. According to Mendelsohn et al.' study titled "The Impact of Financial Structure on the Cost of Solar Energy," sustainable factors affecting solar panel prices and subsidies need capital from sunlight expansion worldwide since significant differences exist between technology costs across countries (Mendelsohn et al., 2012). The calculated cost map reveals that expanding, installing, and operating solar panels may not be as costly as most finance policy plans suggest; especially developing tropical nations can benefit from this approach as their expenses are less expensive than planned policies.

Chandel et al. conducted a study titled "Techno-economic analysis of solar photovoltaic power plant for garment zone of Jaipur city," which evaluated the technical and economic feasibility of a 2.5 MW power plant to meet the annual electricity demand of 1.2 MW in the Jaipur region, considering two modes-connected to the distribution network and independent from it (Chandel et al., 2014). The results showed that the current net value of the project is 249 million rupees, with a mobile capital return period of 14.14 million rupees per year while maintaining an energy cost balance of 14.94 and considering an interest rate of

10%. This study proposes a general framework for investment decisions to transfer technologies from fossil fuels to various alternative energy sources suitable for developing economies, mainly fossil fuel-importing countries.

One of the approaches to the economic analysis of a project is the natural authority approach. This approach involves decision-making in uncertain and complex situations, where determining expectations of future changes while considering existing uncertainties plays a crucial role. The real options approach overcomes these limitations by combining vulnerability and risk with the opportunity for speculation as potential factors that enhance the venture (Neufville, 2003). According to Osman et al., current investments in renewable energy projects are expected to decline by approximately 10% this year, more than the anticipated decline in fossil fuel usage for generating electricity (Osman et al., 2023).

Liu et al. conducted a study on shale gas investment. They found that the current investment climate in China is favorable for immediate investment in shale gas development projects when the initial average daily production reaches at least 30×104 m^3 cubic meters. In addition, financial subsidies and trade in carbon emissions can help advance optimal investment timing (Liu et al., 2022).

Gupta et al. studied the value of increasing installed capacity and investment costs in wind and solar energy in India (Gupta, 2021). Recent increases in public and private sector capacity, investment, and government support schemes have made renewable energy sources more competitive with traditional fuels such as coal in electricity generation. Using a two-factor learning curve to model lower wind and solar energy prices, they used the real options approach with global coal prices as a random variable to calculate the overall value of promotional policies for renewable energy. The results suggest that coal stimulus prices for renewable energy today for electricity generation indicate early adoption of additional wind and solar technologies as optimal policy. With the option of deploying over an extended time horizon, it is more valuable to continue policies to increase capacity and investment costs in renewable energy under global coal prices.

Sayyadinejad and Kimiagari studied investors with a wide range of investment options. The study aimed to demonstrate and evaluate interest in renewable resources to attract immediate investors by determining the optimal level of renewable energy purchase tariff using the real options approach. They modeled a set of five factors, including uncertainty, latency, and climatic differences across 31 provinces in Iran, using the combined algorithm of reverse dynamic programming, Monte Carlo simulation, and mathematical Brownian motion (Sayyadinejad & Kimiagari, 2021).

The study results indicate that investing in renewable resources without subsidies is not attractive for immediate investment. Investors and policymakers should use the simple discretion approach to evaluate and support such investments without delay. With technological advancements and the implementation of carbon dioxide emissions trading plans, the value of investment increases while the ideal allocation decreases. The optimal level of allocation is directly related to factors such as charge rate, capacity, exchange rate, discount rate, and volatility (Sayyadinejad & Kimiagari, 2021). Table 1 summarizes research conducted by various researchers in this field.

Table 1: Summary of research in various fields of energy and uncertainty

Author	Energy source	Uncertainty
Liu et al. (Liu et al., 2022)	Gas	Market, technology, environment
Gupta et al. (Gupta, 2021)	renewable energy	Capacity
Armijo and Philibert (Armijo & Philibert, 2020)	Solar and wind	Flexibility, investment decisions
Sayyadimejad and kimiagari (Sayyadinejad & Kimiagari, 2021)	Solar	Investment amount, electricity market price, carbon dioxide emission price, maintenance cost, and exchange rate
Mauleon and Hamoudi (Mauleón & Hamoudi, 2017)	Solar-wind	Investment cost
Zhang et al. (Zhang et al., 2017)	nuclear	Flexibility, investment decisions, risk
Li et al. (Li et al., 2018)	Wind	Changes in the carbon trading market, national policies
Mashhadizadeh et al. (Mashhadizadeh et al., 2018)	Solar	Flexibility, investment decisions
Cardin et al. (Cardin et al., 2017)	nuclear	Electricity demand, public acceptance
Tian et al. (Tian et al., 2017)(2017)	Solar	REC price, delay cost
Lonkar et al. (Loncar et al., 2017)	Wind	Combined ROA
Tian et al. (Tian et al., 2017)	Solar	Investment cost

***Source**: research findings*

3. Research Method

Recent research combines different methods to leverage their advantages and cover their disadvantages. However, if used correctly, the results of different approaches will be almost similar. Authority pricing was created in the 1970s to evaluate property authority (Black & Scholes, 1973).

After discussing the methodological limitations of “currency” and “real options theory," this article refers to previous research on investment projects using conventional and natural currency methods and various option pricing models. The net present value method is compared with the natural option method. This study expands upon descriptive research purposes, qualitative study procedures, and quality considerations.

Based on our theory, real options valuation effectively addresses data assessment for future projections through dynamic optimization modeling that considers scenarios based on increasing or decreasing plan values' probabilities while considering discretion exercise prices. Additionally, we assume that an average return model can explain changes in new energy prices within Iran's context.

3.1 Real options approach

Myers (1977) initially defined ROA as using option pricing theory to value non-financial assets. Real options provide the right, but not the responsibility, to execute an action (e.g., postponing, expanding, shrinking, or abandoning) at a fixed cost, termed exercise price, during the option's life (Copeland & Antikarov, 2003). Investment choices are irrevocable, high-risk, unpredictable, and flexible (Baecker, 2007). NPV, DCF, IRR, and ROI fail to reflect these qualities, resulting in bad policy and investment choices. However, ROA mixes unpredictability and choice flexibility, which define many energy investment decisions.

This study uses ROA to evaluate diesel vs. RE power-generating investment choices. We base investment choices on fuel price unpredictability.

3.2 Dynamic Optimization

We use Dixit and Pindyck (Dixit & Pindyck, 1994) and Detert and Kotani (Detert & Kotani, 2013) to optimize investment decisions under uncertainty using dynamic programming. We provide a model of an investor that determines the best value of investing in renewable energy or continuing to use diesel for power production in eq. (1).

$$V_{D,t} = \max_{0\le\tau\le T+1}[\{\sum_{t=0\le t<\tau} i^t \pi_{D,t} + i^{T_D} \mathrm{E}NPV_{D,t}(1-\mathrm{I}_{\{\tau\le T\}})\} \,|\, P_{c,0} + NPV_R(\mathrm{I}_{\{\tau\le T\}})] \quad (1)$$

Where

$$\pi_{D,t} = P_E Q_E - P_{D,t} Q_D - C_D - E_D \quad (2)$$

$$NPV_{D,t} = \sum_{t=T}^{T_D} PV_{D,t} = \sum_{t=T}^{T_D} i^t \pi_{D,t} \quad (3)$$

$$NPV_R = \sum_{t=\tau}^{T_R} PV_{R,t} = \sum_{t=\tau}^{T_R} i^t \pi_{R,t} = (\frac{1-i^{T_R+1}}{1-i})[P_E Q_E - C_R] - I_R \quad (4)$$

The description of the parameters and variables is given in Table 2.

Table 2. Description of parameters and variables

Notation	Description
$V_{D,t}$	The option value of investment at each price of diesel, D, at each period of investment, t, in US$
$\mathbb{E}NPV_{D,t}$	Expected net present value of continuing diesel for electricity generation, in US$
$NPVR$	Net present value of investing in renewable energy, in US$
$\pi_{D,t}$	Profit of using diesel for electricity generation from the initial period of investment, 0, to the period of switching to renewable energy, τ, in US$
T	Total period of investment
τ	Period of switching from diesel to renewable energy
$\mathbb{1}_{\tau \leq T}$	Indicator equal to 1 if switching to renewable energy is made; otherwise, equal to 0
i	Discount factor
P_E	Electricity price, in US$/MWh
$P_{D,t}$	Stochastic price of diesel, in US$/barrel
Q_E	Quantity of electricity produced, in MWh
Q_D	Quantity of diesel needed to produce QE in barrels
C_D	Annual marginal cost of electricity production using diesel, in US$
C_R	Annual marginal cost of electricity production using renewable energy, in US$
I_R	Investment cost for renewable energy, in US$

***Source**: research findings*

This model maximizes investment for each diesel price, D, from 0 to US$1000/barrel for each investment period, t, to calculate the option value, $V_{D,t}$. We set the dynamic optimization process to 40 years to simulate an investor having time to decide. After that, he must generate power using diesel. For diesel power plant lifespan, the decision is valued at 25 years. T_R is 25 years old to symbolize renewable energy power production. Finally, terminal-period dynamic programming solves the issue backward (Bertsekas, 2012; Detert & Kotani, 2013).

3.3 Stochastic Prices and Monte Carlo Simulation

According to Postali and Picchetti (Postali & Picchetti, 2006), Guedes and Santos (Guedes & Santos, 2016), and Fonseca et al. (Fonseca et al., 2017), diesel prices are stochastic and follow Geometric Brownian Motion (GBM). Dixit and Pindyck (Dixit & Pindyck, 1994) describe the stochastic pricing mechanism as

$$\frac{dP}{P} = \alpha dt + \sigma dz \tag{5}$$

The following regression equation is used in an Augmented Dickey-Fuller (ADF) unit root test to calculate the standard deviation and drift of P:

$$p_t - p_{t-1} = c(1) + c(2)p_{t-1} + \sum \lambda_j y_{t-j} + e_t \quad (6)$$

Where $c(1) = (\alpha - \frac{1}{2}\sigma^2)\Delta t, e(t) = \sigma\varepsilon_t\sqrt{\Delta t}$. We then estimate the maximum likelihood of the drift $\alpha = \mu + \frac{1}{2}s^2$ and variance $\alpha = s$, where α is the mean and *s* is the standard deviation of the series p_t-p_{t+1} (Insley, 2002).

In Equations 4.2 and 4.3, we utilize the Monte Carlo simulation to calculate the estimated net present value of diesel-powered energy production. We begin by approximating a fuel price vector using GBM's stochastic pricing as follows:

$$\mathrm{E}\{NPV_{D,J} \mid P_{D,0}\} \approx \frac{1}{J}\sum_{j=1}^{J} NPV_{D,j} \approx \mathrm{E}\{NPV_D \mid P_{D,0}\}$$
$$P_{D,t} = P_{D,t-1} + \alpha P_{D,t-1} + \sigma P_{D,t-1}\varepsilon_{t-1} \quad (7)$$

As a final step, we estimate the predicted net present value for each starting price node *i* and then run the procedure J=10000 times, averaging the results.

$$\mathrm{E}\{NPV_{D,J} \mid P_{D,0}\} \approx \frac{1}{J}\sum_{j=1}^{J} NPV_{D,j} \approx \mathrm{E}\{NPV_D \mid P_{D,0}\} \quad (8)$$

3.4 Trigger Price Strategy

The preceding sections' dynamic optimization approach yields optimal investment option values. Based on these modeling findings, we determine the following diesel price at which renewable energy sources become economically viable alternatives.

$$\hat{P}_D = \min\{P_{D,t} \mid V_0(P_{D,t}) = V_{T_R}(P_{D,t})\} \quad (9)$$

Where $\hat{P}_D$ is the minimal price at which the value of the option in the introductory period $V_0(P_{D,t})$ equals the value of the option in the swan song phase of the investment $V_{TR}(P_{D,t})$ (Davis & Cairns, 2012; Detert & Kotani, 2013; Dixit & Pindyck, 1994). Based on this calculation, we find that the minimal fuel price at which switching from a diesel power plant to renewable energy sources yields a maximum return.

3.5 Data and Scenarios

This study uses available data parameters and the number of articles to create a subset of investment value scenarios using the binomial choice valuing model. The discrete random process determines the value of authority for investing in each unsettled scenario. The edge for investing in each period is determined to ensure that investment decisions are valued at any operating value.

The final value of each investment is determined by defining a value function that represents the investor's absolute value across all scenarios, which will show zero if there is room for improvement assuming an ideal venture. Due to the venture esteem work, the streamlined model increases the portfolio’s expected worth. When using dynamic process-based approaches in addition to natural equation options, this approach produces more substantial expected portfolio values compared to traditional budgeting models. This increase in portfolio value outweighs managerial decision-making flexibility tenfold and provides greater returns on investment than traditional methods.

Other features of the proposed model are as follows:

1. Identifying Research Model Variables: In this research, the main variables examined are product prices, operating income, and costs, as well as the value of projects.
2. Prices of Plan Products: This study assumes that the cost of products will follow a process that returns to the long-term average.
3. Plans' Income: One of the primary factors determining a design's value is its revenue. This is equivalent to multiplying product cost by units sold.
4. Operating Costs: Operating costs include raw material expenses, human resources, machinery and equipment purchase prices, marketing expenditures, etc. After deducting these operational expenses, revenues determine profits for each period and free cash flow rates for plans.
5. Net Present Value of Plans: Evaluating plans can be challenging when no tradable market equivalent is available. This study used real options and dynamic planning to estimate asset values concerning random price processes during development’s weighting on resulting products.

4. Renewable energy investment portfolio

This study aims to develop a model for a new energy investment portfolio using complete and accurate data. The objective is to select an optimal basket from 10 proposed projects: five power plant projects and five renewable energy projects that have successfully passed the screening stages. Three investment strategies can be defined: EVA’s strategy focuses exclusively on power plant production plans; the second combined strategy includes both power plant and renewable energy plans; and the third entirely focuses on renewable energy projects. The available budget for implementing this project is 80 billion rials.

The table below summarizes free cash flow, required investment amounts, and net present value for each studied project. Projects 1-5 relate to power plant plans, while codes 6-10 include renewable energy plans. Information about product prices, production amounts, and operating costs can be found in justification reports for these projects and market studies related to feasibility.

Estimating random process parameters for product pricing and determining values with traditional approaches or dynamic planning based on natural authority methods is expected to achieve a combination yielding the highest investment value.

Table 3 shows the initial investments required by each project, while tables 4-6 show free cash flows per period (FCF) and net present values (NPV) of each project, as execution flexibility, respectively.

Table 3. Initial Investment Required for Projects (in millions of rials)

Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10
19500	16800	32000	13000	25800	35000	5700	14300	34000	18000

***Source**: research findings*

Table 4: Free Cash Flow of Production Projects (in millions of rials)

Year / Plan	1	2	3	4	5	6	7	8	9	10
1	672	5684	13769	22530	26108	29821	33890	38346	43221	48550
2	6198	7782	8411	10131	14524	16649	19812	24157	29943	37380
3	219	2686	40667	30857	35652	42412	53124	65247	79411	99141
4	3042	5788	9715	11635	13547	15421	21536	22918	28599	32614
5	11904	15042	17091	18721	20734	25995	27080	33733	37585	40492
6	7441	13570	23923	32446	35952	39836	44062	48658	53654	59089
7	3004	3736	4247	4797	6720	7555	8779	10454	12654	15485
8	5040	8144	12459	14599	16733	18827	25522	27082	33316	37739
9	7650	13513	21807	25884	29947	33930	46828	49781	61771	70259
10	7338	10903	12977	14324	16310	22348	23212	30619	34701	37648

***Source**: research findings*

Table 5. Net Present Value of Projects (in millions of rials)

Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10
5514	9188	5374	6379	5176	4283	3273	7183	3110	6331

***Source**: research findings*

Table 6. Flexibility in execution by year

Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7	Plan 8	Plan 9	Plan 10
1	-	2	2	1	-	2	-	1	1

***Source**: research findings*

This section presents the traditional capital budgeting approach to determine the optimal portfolio of new energy investments. The resulting outcome will be binary, with a value of either 0 (indicating that the plan will not be selected) or 1 (indicating that it will be selected and fully funded)

$$\max \sum_{j=0}^{j} npv_j \, x_j$$

S.T:

$$\sum_j I_j \, x_j \leq B \tag{10}$$

$$x_j \in \{0,1\}$$

$$npv = I_0 + \sum_{t=1}^{T} \frac{FCFT}{(1+r)^t}$$

In the above model, the expected return on investment in new energy projects, according to the board of directors' strategy, is assumed to be 50%. Investments with rates of return at 10%, 8%, 7%, 5%, and 4% will generate the highest net present value for investors. Table 7 presents the value of different investment strategies.

Table 7. Value of Investment Strategies Based on the Traditional Approach and Wortinger Model

Investment strategy	plans selected	Net present value of the investment
25%	5-2-1	12879
50%	10-8-7-5-4	27653
100%	10-8-7	17087

Source*: research findings*

4.1 Implementation of a capital budgeting model based on real options and a dynamic planning approach

As previously mentioned, the assumption is that product prices will return to their long-term average. In order to describe this random price process, modifications are applied to an Ornstein-Olenbeck process using the Schwartz model.

$$dx_t = \alpha(\mu - x_t)d_t + \sigma dz_t \quad , \qquad \mu^* = \mu - \frac{\sigma^2}{2\alpha} \tag{11}$$

$$X_{t+1} = \beta_0 + \beta_1 X_t + \varepsilon_t$$

Normalization was performed using the Max-Min method, followed by weight selection from experts using the AHP method to determine these indicators. As there was relative agreement in behavior between both indicators derived from long-term average return plans' random product pricing processes, their respective parameters, including standard deviation and rate of average return, were investigated using the Schwartz model and the Ornstein-Olenbeck process. Table 8 shows the process parameters of a product price index.

Table 8. Process parameters of product price index

Price index process parameters			Price index process parameters		
Standard deviation σ	Long-term average μ	Average return rate α	Standard deviation σ	Long-term average μ	Average return rate α
0.17	0.83	0.28	0.14	0.74	0.37

***Source**: research findings*

Assessing the underlying VC plans' potential upsides for each future is necessary to address the real options issue with dynamic planning. The value of each project can be estimated using the Guthrie binomial model, and up and down motion values can be determined based on the random process parameters calculated in Table 9. This will involve taking one-year time steps and calculating probabilities for moving up at the end of each node as follows:

Table 9. Magnitude and Probability of Upward and Downward Movements in a Binomial Tree

Equipment	material
U=1.18	U=1.15
D=0.843	D=0.869
π=0.672	π=0.749

***Source**: research findings*

Estimating a plan's value begins with calculating its net present value and multiplying it by appropriate values for upward and downward movements in the binomial tree. This estimation is then performed over five years as follows:

$$V_{i,\mathrm{n}} = V_{0.0} \cdot U^{\mathrm{n}-i} \cdot D^{i} \qquad (12)$$

In this case, the final probability at the starting node equals one. Creating these scenarios involves repeating calculations and generating two methods for each year's price increase and decrease. Tables 10-13 illustrate the value estimation for each plan in the strategy.

Table 10: Estimation of Plan Value for Each Strategy

Year	base	Year 1	Year 2	Year 3	Year 4	Year 5
strategy	v_{00}	v_{01}	v_{02}	v_{03}	v_{04}	v_{05}
		v_{11}	v_{12}	v_{13}	v_{14}	v_{15}
			v_{22}	v_{23}	v_{24}	v_{25}
				v_{33}	v_{34}	v_{35}
					v_{44}	v_{45}
						v_{55}

***Source**: research findings*

Table 11. Estimating the value of the plan in a complete investment strategy

Year	base	Year 1	Year 2	Year 3	Year 4	Year 5
value (Milion Rials)	2188	14157	20544	34269	41510	47386
		7545	15974	24903	30265	38054
			9756	17547	25430	30464
				10702	20247	24571
					18985	22049
						21763

***Source**: research findings*

Table 12. Estimation of project value in hybrid investment strategy

Year	base	Year 1	Year 2	Year 3	Year 4	Year 5
value (Milion Rials)	13654	26724	46125	63731	72605	86954
		22448	38283	54059	65952	70551
			25547	40997	54274	67577
				38422	42955	54301
					40704	54769
						53518

***Source**: research findings*

Table 13. Estimation of project value in production investment strategy

Year	base	Year 1	Year 2	Year 3	Year 4	Year 5
value (Milion Rials)	11466	61628	30958	36106	52605	60247
		18527	23937	27246	33331	49542
			20310	33726	30997	45214
				18712	29080	40287
					20785	37885
						32911

***Source**: research findings*

The next step involves determining the investment threshold's value by evaluating the arrangement's worth at various time points in the project tree, and this will enable us to identify optimal investment policies using real options theory and dynamic planning. To accomplish this, we can use the Bellman equation. We can solve for simple scheduling options through a binomial network by determining continuity values. The Bellman equation is expressed as follows:

$$f_t = \max\left(v_t - I.\frac{1}{rf}\varepsilon(f_{t+1})\right) \tag{13}$$

The continuity value (ε) for *f(t+1)* is equivalent to the expected value of *F* in the following node:

$$\varepsilon(f_{t+1})_t = \pi_{i,n} f_{i,n+1} + (1 + \pi_{i,n}) f_{i+1,n+1} \tag{14}$$

Incorporating the continuity value (ε) into the Bellman equation allows us to account for the expected future rewards obtained by following an optimal policy from state *f(t+1)* onwards. This is important because our goal in dynamic programming and reinforcement learning problems is often to maximize cumulative rewards over a sequence of states. The Bellman equation expresses the value function of a given state as a combination of immediate reward and discounted values of all possible following states weighted by their probabilities under current policies. By incorporating continuity values into this equation, we can make more informed decisions about which actions to take at each stage. In practical terms, we can optimize our decision-making process over time and arrive at better solutions for complex optimization problems with many possible outcomes. Incorporating continuity values into the Bellman equation helps us take a long-term perspective on problem-solving, allowing us to achieve better performance and efficiency in dynamic programming tasks such as pathfinding or resource allocation.

$$f_{i,n} = \max\left(v_{i,n} - I.\frac{1}{rf}\pi_{i,n}f_{i,n+1} + (1+\pi_{i,n})f_{i+1,n+1}\right) \quad (15)$$

In your study, investment decisions are made only once a year, and specific nodes in the decision tree do not require further judgment. Investing in that option is only possible if a node requires a decision. In such cases, the value of that investment option is considered equal to its continuation value.

To solve this problem, researchers determine the final point for decision-making and optimize all previous decisions by working backward through the tree. It is worth noting that in this research project, they assumed a risk-free rate of return of 10%.

As we make investment decisions at each node in the decision tree, there may be points where our expected returns have reached their maximum potential values. When no further room for growth exists, or an alternative path leads to better outcomes elsewhere within our model structure (i.e., another branch), those specific nodes will typically disappear from view altogether while retaining their current value as zero. Overall, considering risk-free rates of return and optimizing past decisions can help us make more informed choices as we navigate complex decision trees with many possible outcomes.

Hence, the decision problem involves choosing between immediate investment and making an optimal decision based on traditional investment principles (i.e., where $V > I$). We can arrive at an optimal, robust decision over time by applying relevant equations and using return inference. For instance, Table 14 in our example shows how to calculate option values for two cycles within a two-cycle tree. This type of analysis allows us to evaluate different investment options against one another and make more informed decisions about which path offers the most outstanding potential returns given our constraints and objectives. By incorporating mathematical models into our decision-making processes, we can optimize our investments over time and achieve better outcomes in complex financial scenarios.

Table 14. The value of the investment scheduling option in a binomial tree

$f_{i,n}$	0	1	2
0	$\max\,(v_{00} - I.\,\varepsilon_{00}(f))$	$\max\,(v_{01} - I.\,\varepsilon_{01}(f))$	$\max\,(v_{02} - I)$
1		$\max\,(v_{11} - I.\,\varepsilon_{11}(f))$	$\max\,(v_{12} - I)$
2			$\max\,(v_{22} - I)$

Source*: research findings*

After creating the binomial tree, the researcher defined the option value using the sub-equation value *V**. Thus, one can evaluate each investment option within a given cycle based on its expected returns compared to waiting for a later period. It may be worthwhile if an investor can delay making an investment decision without significant negative consequences. By calculating *V**, we can determine whether or not it is optimal to invest immediately or wait until a later point when more information is available.

This analysis requires careful consideration of risk tolerance and market volatility factors. By incorporating these variables into our decision-making process, we can arrive at more informed decisions about allocating our resources over time and maximizing potential returns while minimizing risks.

$$V^*{}_n - I = \frac{\pi_{i,n} f_{i,n+1} + (1 + \pi_{i,n}) f_{i+1,n+1}}{RF} \tag{16}$$

Table 15 shows the provincial investment value for the three strategies.

Table 15.Provincial investment value for the three strategies

Investment strategy \ Year	1	2	3	4	5
25 %	10689	15518	25874	31342	35776
50 %	20177	34824	48117	54817	65653
100 %	21605	23101	27260	39717	45507

Source*: research findings*

The strategies are represented by percentages in column 6 of the table - 25%, 50%, and 100%. The investment values associated with each strategy are listed in columns 1-5, representing different scenarios and up and down motion probabilities.

It is important to note that these estimated values are subject to change based on market conditions, government policies or regulations, etc. As such, it is crucial to regularly review and update investment strategies to ensure they remain aligned with changing circumstances.

Regarding the optimization model mentioned in the statement, the final expected value of an investment should be determined based on a threshold value (v_j) of a given plan (*j*) at a specific point in time (*t*). This approach allows investors to focus only on optimal investments while minimizing risks and maximizing returns.

If the expected value for future periods exceeds a project's current net present worth, this function assumes that the investment value is zero. In ideal scenarios, the final asset value equals the probability of its occurrence multiplied by its scenario outcome. The project's profitability is determined by subtracting any investment costs from this amount.

Thus, an investment value tree can be created for scenarios (*k*) and periods (*t*). This currency function forms two iterations of such a tree. Figure 1 illustrates how this process works over two years. By utilizing this approach to model potential outcomes, investors can make informed decisions about which investments will most likely yield positive returns while minimizing risks associated with market volatility or other factors that may impact performance.

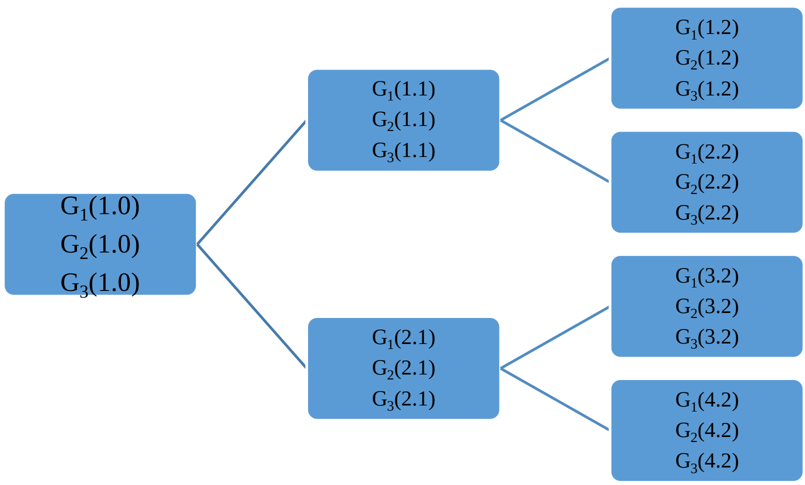

Figure 1. The final expected valuation tree of the investment
Source*: research findings*

The above schema serves as input for Myers's dynamic improvement model, which aims to enhance the net present value of a portfolio in all scenarios while accounting for budget constraints. In one particular situation, waiting to invest is not an option since it results in a loss of opportunity. Various strategies must be defined by creating a vector and copying $G_j(t.t)$ for each associated method at every node. The result is a grid with j × t × p elements where each row represents a scenario, and each column corresponds to a time step.

However, additional constraints are required to ensure that decision variables remain consistent across all copied values relative to their parent nodes within the scenario tree. This approach can help investors make informed decisions about investments that maximize returns while minimizing risks associated with market volatility or other factors that may impact performance.

A constraint is created using the extensive M method to ensure consistency across all copied decision variables relative to their parent nodes. This approach ensures that all copied variables are either zero or equal to the number of nodes that have been copied.

The total number of nodes for each scenario in vector format (p) is defined as N, where p represents the given situation. Note that scenarios within the scenario tree do not address different aspects but instead provide data about each situation in the decision tree.

With these considerations in mind, we can create a new model with updated constraints and decision variables as follows:

$$\begin{aligned}
& max \sum_{j=1}^{J}\sum_{t=0}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} e^{-t\Delta t.r} x_{j.t.s.p} \frac{G_{j.t.s.p}}{N(p)} \\
& s.t \sum_{t=0}^{T}\sum_{j=1}^{J}\sum_{P=1}^{P} I_j x_{j.t.s.p} \leq B \qquad S = 1 \ldots\ldots S \\
& s.t \sum_{t=0}^{T}\sum_{P=1}^{P} X_{j.t.s.p} \leq 1 \quad s = 1 \ldots\ldots s \quad j = 1 \ldots\ldots J \\
& s.t = \sum_{s=1}^{S} x_{j.t.s.p} \leq 0 + M(1 - y_{t.p}) \;\; t = 1 \ldots\ldots T \;\; j = 1 \ldots . j \quad p = 1 \ldots . p \\
& s.t = \sum_{s=1}^{S} x_{j.t.s.p} \leq N(p) - My_{j.p} \qquad t = 1 \ldots\ldots . T \;\; j = 1 \ldots\ldots J \quad p = 1 \ldots . P \\
& s.t \; x_{j.t.s.p} \epsilon \{0,1\} \quad s = 1 \ldots S \quad t = 1 \ldots T \;\; j = 1 \ldots J \;\; p = 1 \ldots . P
\end{aligned} \tag{17}$$

By incorporating these techniques into our investment strategies, we can make more informed decisions about which investments are most likely to yield positive returns while minimizing risks associated with market volatility or other factors that may impact performance.

The abovementioned problem involves maximizing the sum of the final expected investment values in matrix nodes. To avoid counting a scenario multiple times, $G_{j\text{tsp}}$ is divided by the number of copied vector values (*n(p)*) to obtain a normalized worth. Additionally, there is a constraint that allows investing in a project only once per situation while ensuring consistency with its original node in the scenario tree.

Another constraint requires all decision variables to be either zero or one. In this model, the total number of variables equals the number of hubs within the grid. Table 15 displays results from calculations using FICO software for expected final portfolio value and adjusted Myer's model based on options value at each period across three different strategies examined. By incorporating these techniques into our investment strategies, we can make more informed decisions about which investments are most likely to yield positive returns while minimizing risks associated with market volatility or other factors that may impact performance.

Table 16. The final value of the investment is adjusted, taking into account the value of the deferral option in Myer's model

Strategy	Selected plans						Final value ($ million)
	Base year	Year 1	Year 2	Year 3	Year 4	Year 5	
Power plant	2	2-5	3-5	1-2-4-5	1-2-4-5	1-2-4-5	32.295
renewable energy	2-6-8	1-2-6-9	2-4-7-9	2-5-7-9	2-4-7-8	2-4-7-10	60.161
Together	6-8	6-8-10	7-8-10	7-8-9	6-8-9	6-8-10	43.428

***Source**: research findings*

The table displays the selected plans, corresponding expected values for each year (year 5 through year 1), and a base year. The strategies listed include a power plant, renewable energy, and a together plan. For example, in the power plant plan strategy, selecting investment plans 1-2-4-5 yields a final value of $32.295 million after five years. In contrast, choosing different investment plans results in lower expected returns over time.

By considering deferral options within Myer's model when making investment decisions, investors can better evaluate potential outcomes and make more informed choices about which strategies will most likely yield positive returns while minimizing risks associated with market volatility or other factors that may impact performance.

4.2 Electricity Price Scenario

Changes to the cost of power in the area are reflected in this scenario via changes to the option values and the trigger price. The dynamics of option values with changing power prices are shown in Figures 2 and 3. When power rates rise, option prices rise along with them. The value of both renewable energy and diesel-based power rises as the price of conventional electricity rises. From the initial electricity price of US$202/MWh, diesel trigger prices rise to US$172/barrel at US$220/MWh and US$185/barrel at US$250/MWh. Results show that rising electricity costs discourage immediate investment in renewable power sources.

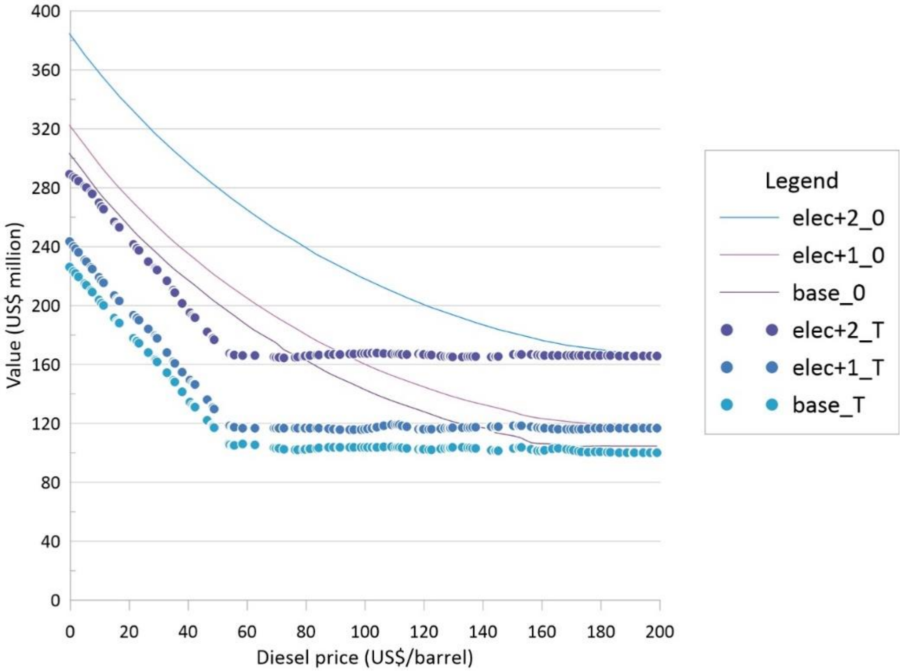

Figure 2. Option values at increasing electricity price scenario
Source*: research findings*

Take note of the following notations: base 0 -option values of energy investment in the beginning period; base T -option values of energy investment in the end period; elec+1_0 -option values at electricity prices 10% higher than the base in the beginning period; elec+1_T- option values at electricity prices 10% higher than the base in the end period; elec+2_0 -option values at electricity prices 25% higher than the base in the beginning period; elec+2_T

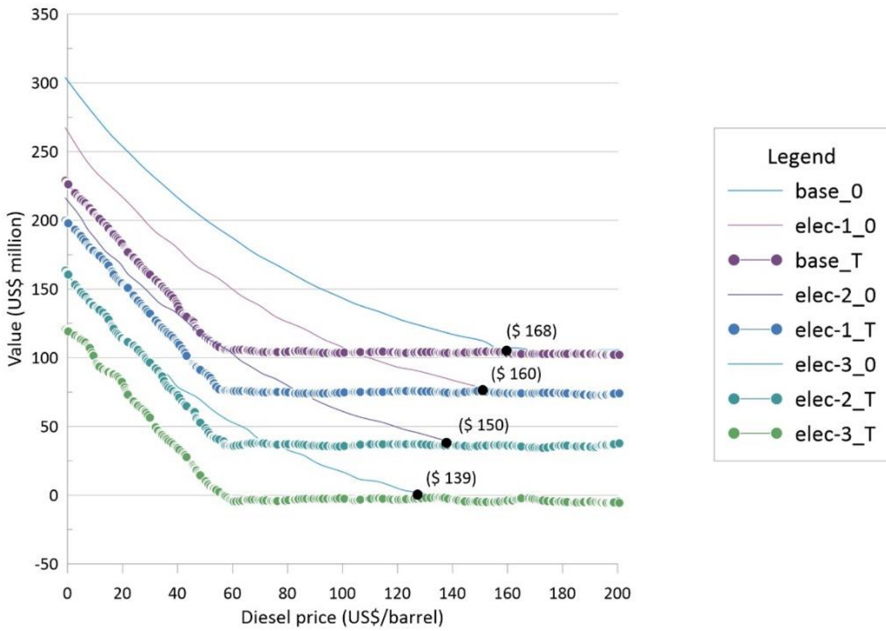

Figure 3. Option values at decreasing electricity price scenario
***Source**: research findings*

The following values should be noted: base 0 -option values of energy investment at the beginning of the contract; base T -option values of energy investment at the end of the contract; elec-1_0 -option values at 10% lower electricity price than the base at the beginning of the contract; elec-1_T -option values at 10% lower electricity price than the base at the end of the contract; elec-2_0 -option values at 25% lower electricity price than the base at the beginning of the contract.

However, When electricity costs drop, the option value curves change lower, bringing the diesel trigger price down. Reduced income and profits are predictable outcomes of a decline in power prices. At electricity costs of US$180/MWh, US$150/MWh, and US$120/MWh, diesel trigger prices drop to US$160/barrel, US$150/barrel, and US$139/barrel, respectively (Figure 4). Results indicate that the time needed to invest in renewable energy might be shortened if power prices were lowered. Furthermore, the option values become negative at power prices below US$120/MWh. Policymakers and power generators can only afford to set the price of electricity at a maximum of US $ 120/MWh since doing so would lead to a loss when generating power from diesel and discourage investment in renewable sources.

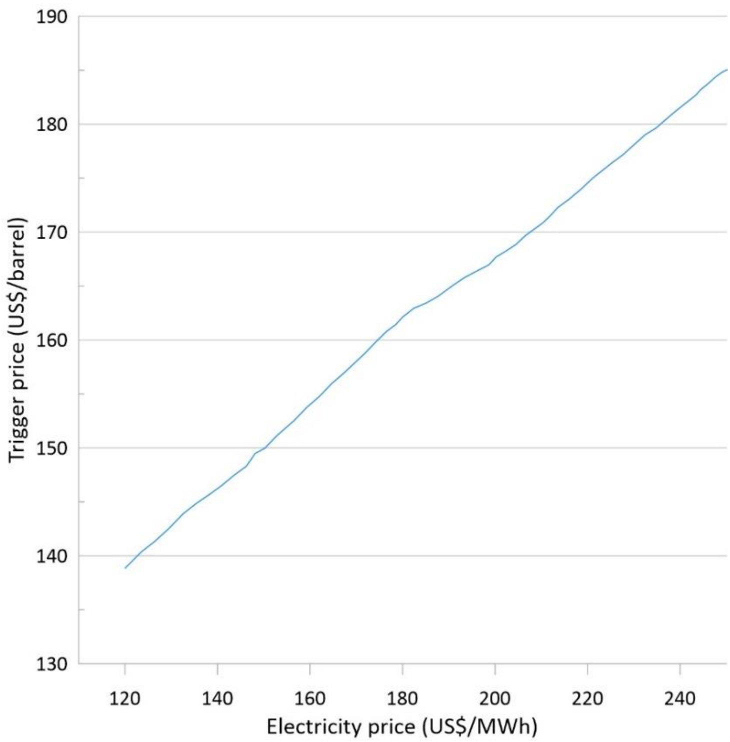

Figure 4.Trigger prices of diesel over electricity price
***Source**: research findings*

The figure indicates domestic power costs at which a change in electricity generation strategy from bunker fuel to solar PV will be triggered.

5. Conclusion and Policy Implications

The research literature suggests that traditional approaches to cash flow reduction underestimate the value of new energy investments in uncertain environments, particularly when considering Lara. Relying solely on these methods could lead to incorrect decisions; therefore, they may not be appropriate.

The cash flow discount method for valuing new energy investment opportunities has some areas for improvement, leading to the consideration of alternative approaches for capital budgeting and portfolio selection. The research literature suggests that natural authority-based analyses are appropriate for valuing capital opportunities in new energy investments. It also highlights the significance of calculating managerial flexibility in decision-making when assessing investment opportunities.

Three management strategies, two investment groups, and scenarios of increasing or decreasing value in each period must be considered when investing in new energies. Relying solely on discounting the present value of projected revenue and Wein Gartner's objective function may lead to a stagnant approach without considering managerial decision-making flexibility. However, we can determine an investment value tree using the Myers objective function by defining random finds of product group prices and factoring in real options for delaying decisions made by management dynamically.

This dynamic approach leads to determining optimal portfolios with combined strategies comprising different plans than those suggested by traditional methods. Compared with static approaches without considering flexibility and uncertainty, this dynamic approach yields almost twice the estimated portfolio value due to the option value associated with delayed processes. Despite its potential advantages over traditional methods, this model has limited implementations.

This research considers the random process of product prices as the primary factor in estimating plan value. A more accurate model accounts for uncertainty factors; it is recommended to study random processes separately. Furthermore, decision trees with longer time horizons could provide more precise estimates of innovative plan value when implementing the dynamic method.

We assess Iran's investment conditions and decision-making processes for replacing diesel power plants with RE. We calculate option values, diesel trigger prices, and RE investment value under diesel price uncertainty using actual options. Investment choices are sensitive to power costs and fuel externality taxes. ROA emphasizes investment timing flexibility. Our findings show that a developing nation heavily reliant on imported diesel should switch to RE. Policies should discourage fossil fuel use or lower power prices to encourage investment in renewable energy. Power producers may suffer but switch to renewable energy.

Replacing diesel with RE for electricity production is a novel energy investment strategy. This research's ROA framework is a promising benchmark. ROA may consider environmental and social consequences. Deforestation for solar farms, animal and habitat loss, air and water pollution, public health impact, and employment loss may be involved—finally, RE resource analysis. We hope this study advances sustainable energy investment analysis.

However, finding suitable solutions within this complex analysis takes time and effort. Real-world situations often involve modeling several uncertainties and require a more comprehensive approach to problem-solving. The literature presents various project selection issues, including selecting portfolios for multi-period renewable energy projects based on criteria beyond financial standards.

In summary, this research focuses on portfolio selection for renewable energy investments while accounting for uncertain factors and non-financial criteria. While challenges remain in finding optimal solutions under these circumstances, advances in modeling techniques can help address these complexities and lead to better investment decisions.

Author Contributions

Conceptualization, all authors; methodology, all authors; validation, A. Arasteh; formal analysis, M. Aghaei; resources, M. Aghaei; writing—original draft preparation, M. Aghaei; writing—review and editing, A. Arasteh; supervision, A. Arasteh. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest:

The authors declare no conflict of interest.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available in the paper.

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