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Technoeconomic Evaluation of Commercial- and Industrial-Scale Solar Plants in Iran Under a New Purchasing Power Agreement (Ppa) Framework: Case of the Yazd Solar Project

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Abstract
The solar industry is booming worldwide, providing stable and secure energy and combating environmental threats. Currently, investments in renewable energy are increasingly overtaking investments in all other forms of energy. In this study, the potential for investment in commercial and industrial-scale solar plants in Iran under the new terms of the PPA is assessed. Iran has faced seasonal power deficits and has consolidated renewables to address these imbalances. Therefore, the state ratified regulations for two key market segments—industries and governmental bodies—to adopt renewable energy. The new Iranian PPA guaranteed a feed-in tariff (FiT) for more than 20 years, and to facilitate power transactions, a green trade board platform was introduced within the energy stock market. This platform is dedicated to suppliers and industries for trading electricity with minimal state intervention. Accordingly, in this paper, for the first time, an economic analysis of commercial-scale solar energy is conducted in a new market environment. For this purpose, a case study of a 1 MW solar capacity in YAZD Province under new PPA terms is analyzed. Stochastic studies using Monte Carlo simulations were performed to evaluate the risk factors. The five main key variables change with a triangular basis in 10,000 iterations to provide the probability density function (PDF) of the financial results. The median (P50) of the net present value (NPV) is $1.8 million, and the internal rate of return (IRR) is 25%. The results of this study show substantial economic returns for investors, considering a new market opportunity.

Keywords: Renewable Energy, Economic Evaluation, Energy Policy, Stochastic Study, Monte Carlo Simulation

Competing Interest: The authors declare that they have no relevant financial or non-financial interests.

Introduction
The electricity deficit in Iran has become a major problem in recent years. In the summer of 2021, the power shortage reached a level of 12 GW, followed by a 17 GW electricity shortage in the summer of 2024 [1,2]. The gas shortage during winter led the country to burn Mazut for power generation. The role of renewables is essential for energy diversification, ensuring energy security and economic stability [3]. According to the Energy Institute's Statistical Review of World Energy 2025, over 85% of the country's electricity generation was derived from natural gas resources in 2024 [4]. Likewise, the World Bank Energy Sector Management Assistance Program report in June 2020 shows that Iran ranked 25th in the world in terms of partial solar PV potential [5]. Additionally, statistics from the International Energy Agency (IEA) estimate that the global clean energy investments in 2024 are almost twice the investment in fossil fuels [6]. This tends to lead to a remarkable cost drop for new PV modules, culminating in a decline in the levelized cost of electricity (LCOE). According to Lazard's levelized cost of energy analysis (version 16.0), the LCOE of the solar PV utility

scale declined from $359/MWh to $60/MWh between 2009 and 2023 [7]. Likewise, on the basis of the International Renewable Energy Agency (IRENA) report 2023, the weighted average utility-scale photovoltaic LCOE decreased substantially from $460/MWh in 2010 to $44/MWh in 2023 [8]. Wood Mackenzie reported an average of $60/MWh for fixed-axis solar PV systems in 2024 [9]. Considering these values, PV power units are competitive with conventional thermal power plants in countries with large fossil fuel reserves. Reza Bakhshi-Jafarabadi et al. (2020) reported that the LCOE of residential scale grid connected PV (GCPV) with a capacity of 120 kwp in Iran was 0.0477 $/kwh in 2017 [10]. Similarly, another study in Saudi Arabia by Ahmed Saeed et al. (2024) reported the LCOE for 1-MW capacity grid-connected floating PVs at three locations, Riyadh, Mecca, and Bisha, which were approximately 0.053, 0.057, and 0.063 $/kWh, respectively [11]. According to Mousavi Reineh et al. (2021), the LCOEs of steam turbines, gas turbines, and combined cycle gas turbine (CCGTs) in Iran are approximately 0.0446, 0.0403, and 0.0219 $/kWh, respectively, owing to low fuel costs [12]. Furthermore, when the liberated fuel price is used, the LCOEs will change tremendously to 0.2063, 0.2791, and 0.1781 $/kWh, respectively.

In this study, the LCOE of a 1 MW solar PV system in Yazd Province was calculated to be approximately 0.04 $/kWh. A summary of these estimations is presented in Table 1.

Power Plant	Capacity	Country	LCOE ($/kwh)	Year	Source
Solar PV	Utility-scale	Entire World Average	0.06	2023	Lazard
Solar PV	Utility-scale	Entire World Average	0.04	2023	IRENA
Solar PV fixed-axis	Utility-scale	Entire World Average	0.06	2024	Wood Mackenzie
Grid-Connected PV	Residential-scale	Iran	0.05	2017	Reza Bakhshi-Jafarabadi et al
Grid-Connected Floating PV	Commercial & Industrial-scale	Saudi Arabia	0.06	2024	Ahmed Saeed et al
Steam turbine	Utility-scale	Iran	0.04	2021	Mousavi Reineh et al
Gas turbine	Utility-scale	Iran	0.04	2021	Mousavi Reineh et al
CCGT	Utility-scale	Iran	0.02	2021	Mousavi Reineh et al

Table 1: LCOE Estimations for Different Power Plants and Condition

Literature Review

Electricity has become a major problem in Iran, and the power imbalance hit a historical record of 17 GW in the summer of 2024 [13]. Likewise, gas consumption has increased remarkably at an unprecedented pace, which threatens the main source of power generation [14,15]. Natural gas accounts for almost 69% of primary energy consumption, whereas it accounts for more than 85% of power generation [16,17].

Similarly, fossil fuels account for more than 94% of the power produced in Iran, culminating in massive reserve depletion, air pollution, and hazardous social and environmental implications [18]. The study conducted by Arash Sadeghi and Taimaz Larimian (2018) on the sustainable electricity generation mix for Iran used the fuzzy analytical network process (ANP) to determine the most efficient energy mix [19]. According to the authors, in the best energy mix of Iran, the share of renewables would be 32%, whereas the share of fossil fuels would equal 47%, including 25% natural gas. Surprisingly, in the study by Aryanpur et al. (2019), the same results were obtained, contributing to 32% of nonhydro renewables [20]. Similarly, Farnoosh (2016) conducted an economic optimization analysis of Iran's power generation portfolio and concluded that an optimal strategy would involve sourcing approximately 36% of electricity from renewable energy technologies [21]. Portfolio theory is applied to identify scenarios characterized by minimal cost, median performance, and reduced risk. Despite its promising potential, the transition to sustainable energy faces numerous challenges. Solatni et al. (2024) employed the fuzzy analytical hierarchy process (fuzzy AHP) to systematically examine these impediments [22]. Their findings indicate that the most significant barriers to achieving a flexible energy mix are restrictive governmental policies and inadequate financial support mechanisms. Many studies have focused on the technoeconomic evaluation of various solar technologies worldwide. For example, Boruah and Chandel focused on a grid-connected photovoltaic system with battery storage [23]. The economic results for a simple 200 kwp solar photovoltaic + battery energy storage system show an IRR fluctuation of 10–20% with a payback period (PBP) of approximately 6–11 years. Similarly, according to the assessments of Seyed Mousavi et al. (2024), the grid-connected photovoltaic system with a capacity of 102 kW in the Mashhad waste management organization building contributes to an IRR of 34.5% and a PBP of approximately 8 years, with a benefit cost ratio (BCR) of 1.6 [24]. The same study by Reza Bakhshi-Jafarabadi et al. (2020) for the economic evaluation of commercial grid-connected PV, with a capacity of

120 kwp, which is a case study in Iran, has the following results: NPV of $271,006, BCR of 2.717, IRR of 31.88%, PBP of 5 years, and LCOE of 0.0477 $/kWh [9]. In addition, some authors have provided insights into innovative solutions to enhance solar capacity factors. Noorollahi et al. showed how solar collectors can replace natural gas for heating buildings in Iran, with a reduction in both energy costs and CO2 emissions [25]. In addition, the study of grid-associating 10 MWp solar PV at UP India by Singh et al. (2022) revealed an emission reduction of approximately 19,546 tCO2/year [26].

Sakhr M. Sultan et al. (2024) described the effect of reflectors on power efficiency for both solar PV grid-connected and battery storage systems [27]. In Iran, according to the Renewable Energy and Energy Efficiency Organization (SATBA), the cumulative power generated from nonhydro renewable sources of energy until March 2025 is approximately 14,000 million kwh, with a total installed capacity of 1.6 GW [28]. Likewise, owing to this report, the cumulative GHG emission prevention capacity is approximately 8.7 Mt CO2 equivalent.

There are many criteria for selecting the best location to obtain the maximum revenue. Navid Hooshangi et al. (2023) reported that approximately 14% of the country's land is suitable for a solar power plant [29]. The measurement of solar irradiation is essential for many applications, and several empirical models have been developed to estimate solar irradiation for different areas in developing countries (S.M. Robaa, 2009). M.R. Shahnazari et al. (2017) used irradiation data for YAZD city to model concentrated solar power (CSP) for generating utility-scale electricity [30,31]. They reported that the city's average solar insolation is approximately 1800 kwh/m2/yr. Similarly, according to studies by Shorabeh et al. (2019), the country has, on average, more than 2800 h of sunlight, with an average annual solar irradiation of 2200 kWh/m2 [32]. There are many criteria for selecting the best location. For example, Firozjaei et al. (2019) used the solar radiation normalized difference vegetation index (NDVI), distance from roads/cities, and slope to evaluate desirable sites [33]. Similarly, Asakereh et al. (2017) reported that the land in Khuzestan Province was capable of generating as much as 1.75 times the entire country's power consumption in 2013 [34]. The same study by Charabi et al. (2011) shows that by implementing the CPV in Oman and suitable lands, it is almost viable to generate approximately 45.5 times the country's power consumption [35]. In this study, using insights from other scholars, Yazd Province is considered the best location. This area has an average global horizontal irradiance of 20.41 MJ/m2 and a clearness index of 0.66 (H. Khorasanizadeh et al, 2014), with mostly sunny days [36]. The construction of a CSP power plant in 2009 (Kasra Mohammadi et al. 2019) close to the Shirkoh power station in Yazd was one of the first solar projects in Iran [37]. Similarly, in light of the study by M.R. Shahnazari et al. (2017), the case of the Yazd power complex appears to be the best suited for large-scale utility plants in Iran [38]. Ultimately, for this study, locations close to YAZD city (approximately 30 min by car) with latitudes and longitudes of 32.101167° and 054.263389°, respectively, were selected. Topographic and satellite images of this location, map data, and solar azimuth elevation trends are shown in Figure 1. According to the Global Solar Atlas (GSA) report for this area, considering a 1 MW solar plant, a total of 1.76 GWh of electricity with an average tilted irradiation of 2306.7 kwh/m2 per annum is expected [39].

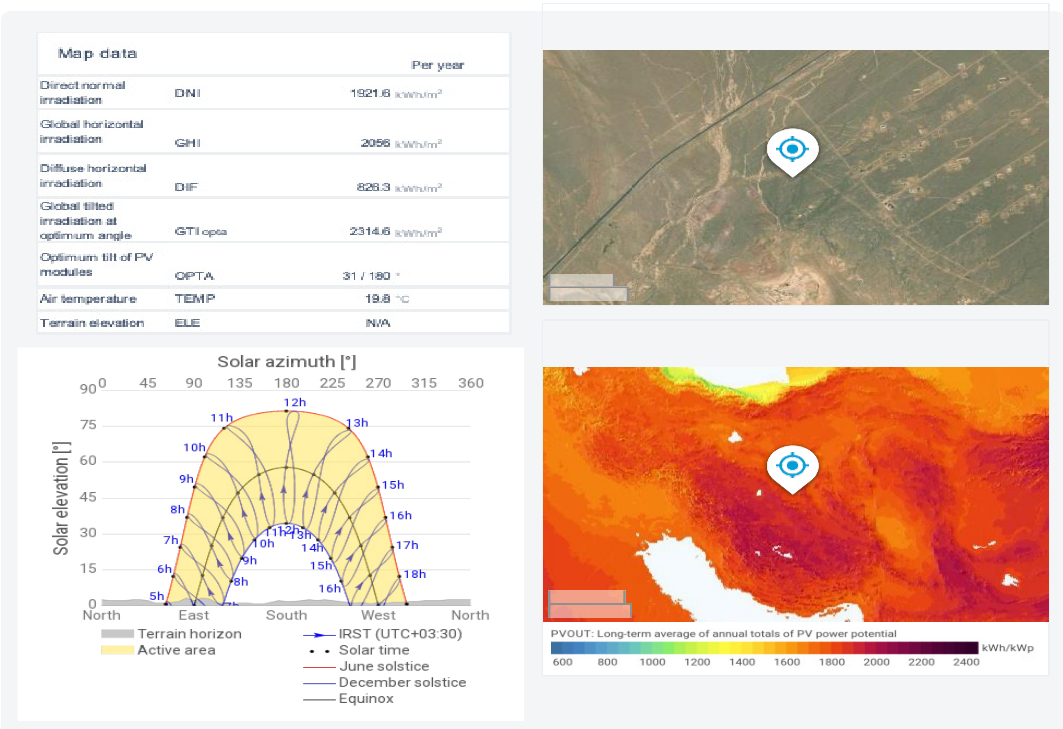

Figure 1: Satellite and Topographic Images, Map Data, and Solar Azimuth Elevation Trends of the Selected Location Close to YAZD City, Using GSA

In this study, using the data available from elevation finders, such as Vividmaps, the location is estimated to be at 1121 m above sea level [40]. An average air temperature of approximately 20°C indicates entirely desirable climatic conditions for mitigating operation and maintenance (O&M)-related costs.

The annual power output trend peaks in August at approximately 165,000 kWh, whereas it hits the troughs by December, with total power generation of approximately. 123,000 kWh.

Methodology

The main objective of this research is to assess the potential of Iran's solar industry as a sustainable solution for meeting future energy demands under the revised Power Purchase Agreement (PPA) terms. These new terms offer various opportunities through the recently launched Green Trade Board—a platform inaugurated in June 2023 that connects numerous renewable energy suppliers with industries requiring additional electricity during outages. This energy, referred to as "green electricity," is subject to a newly implemented renewable tariff.

Under the new PPA framework, the state guarantees the purchase of electricity. However, suppliers are also allowed to trade their energy competitively within the energy stock market. If electricity remains unsold on the Green Trade Board, the state is obliged to purchase it at the official feed-in tariff (FiT), which is 30% lower than the green electricity price.

An economic evaluation of solar plants at commercial and industrial scales is also conducted, incorporating strategic planning tools such as environmental scanning and situation analysis. The Iranian energy sector is examined with consideration of future uncertainties. Critics often argue that risk-averse investors are reluctant to engage in business within unstable environments. Therefore, ensuring investment security is essential before any financial gains can be realized. The key prerequisites include sociocultural consumer behavior and prevailing industrial economic conditions. Additionally, political stability plays a crucial role, as it affects the consistency of regulatory frameworks and policy initiatives.

To comprehensively evaluate the solar industry's viability, this section addresses all relevant factors and presents strategic roadmaps for economic analysis. A PESTEL framework is applied to examine the external influences impacting the industry, offering detailed insights into the environment in which it operates . Porter's five-force model is subsequently utilized to analyze internal dynamics and their implications. To consolidate these findings, a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) is performed to determine the overall attractiveness of solar energy investments in Iran.

The methodology for assessing the economic feasibility of a 1 MW solar power plant in Iran is also outlined. In the first phase, key project costs—including capital expenditure (CAPEX), operation and maintenance (O&M), dismantling expenses, and levelized cost of electricity (LCOE)—are evaluated. The second phase involves a market analysis to understand pricing trends. The third phase focuses on constructing a business model for the base case. Finally, a Monte Carlo simulation is conducted using the model's core variables to perform a probabilistic analysis.

The next section elaborates on the initial phase in detail.

Solar Industry Macro Analysis

This section examines the macroeconomic determinants influencing the industry, applying the PESTEL framework—political, economic, social, technological, environmental, and legal factors. Alipour et al. (2019) employed a fuzzy cognitive map (FCM) methodology to assess prospective scenarios for the development of solar photovoltaic (PV) systems in Iran [42]. Their findings indicate that economic and political variables exert the most significant influence on project outcomes. Comparable investigations have been conducted in analogous contexts. For example, Castro Antonio Soares et al. (2023) utilized the PESTEL framework to perform a comprehensive analysis of Mozambique's mini-grid solar initiatives [43]. Their study underscores the centrality of political considerations in shaping policymakers' priorities.

In summary, the literature suggests that political and economic factors have the potential to substantially—and often contentiously—affect the business landscape. Subsequent sections offer a more granular exploration of these influences.

Political

This factor can reversely impact the business due to political tensions, frequent policy and paradigm shifting, and other factors that can insecure investments. The National Development Plan goals are set to emphasize the role of renewables in the country's energy mix. According to the United Nations Development Program (UNDP) report, Iran aims to increase its renewable capacity to 30,000 MW and reduce power consumption by 10,000 MW by 2030 [44]. With only 1,500 MW of current installed capacity (by the end of 2024), it seems that this goal is somewhat optimistic, and it will require an additional capacity of almost 6,000 MW per annum for the next five years, requiring a total of 3 billion USD each year. Likewise, government initiatives, such as customs duty exemptions and additional electricity taxes to fund renewable projects, are part of the state incentives [45]. Nevertheless, considering the significant implications of sanctions, the political factor is considered to negatively impact business

Economic
This factor is also negative in regard to launching any business in the domestic market. According to the World Bank, after the implementation of US and EU sanctions in 2012, foreign direct investment inflows in Iran fell by 94% until 2023 [46]. The GDP decreased by 37%, followed by GDP per capita by 45%. The average consumer price index changes (inflation rate) increase by 17%, whereas the unemployment rate decreases by 3%. The consumer's and business's disposable income is not attractive, which can have implications for project economics.

Social
Society in Iran is assessed by Hofstede's cultural dimensions. This theory is a dimensional tool that enables comparisons of cultural differences across countries [47]. The results of this assessment for Iran show a "power distance" rank of 58, indicating a hierarchical society. The "individualism" score is 23, which reflects a collectivistic cultural structure. Similarly, the country's rank in "motivation toward achievement and success" is 43. This shows that society is relatively stable and that people prefer not to show their achievements. The "uncertainty avoidance" score is 59, which shows that there is high resistance to the uncertain alternatives. Similarly, the next dimensions' scores for "long-term orientation" and "indulgence" are 59 and 30, respectively. These rankings show that society has great respect for traditions and is so reluctant to save money and invest.

Social aspects are taken into account in various studies by other authors, who consider different key factors. These factors include population demographics; religion, language, and education; family size and structure; and lifestyle trends. These are described in the research by Hengtian Wang et al. (2021), with mostly positive and neutral effects [48]. In conclusion, the social feature is considered positive for this business.

Technological
In this context, the lack of investment and transfer of technologies are the main issues that negatively impact this business. This type of power generation is completely new in Iran. There is only a single company that is actively manufacturing solar panels, cells, and silicon wafers. This firm is capable of producing approximately 1,500 MW of silicon wafers and solar cells and 2,300 MW of solar panels each year via new technologies such as TOPCon and PERC for the application of both mono- and bifacial panels [49].

Legal: Many Ratifications, Decrees, And Laws Have Been Implemented To Support Green Energy, Which Are Classified As Follows:
- Value added tax exemption for at least five years
- Mandatory regulations for industries to provide power from renewables (Article 16 of the law entitled "knowledge-based production leaf") [50].
- Resolution of the Council of Ministers to provide 20% of the administrative building electricity from renewable sources [51].
- Fair feed-in tariff for a PPA duration of 20 years
- Ease in the registration process
- Market drivers for price determination

This business is exempt from VAT and does not have any specific tax on revenues for entities or corporations. This condition will be effective for at least 5 years [52].

- Environmental concerns, such as pollution, drought, and climate change, are becoming vital in Iran [53]. The use of heavy fuel oil, such as Mazut, as a fuel for power generation, especially during winter, has raised concerns about its severe implications [54]. Air pollution, substantial droughts, and an increase in carbon intensity need to be neutralized by developing green energy. The environmental drivers are the main positive aspects that impact this business.

In this section, the external factors that impact the industry are assessed and listed. The results show that the main challenging macroenvironmental factors are political and economic. To evaluate the internal factors that impact the industry, Porter's force model is assessed.

Industrial Micro Analysis
In this section, the main internal parameters are determined for the solar industry in Iran. Given the lack of similar studies concerning this topic, literature reviews are not available in this section. Daniel Gonzalez Peñaa et al. (2015) studied the solar industry in Spain [55]. Further studies on the same topic in Iran are recommended. The main Porter parameters are competitive rivalry, the bargaining power of suppliers, the bargaining power of customers, the threat of substitution, and the threat of new entrants [56]. For each of these parameters, assessments are made for the business environment that is affected by low-to-moderate international tensions. A summarized assessment of the internal factors of the industry is presented in Figure 2.

Figure 2: Porter's Five Forces Model For The Solar Industry In Iran

Considering that all the microeconomic factors impact the industry, this business is attractive and could be much more appealing in the future. The main factors that make the industry attractive are the power of buyers (low), competition rivalry (low), and the threat of new entries (low). The main threat exposed by the solar industry is the substitution of conventional thermal power plants.

In the following section, the SWOT analysis is described.

SWOT Analysis

This technique is used to identify the strengths, weaknesses, opportunities, and threats of the organization, and it is used for strategic planning for the business. The intrinsic role of SWOT is to identify and raise awareness of the key factors for business decisions [57]. In addition to other market-related studies, this method is dynamic and needs to be flexible by changing market trends [58]. Nanimpo Kansongue et al. (2023) used PESTEL and SWOT analyses to identify the external and internal factors, respectively, related to the Togolese renewable industry [59]. Similarly, in the study by Eva Segura and other scholars (2023), regarding the strategic analysis of solar photovoltaics in Spain, SWOT analysis was used as a simple and effective method to make necessary decisions about the future market. Furthermore, Z. Molamohamadi and M. Talaei (2022) showed how the strengths and opportunities of the solar business in Iran offset its weaknesses and threats via the internal and external evaluation matrix [60,61]. In contrast, Abtin Boostani et al. (2022) reported that the opportunities and weaknesses of small-scale building solar power plants in Iran outweigh the threats and strengths [62].

For each strategic planning tool, different multicriteria decision-making (MCDM) techniques are suggested. These techniques include the fuzzy analytic hierarchy process (AHP), the analytic network process (ANP), and the technique for order of preference by similarity to ideal solution (TOPSIS).

Economic Evaluation of a 1 MW Solar PV Plant in Yazd Province

In this context, capital expenditures are investigated via inquiries and price quotations from the main suppliers. All costs are divided into five main domains: Engineering, Procurement, Construction, business authorization, and contingencies. This segmentation is initiated for the current study; however, there are many other types of capital expenditure split models. Eero Vartiainen et al. (2019) determined future LCOE detection for utility-scale solar PV module installation in European countries [63]. In their studies, they assumed three different paces for capacity additions in the future, including slow, base, and fast growth, and by the slow pace, the average cost will change to circa. $400,000/MW in 2024. Furthermore, the IRENA report of the renewable power generation cost in 2023 analyzed the total installed costs of the PV utility scale for 33 countries, including European, Asian, and African nations in addition to the United States and Australia [7]. They showed that the average unit upfront capital costs for installation in these 33 countries stand at $842,000/MW. This amount is measured using the 2023 dollar and will be inflated by 3% to represent future values (considering the historical trend of the purchasing power of one dollar) [64]. Considering these estimations, the details of capital expenditures for a 1 MW solar PV installation in a location close to YAZD city are presented in Table 2.

Stage	Item	Quantity	Unit price	Total price
Engineering	Design, Engineering and basic studies	1	USD 14,286	USD 14,286
Procurement	Solar pannel (670 w)	1568	USD 98	USD 152,880
	Solar inverter (125 kw)	8	USD 3,985	USD 31,880
	Single-core PV cable (4 mm2)	6667	USD 1	USD 6,667
	MC4 connector (Rated current 30A)	667	USD 1	USD 667
	Mounting system	67	USD 800	USD 53,600
	Sunpal safe protection	67	USD 130	USD 8,710
	Shipping cost	-	-	USD 57,867
	Import duties	-	-	USD 32,659
Construction	Costs of Workshop and Construction Equipment (Internal Path, Leveling, Compaction, Foundation, Earthen Channels, etc.)	1	USD 50,000	USD 50,000
	Costs of Implementing Bifacial/Monofacial Groundwork	1	USD 6,429	USD 6,429
	Costs of Installation, Inspection, Commissioning, Trial Operation, and Training	1	USD 41,429	USD 41,429
Business authorization	Provide the permits, grid connection proposal, location	1	USD 5,714	USD 5,714
Contingency				USD 62,733

Table 2: The Split of CAPEX for Running a 1 MW PV Power Plant, 2024 USD (from Chinese Suppliers and Iranian Contractors)

There are more than 1,500 panels with a capacity of 670 watts, and 8 inverters of 125 kilowatts are used. The sum of $525,520 is required as upfront capital costs for project commissioning.

Operation & Maintenance (O&M), And Abandonment Cost

The O&M component, which includes the fixed costs, is estimated every month. According to the IRENA report on renewable costs, the O&M items are divided into technical operation, insurance, preventive maintenance, commercial operation, corrective maintenance, greenkeeping, security, and panel cleaning [6]. According to IRENA, the weighted average O&M costs decreased by more than 60% between 2010 and 2023, whereas the median utility scale O&M costs declined by 7% in 2023 and stood at USD 7.56/kW/year. In this report, we aim to add inverter costs to the O&M, considering two replacements in years 8 and 16. Consequently, the discounted expenditures resulting in a 39% increase in current values of unit O&M costs will be used. Hence, the annual O&M expenditures for a 1 MW solar PV plant will be approximately USD 10,542 and monthly USD 879. This value will be inflated for the next years.

LCOE

For the LCOE calculations, generating an annual power profile is necessary. Similarly, the investment profile encompassing the initial capital costs, maintenance, and operating expenditures is needed. The present value of plant costs over its lifetime divided by the present value of the grand total power produced will obtain the LCOE. This value is obtained via equation (1):

$$LCOE = \frac{\sum_0^n (I_t + M_t + F_t) / (1+r)^t}{\sum_0^n E_t / (1+r)^t} \qquad (1)$$

where r is the discount rate and where I_t, M_t ,F_t, and E_t refer to the CAPEX, O&M, fuel cost, and power generated at year t, respectively. In this case, the fuel cost is zero, whereas the discount rate is a controversial value that considerably impacts NPV and LCOE. This rate encapsulates the time value of money and investor risk preferences, exerting substantial influence on the financial viability of renewable energy investments. Its determination may follow various methodologies, contingent upon the project's financing structure and risk profile.

For projects with a balanced mix of debt and equity, the weighted average cost of capital (WACC) is commonly employed. In contrast, equity-dominant financing structures often warrant the use of the capital asset pricing model (CAPM), which incorporates market risk premiums and asset-specific betas to estimate the required return on equity. Empirical evidence suggests that discount rates for solar ventures in developed economies typically range between 6% and 10%, reflecting relatively low risk and stable macroeconomic conditions [65]. However, this range may vary depending on regulatory certainty, technology maturity, and investor confidence. Nevertheless, Chandel et al. evaluated grid-connected PVs with a battery storage system in India using a discount rate of 10% [23]. However, Saeed et al.11 used a discount rate of 5% for developing a 1 MW grid-connected floating PV plant in Saudi Arabia. In this study, an industrial average discount rate of 7% is used. The development CAPEX is estimated using the data available in Table 2, which, according to the inquiries from relevant contractors, will take over one year to launch the plant. Similarly, the estimated O&M profile is generated taking into account the values obtained in this study. The annual power output is measured via solar map data acquisition, which is validated via simulator tools. The power output of the first year using the GSA and validated by PVsyst is approximately 1,757,586 kWh [40]. The panel degradation factors (DGs) are essential for predicting future power output, and all manufacturers display DG values in their product specifications. Indeed, this value is the ratio by which the panels are depreciated in terms of annual power generation. This ratio is approximately 0.6% (according to the panel catalogs provided by the suppliers) and will be used for the determination of future electricity generation.

The LCOE is estimated via equation (1), and the value is equal to $0.04/kWh. This value is 33% higher than the country's average thermal power plant LCOE (Reineh et al.), which reflects a competitive situation for the solar industry [12]. Notably, the LCOE of industrial-scale solar energy is approximately equal to that of steam and gas turbines (Table 1), despite the substantial fuel subsidies received in these conventional power plants. Nonetheless, the combined cycle gas turbine (CCGT) has the lowest LCOE, which is approximately 0.02 $/kwh owing to higher efficiency. In contrast, in light of economies of scale, the avoided energy cost—based on the prevailing national energy mix—is comparatively less significant in the context of utility-scale solar installations than in industrial and commercial-scale systems [13].

Economics Inputs

This section is dedicated to price schedules and market analysis. The main components used in the model are the price and quantity of power sold, the inflation rate, the discount rate, and the selling mechanism, which are all elaborated.

Price Schedule

The revenue of the project will be measured using each year's power output and electricity price. The new PPA introduced the green trading board of the energy exchange market. This exchange market was inaugurated in June 2023 and was dedicated to renewable suppliers. According to Article 16 of the law on "increasing knowledge-based production,"45 large industries are required to purchase green power, accounting for up to 5% of their total consumption [45]. Likewise, according to the resolution of the ministry's council, government administrations are required to provide 20% of their power demand from renewables [46]. Therefore, these plans are much more appealing than the previous announcement for guaranteed purchase for 20 years [66]. Likewise, the remaining power that is not sold on the green trading board will be guaranteed by the state to be purchased at a tariff worth 70% of the green electricity price [67].

The green trade board is divided into two main domains: derivative and physical markets. According to the SATBA, the cumulative power supplied reached 937 million kwh, which was worth 3,200 billion Rials until March 2025 [68]. According to our analysis, the cumulative power demanded in the entire market until July 2025 is 1276 million kwh, with a value exceeding 82 million USD.

This market serves industries vulnerable to power disruptions during seasonal peaks. Companies can secure electricity in proportion to their renewable energy contributions, promoting reliability despite high demand. The two main factors encouraging industries to purchase green electricity are as follows:
• Firms prioritize continuity over cost, opting to purchase electricity even at elevated rates to avoid shutdowns.
• Renewable-linked access fosters long-term stability and reduces exposure to grid volatility.

The data obtained from the exchange market show an average increase of 16% in the volume of green electricity demand over the two years since commissioning. Likewise, the trade values (measured in USD) indicate a 25% increase in sales of green electricity [69]. While the derivative market continues to account for the largest share of cumulative demand, the growth rate of physical electricity demand has surged significantly. This trend suggests that more risk-averse buyers are prioritizing direct access to physical electricity over acquiring derivative instruments—such as shares or securities—to mitigate exposure to potential penalties. Furthermore, this shift may indicate an increasingly constrained power supply environment for entities seeking reliable electrification of their infrastructure.

The historical green electricity price trend is aggregated in a pivot table to prepare a weighted average value for each month. The monthly prices are presented in Figure 3. According to real-time data from the energy stock market, the annual inflation rate between June 2023 and July 2025 was approximately 11% (in USD).

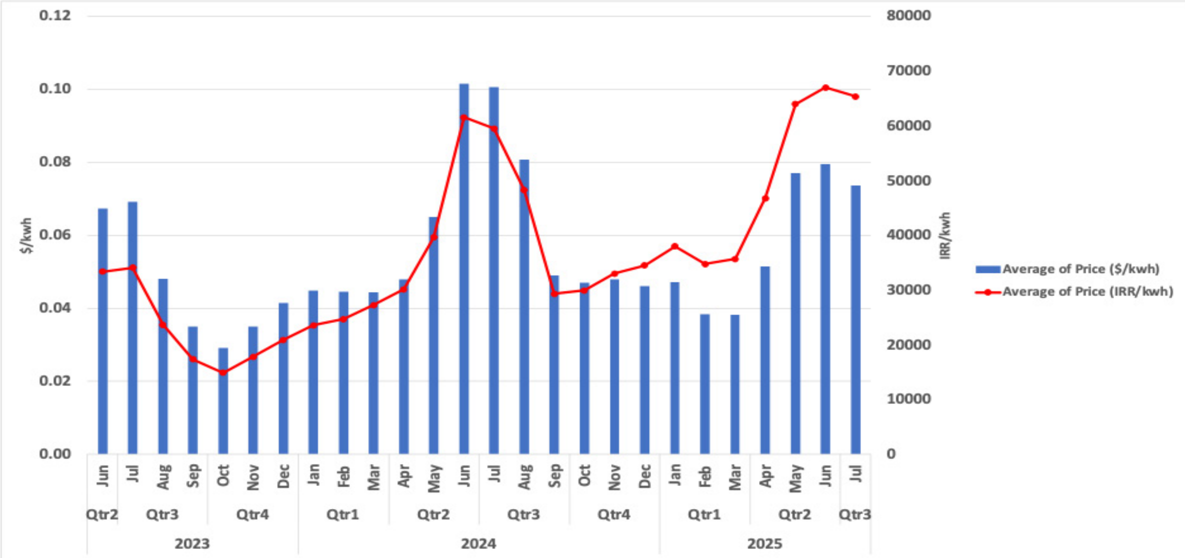

Figure 3: Price of Green Electricity Supplied On The Green Trade Board from the Iran Energy Exchange Website

One of the key signs of a market-driven mechanism for price determination is fluctuations over different months. The power disruption during the cold seasons is less intense, and this has a substantial effect on price behavior.

Despite pronounced price volatility during the initial year following market commissioning, the subsequent year exhibited a more stable trend. As a result of this evolution, price forecasting through machine learning methodologies—particularly the long short-term memory (LSTM) algorithm—is recommended for scenario-based analysis. Nevertheless, given the limited historical dataset, reliance on such techniques may lack methodological rigor. Accordingly, while predictive modeling offers valuable insights, caution should be exercised when interpreting results derived from abbreviated time series.

The average electricity price values were initially denominated in the Iranian Rials per kilowatt-hour (IRR/kWh). To facilitate comparative analysis on an international scale, these values were converted into US dollars by referencing historical currency exchange rates. For this purpose, a web scraping methodology was employed to systematically extract exchange rate data from online financial repositories. The extracted rates were then temporally aligned with the electricity price time series to ensure consistent and accurate normalization.

Revenue Schedule

There are two main targets for selling electricity: industries (the green exchange market) and the state (PPA). The priority is to sell as much as possible to industries through the green trade board system. However, the remaining power that is not sold on the trade board is purchased by the state at a 30% price decline (PPA contractual framework). In this analysis, owing to the probabilistic studies, the power is considered to be sold entirely in the green exchange market in the main case. At the end of this section, the inputs of economics used for cash flow statement evaluations are summarized in Table 3.

Inputs of economics	Values	Description
EA	1.76	Annual power production (GWh)
DG	0.6%	Pannels annual degradation rate
p	0.06	Average annual electricity price ($/kwh)
Ck	USD 525,520	Total Capital Expenditure
CO&M	USD 879	Fixed Operation & Maintenance monthly
jp	11%	Green electricity price inflation rate
jO&M	6%	CO&M inflation rate
i	7%	Discount rate
d	100%	Share sold to industries (by green trade board)
1-d	0%	Share sold to state (by PPA)

Table 3: Summary of Economic Inputs Used for Cash Flow Statement Evaluation

Financial Indicators

This section is dedicated to the construction of the cash statement model using economic inputs. Indicators such as the IRR, NPB, NPC, NPV, financial exposure, PBP, and BCR are evaluated. The abbreviations are described in Table 4 and are used in this format for the model.

Financial indicators	Description
IRR	Internal Rate of Return
NPB	Net Present Benefit
NPC	Net Present Cost
NPV	Net Present Value
FE	Financial Exposure
PBP	Pay-Back Period
BCR	Benefit Cost Ratio

Table 4: Financial Indicator Abbreviations and Descriptions

Likewise, for the measurement of each of these values, the following equations are used.

$$NPB = \sum_{t=0}^{N} \frac{\left[E_A \times (1-k)^{t-1} \times p_t \times (1+j_p)^t\right] \times (70\% + 30\% \times d)}{(1+i)^t} \tag{2}$$

$$NPC = \sum_{t=0}^{N} \frac{C_k + C_{O\&M} \times (1+j_{O\&M})^t}{(1+i)^t} \tag{3}$$

$$NPV = NPB - NPC \tag{4}$$

The amount of IRR is calculated via the following formula.

$$\sum_{t=0}^{N} \frac{\left[E_A \times (1-k)^{t-1} \times p_t \times (1+j_p)^t\right] \times (70\% + 30\% \times d)}{(1+IRR)^t} = \sum_{t=0}^{N} \frac{C_k + C_{O\&M} \times (1+j_{O\&M})^t}{(1+IRR)^t} \tag{5}$$

The PBP is the time that is required to compensate all expenditures with revenues. The BCR is also simply calculated via the cumulative NPV divided by the NPC. This item shows the extent to which business expenditures create value. The amount of electricity generated, average power price, revenue, NPB, NPC, and NPV values for each year are shown in Table 5. The accumulated cash flow (cumulative NPV) is measured, and the trend is shown in Figure 4.
In the following section of this research, probabilistic studies on financial outcomes are investigated via the Monte Carlo simulation method.

The financial results of the project are shown in Table 6.

Year	Electricity generation (Gwh)	Average green power price ($/kwh)	Revenue	NPB	NPC	NPV
0	0.0	0.06	USD -	USD -	USD 525,520	USD (525,520)
1	1.8	0.07	USD 119,140	USD 111,346	USD 10,443	USD 100,902
2	1.7	0.07	USD 131,348	USD 114,724	USD 10,346	USD 104,378
3	1.7	0.08	USD 144,806	USD 118,205	USD 10,249	USD 107,956
4	1.7	0.09	USD 159,644	USD 121,792	USD 10,153	USD 111,638
5	1.7	0.10	USD 176,002	USD 125,487	USD 10,059	USD 115,429
6	1.7	0.11	USD 194,037	USD 129,295	USD 9,965	USD 119,330
7	1.7	0.12	USD 213,919	USD 133,218	USD 9,871	USD 123,346

8	1.7	0.14	USD 235,838	USD 137,260	USD 9,779	USD 127,481
9	1.7	0.15	USD 260,004	USD 141,425	USD 9,688	USD 131,737
10	1.7	0.17	USD 286,645	USD 145,716	USD 9,597	USD 136,119
11	1.7	0.19	USD 316,016	USD 150,137	USD 9,507	USD 140,630
12	1.6	0.21	USD 348,397	USD 154,693	USD 9,419	USD 145,274
13	1.6	0.23	USD 384,096	USD 159,386	USD 9,331	USD 150,056
14	1.6	0.26	USD 423,453	USD 164,222	USD 9,243	USD 154,979
15	1.6	0.28	USD 466,843	USD 169,205	USD 9,157	USD 160,048
16	1.6	0.31	USD 514,678	USD 174,339	USD 9,071	USD 165,268
17	1.6	0.35	USD 567,415	USD 179,629	USD 8,987	USD 170,642
18	1.6	0.39	USD 625,556	USD 185,079	USD 8,903	USD 176,177
19	1.6	0.43	USD 689,654	USD 190,695	USD 8,819	USD 181,876
20	1.6	0.48	USD 760,320	USD 196,481	USD 8,737	USD 187,744

Table 5: The Power Generated, Price, Revenue, Npb, Npc, And Npv Of Each Year

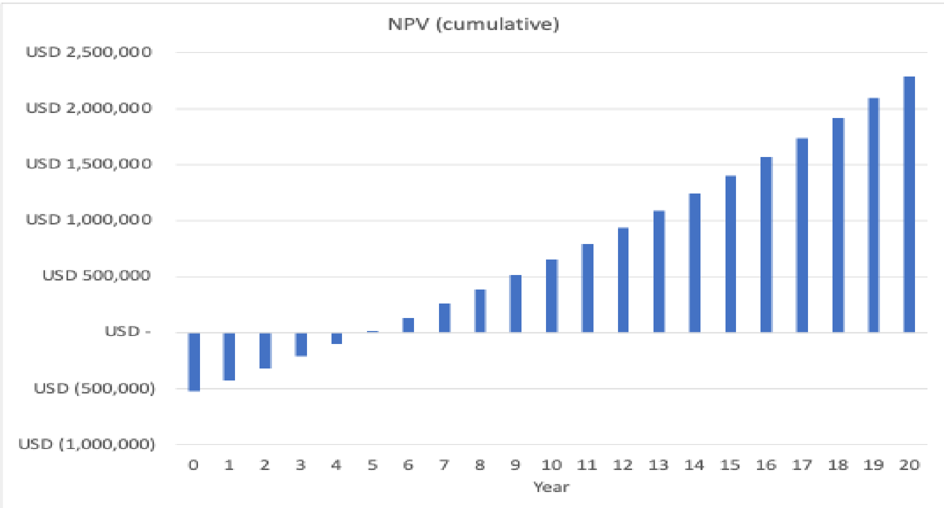

Figure 4: Accumulated Cash Flow (Cumulative Npv)

LCOE ($/kwh)	0.040
IRR	29%
NPB	USD 3,002,335
NPC	USD 716,845
NPV	USD 2,285,490
Financial Exposure	USD (525,520)
Pay-Back Period	5.9
Benefit Cost Ratio	3.2

Table 6: Financial Indicators Of The Business

Probabilistic Studies Using Monte Carlo Simulation

In this study, many assumptions are made to construct the business model. However, given the novelty of this business in Iran, many uncertainties exist. To cover these unforeseen errors and for risk assessment purposes, stochastic studies are indispensable. The probabilistic method, which encompasses the random changes of independent variables in the model, is assigned. Some of the main independent variables are considered to predict financial outcomes via a triangle basis with the minimum, most likely, and maximum ranges. For each variable, the dedicated value for the basic model is used as the most likely component (except for the share sold in the green exchange market variable). The variables and their range of fluctuations are shown in Table 7.

Input variables	**Lower**	**Most Likely**	**Upper**
Annual power production (GWh)	1.23	1.76	1.93
Average annual electricity price ($/kwh)	0.05	0.06	0.07
Total Capital Expenditure	USD 420,416	USD 525,520	USD 630,624
Inflation rate	9%	11%	13%
Share sold to green exchange market	40%	70%	100%

Table 7: Range Of The Input Variable Distribution Via The Triangle Method For Monte Carlo Simulation

Some of these variables are observatory and are determined on the basis of realistic trends (such as power prices) or industrial quotations (such as capital expenditures). Similarly, the annual power output is estimated via climatic data and validated via simulation tools for the selected GIS locations. However, two remaining variables require forecasts of future conditions. The inflation rate can vary significantly and depends on future political tensions. Similarly, the share of generated power sold on a green trade board is highly dependent on market dimensions, which are not predictable. Therefore, for these components, the range of fluctuations is wider, covering all possible scenarios.

The financial indicators are selected as Monte Carlo simulator outputs. These factors, including IRR, NPV, PBP, and BCR, are the intrinsic benchmarks for economic evaluation. A total of 10,000 iterations are dedicated for simulation. Likewise, for each risk factor, P10, P50, and P90 are identified. The simulation statistics for these risk factors are shown in Table 8.

Item	IRR	NPV	PBP	BCR
Mean	25%	USD 1,846,352	6.8	2.6
Median	25%	USD 1,827,054	6.8	2.6
Std. Deviation	0.04	413620	0.92	0.6
Variance	0.002	2E+11	0.85	0.4
Kurtosis	-0.11	-0.13	0.49	0.0
Skewness	0.04	0.27	0.61	0.4
Minimum	10%	USD 596,959	4.4	0.8
Maximum	40%	USD 3,514,675	11.8	5.2
Range	30%	USD 2,917,716	7.3	4.4
Count	10000	10000	10000	10000
Error Count	0	0	0	0
Std. Error	0.0004	4136	0.01	0.01
Confidence Level (95%)	0.0008	8108	0.02	0.01

Table 8: Monte Carlo Simulation Statistics

The standard deviation of the IRR is approximately 4%. This can be used alongside the median (P50) value of 25% for portfolio theory studies, which is recommended for investigation. Similarly, the kurtosis value shows a platykurtic distribution curve for the IRR, meaning that the probability distribution trend contains light tails. This suggests that the density of outliers is less than that of the normal curve. A low value of skewness indicates a relatively symmetrical trend in the IRR. The NPV has a negative kurtosis factor, indicating a platykurtic curve that has quite similar tails compared with those of the IRR. However, the skewness is relatively high (right-skewed), which can be interpreted as the mean value being greater than the median. The PBP is leptokurtic because of its high kurtosis factor, whereas the BCR is similar to a normal curve, which is mesokurtic because of its low kurtosis value. Similarly, the skewness of those components is high, indicating that the curve peak is close to the left axis (or that the median is less than the mean).

The median (P50) values of the IRR, NPV, PBP, and BCR are 25%, USD 1,827,054, 6.8 years and 2.6, respectively. The probability distribution graphs for each risk component are generated and shown in Figure 5 to Figure 8, and Table 9 shows percentiles for each risk component.

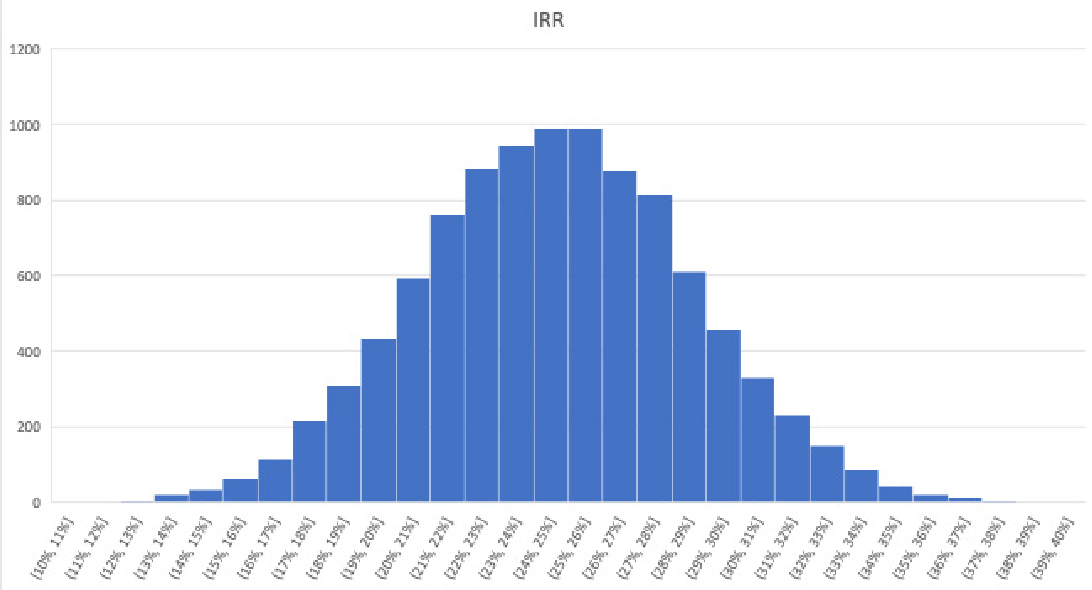

Figure 5: Probability Distribution Graph for the IRR

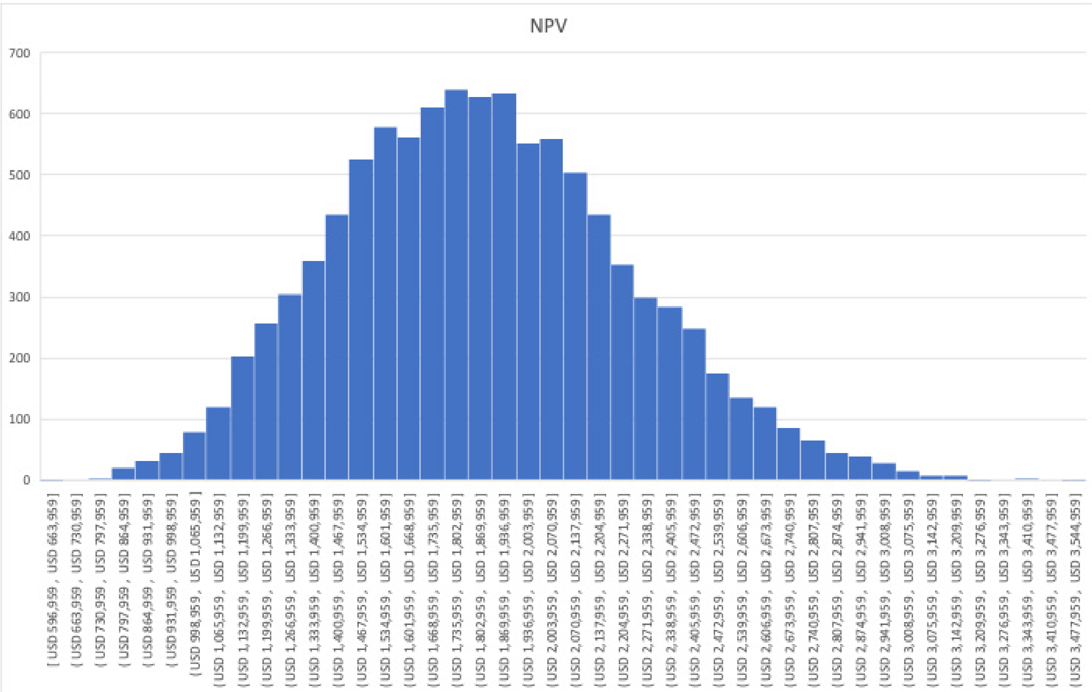

Figure 6: Probability Distribution Graph For NPV

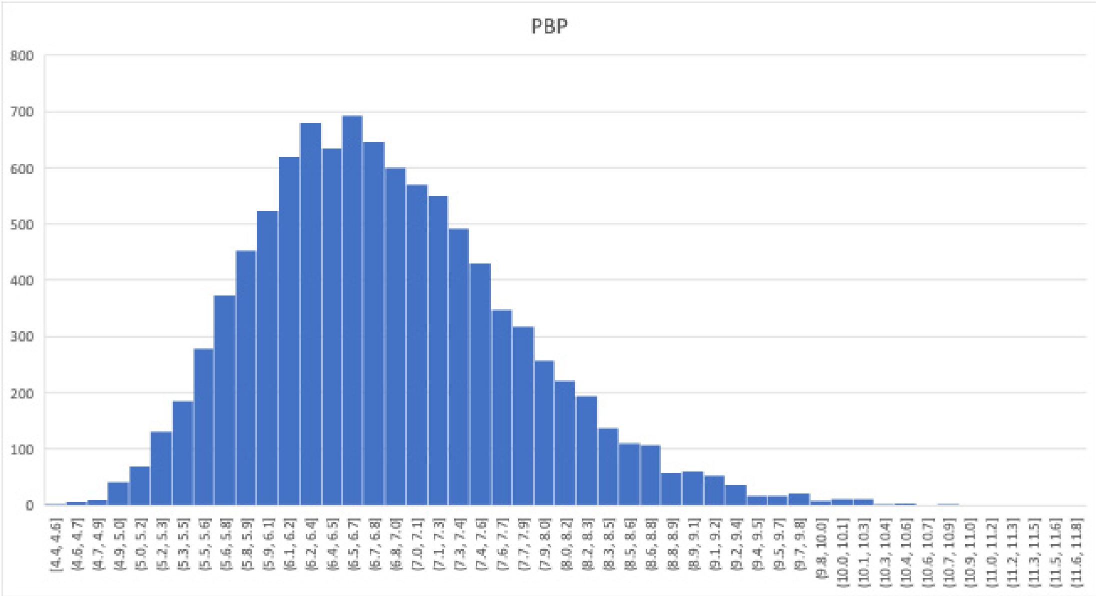

Figure 7: Probability Distribution Graph for PBP

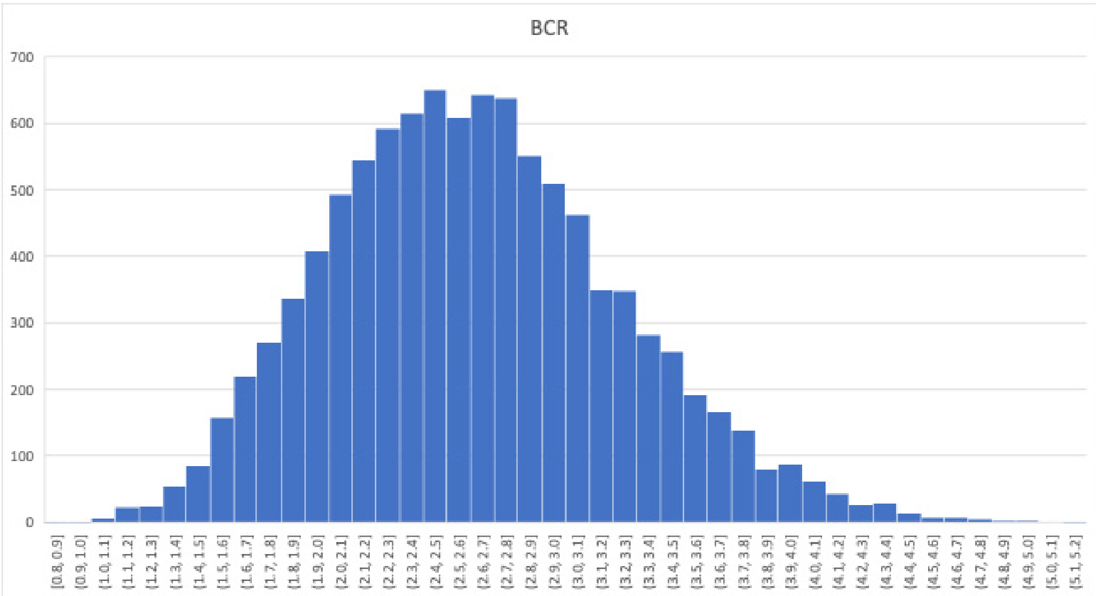

Figure 8: Probability Distribution Graph for the BCR

Percentile	IRR	NPV	PBP	BCR
P10	20%	USD 1,322,852	5.7	1.8
P50	25%	USD 1,827,054	6.8	2.6
P90	30%	USD 2,399,556	8.1	3.4

Table 9: P10, P50, And P90 For All Risk Components

To evaluate this business opportunity in Iran, it is vital to compare other businesses in the individual and private sectors within the energy environment. The most competitive portfolio in the Iranian energy industry is businesses related to the development of oil and gas fields. These cases are studied via the drafts of Iranian Petroleum Contracts (IPCs).

IPC is the term introduced for the private sector alongside the governmental bodies for the development of Iranian oil and gas fields. This type of contract is categorized as a service contract and is a modification to conventional buy-back contracts. According to the IPC, the contractor will recover its expenditures and benefit from the quantity of the hydrocarbon it participates in producing. This means that the contractor will receive a fee per unit volume of hydrocarbon it produces out of the corresponding field. These types of contracts have been introduced in the last decade for the benefit of the contractor and attract investors to the energy industry. For this purpose, we analyzed the recently published "Investment and financing opportunities in National Iranian Oil Company projects," which introduced 59 IPC and EPCF/EPDF opportunities for exploration and production firms to participate. According to our assessment of different kinds of oil and gas fields in Iran, the median (P50) IRR is approximately 18%, with a standard deviation of 3%. Similarly, the PBP is approximately 9 years. That is, the investment in solar plants is estimated to be associated with higher returns while also being exposed to a higher level of risk. In the meantime, further assessments should be conducted for portfolio optimization in the Iranian energy industry.

Conclusion

The solar industry is becoming essential in Iran, similar to the entire region, to comply with energy security and stability policies. Energy transition is one of the most critical factors for ensuring safe and reliable electricity accessibility. For many decades, critics have argued that the implementation of renewable energy in Iran is not viable because of its high upfront costs. They believed that, owing to giant fossil fuel reserves, Iran should not develop renewables. Currently, with respect to tremendous investments in clean energy worldwide, the overall costs have declined remarkably, resulting in competitive advantages over conventional power plants. In this paper, the aim is to evaluate the business opportunities for individuals in industrial- and commercial-scale solar plants in Iran using new purchasing power agreement opportunities. Similarly, this study offers comparative insights relative to conventional resource development initiatives, thereby informing strategic decision-making processes. Despite political tensions and economic vulnerability, it seems that the market is booming due to several factors, including an imperative need to confront power deficits. Thus, industries with high power consumption are obliged to provide an incremental share of their demand from renewables with fair feed-in tariffs. This has strengthened the role of renewables in the energy basket and particularly sharpened solar domestic capacity trends. In light of the substantial workflow requirements to compensate for these deficits and the long-term approach to provide adequate fuel for conventional power plants, new sources of energy with minimum O&M costs are strongly recommended to balance the shortages. Nevertheless, political and economic conditions remain pivotal determinants of business performance, exerting substantial influence across various sectors in renewable development. These external factors disrupt broader business activities within the energy industry. A particularly contentious issue concerns the extent to which energy-related industries are susceptible to such external pressures. The relative vulnerability of renewable energy enterprises, compared with that of conventional energy (such as oil and gas), continues to be debated within scholarly and policy-making circles. As of now, definitive conclusions remain elusive, which means that the jury's still out for these discussions. In this research, in addition to strategy planning analysis, a case study of a 1 MW solar plant in Yazd Province, with high irradiation and optimum climatic conditions, is conducted for economic evaluation. As a result of our analysis, the sound business plan culminates in an internal rate of return of 25% and a net present value of 1.81 million dollars over 20 years. The payback period is 6.8 years, and the benefit–cost ratio is 2.6. To illustrate the risk factors, the probabilistic technique was conducted via Monte Carlo simulation and by changing the main economic and technical input variables within a triangular range. A total of 10,000 iterations were used to check the main risk factors. Similarly, to determine other businesses' profitability, the development cases of Iranian oil and gas fields are assessed. The terms Iranian petroleum contracts (IPCs) are used for the evaluation of the economic factors in the development of these cases. Given these studies, the average IRR for oil and gas development projects in Iran for contractors is approximately 18%, with a standard deviation of 3%. Similarly, the median payback period for these cases is approximately 9 years. Therefore, while solar deployment for commercial and industrial cases will result in higher returns, it will be accompanied by higher levels of risk. Hence, for further and future research, performing portfolio optimization studies to determine the best strategic planning for investment in the energy sector in Iran is recommended.

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