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Economic Analysis of Feed-in Tariff Policy in Iran: Fresh Results from a Real Options Model for Solar Energy Promotion

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Abstract

Given the 95% share of electricity generation from non-renewable energies, implementing effective policies to motivate electricity generation from sustainable energy resources is essential. Since the current Feed-in Tariff (FiT) policy increases the government's expenditures to support renewable energies, a real options (RO) model is proposed to estimate solar power generation incentive subsidy. Moreover, establishing a carbon emission trading (CET) scheme under uncertainty is proposed, and sensitivity analysis is conducted for the project value, threshold value, and subsidy. Our results show that establishing a CET market could significantly reduce the economic costs of achieving renewable energy promotion goals. Based on the net present value (NPV) and RO criteria, in the case "with the possibility of CET," the amount of incentive subsidy that should be paid to electricity generation from a solar project (case of a 5 kW plant) are 37.49 and 42.42 million Rials/kW, indicating 20% and 12% reduction compared to the base case (without the possibility of CET), respectively. The results also indicate that more electricity price volatility can increase the incentive subsidy while enhancing the market price of electricity can slightly decrease the required subsidy, which triggers solar investment.

Highlights

- Extensive use of fossil resources resulted in Iran's poor performance in the energy transition.
- A real options (RO) Model under Uncertainty was applied to estimate the solar incentive subsidy.
- The impacts of the carbon emission trade (CET) market on solar generation are evaluated.
- By implementing the CET, the amount of incentive subsidy will be reduced by 20%.
- CO2 price volatility could significantly increase the subsidy triggering solar investment.

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1. Introduction

Iran's transition readiness is only 33% (ranked 101st in the world) in the energy transition index (ETI) (WEF, 2019). ETI is designed to track energy transitions evolving the system's ability to support economic development, environmental sustainability, and secure and reliable access to energy (Sayadi & Khosroshahi, 2020). Iran's performance in the sub-index of capital and investment and energy system structure was significantly far from the world's performance. In this regard, Iran's annual growth in new renewable capacity built and share of electricity from renewables was 0.01% and 5.1%, respectively. While renewable energies contributed to 26.6% and 34.7% share of electricity generation in the world and European Union, respectively (Global Energy Statistical Yearbook, 2020).

Considering the exhaustibility of fossil resources, probable peak fossil resources (oil) demand and increasing environmental concerns and climate change alongside a rapid increase in demand for energy, highlighted the need to the diversification of the energy mix through expanding the use of renewable energies developing fossil fuel-rich countries (Brandt et al., 2013; Lloyd & Forest, 2010; Pickl, 2019; Wirth, 2008). According to the International Energy Agency (IEA), in 2018, about 33 billion tons of CO_2 were released into the atmosphere, and its amount is increasing critically, caused mainly by burning fossil energies such as coal, oil, and gas (IEA, 2019). Iran is one of the countries with an increasing trend of CO_2 emissions and intensity. As seen in Fig 2, CO_2 emissions from fuel combustion have dramatically increased from 181.2 million tons in 1990 to 631.7 million tons in 2018. CO_2 intensity had increased from 0.27 kilo CO_2 per dollar (constant 2015) in 1990 to 0.39 kilo CO_2 per dollar (constant 2015) in 2018. Accordingly, contributing to 1.8% of the total carbon dioxide emissions in the world, Iran ranks seventh among all the countries (Mamipour et al., 2019). Meanwhile, the electricity generation (power) sector, with a 24% share, has the largest share among all the sectors contributing to carbon dioxide omission in Iran.

Due to the sustainable development goal, Iran's 20-year Vision Plan and the Fifth Development Plan target a 10% share of renewable energies in total electricity generation by 2025 (Chaharsooghi et al., 2015), it seems that thermal power plants contribute to the dominant share of the electricity generation in the country. Enjoying around 300 sunny days per year and large available land, Iran has great potential in generating electricity from RE, especially solar energy (Fig. A.1 in Appendix A).

Promoting electricity generation from renewable sources is one of the effective energy policies to accelerate the energy transition. Considering the different structures of renewable energies, the investment cost of these technologies is high. More strictly, the ratio of the investment costs to the total cost of renewable energies is about 1. This issue causes the development trend and motivation for renewable energy production to depend on various policy instruments. In this regard, the first and most successful structure for developing renewable energies in the world is the Feed-in tariff (FiT) policy because the private investor can be sure that the electricity is purchased and decide on investment by conducting feasibility studies (Sijm, 2002; Dong, 2012; Requate, 2015; Ye et al., 2017). The support policy is implemented as purchasing the electricity generated by renewable energies to prices higher than that of the electricity generated using fossil energies in a specified period. FiT is a price-based policy for stimulating RE expansion where the government offers a guaranteed purchasing price for electricity generated from RE sources for fixed periods (Wang et al., 2014; Campoccia et al., 2014).

Taking incentive policies can increase investments' certainty, decrease the risk, and increase the tendency to invest in renewable energies (Zhang et al., 2017). How to apply the tariff and the appropriate tariff rate are important in the countries' energy policies to achieve a specific growth rate in renewable energies so that, besides motivating private investors to involve in renewable electricity generation, it does not lead to excessive burden on governments (Ahmad et al., 2015; Lyu et al., 2017).

The Renewable Energies Organization of Iran has proposed a financing plan for RE expansion and achieving the target of 5GW installed capacity from renewable sources by 2020 by offering a FiT scheme in the form of purchasing generated power by guaranteed prices for periods of up to 20 years (IPG, 2018).[1] In terms of a rise in the price of electricity, under the current economic situation of Iran, the benefits from investments in solar PVs power plants would be guaranteed by financing a minimum of 20% increase in annual electricity rates (Edalati et al., 2017). Further, a consumer-based FiT policy through subsidizing the RE-based electricity generation can reduce social costs and generate electricity from RE sources. However, the continuation of the current FiT policy significantly increases the government's expenditures to support renewable energies in Iran. The government in Iran raises FiTs over time to incentivize renewable energy producers. For example, in Biomass (Anaerobic digestion), there was a 66% increase in the FiT in 2019 compared to 2015. Continuing this trend makes it difficult for the government to finance a guaranteed tariff policy.

Considering the increasing challenges arising from RE financing in Iran, CET may be an effective policy that increases the motivation to generate electricity from renewable energies and decreases the total cost of electricity generation by providing the possibility to sell the unused carbon credits. This mechanism can be used as a complement to FiT because one advantage of this approach, compared with the control-based approach[2], is that, in addition to motivating the electricity generators from renewable energies, it can reduce the FiT assigned by the government to motivate renewable electricity generators

[1] According to Iran's FiT table, the contract for purchasing electricity from Biomass, solar, wind, and geothermal source is for 20 years, and expansion turbines, industrial waste heat recovery, and small hydropower sources, the contract is for ten years.

[2] This approach generally involves taxation on industrial units that release excessive pollution or greenhouse gas.

through allowing them to earn a profit of selling pollution credits (Lin et al., 2016; Ciarreta et al., 2017).

The main motivation to consider the CET in this research, while its market still has not been established in Iran, is to investigate that how can the establishment of this market affect the FiT paid by the government to electricity generators. Indeed, since generating electricity from renewable energies emits fewer greenhouse gases than thermal resources, establishing such a market can cut the actual cost of the electricity generated from renewable resources. Consequently, a lower FiT is needed to encourage investors to generate electricity from renewable energies[3]. So, this research mainly aims to present a real options model to determine the level of incentive subsidy (tariff) as a threshold value to support investment in solar energy under uncertainty in Iran. Using a real options model based on Monte Carlo simulation, the incentive subsidy is analyzed in two scenarios, with and without CET, to specify the possible advantage of establishing the CET market in Iran. Furthermore, electricity price, CO_2 price, variation, and the discount rate are entered into the analysis as the uncertainty variables, and sensitivity analysis of the changes in subsidy, project value, and a threshold value of solar project assigned to each variable is conducted.

The remainder of this research is organized as follows: In section 2, the theoretical background and literature review are provided. The methodology is described in Section 3. Section 4 analyzes the empirical results. Finally, Section 5 is devoted to concluding remarks.

2. A Review of the Related Literature

Performing any economic activity requires consuming energy. Therefore, on the one hand, energy is considered a driver to economic growth and improvement of life quality in communities. On the other hand, its consumption leads to the emission of environmental pollutants. Accordingly, environmental destructions and development and growth have arisen a substitution between interests earned by the growth and environmental destructions. This substitution has caused the importance of environmental remarks and attention to its consequences in designing the policies and pursuing the process of growth and sustainable development (Bretschger, 1998; Hediger, 2006). Carbon policy refers to policies that lead to reducing carbon dioxide emissions. There are several carbon policies in the world that some are global, and some are specific to a region, such as the CET scheme.

2.1 Carbon Cap Policy

The carbon cap policy is one of the most inflexible policies. In this policy, the policy-maker assigns a limit on the emission level, and the organization has

[3]. Iran's energy stock exchange has now provided the infrastructure necessary to start carbon emission trading, in cooperation with other relevant agencies, including the Environment Organization, Stock Exchange, the Oil Ministry, Power Ministry, and Industry, Mining, and Commerce Ministry. However, the policy has not yet come into effect.

to set its activities so that the amount of its greenhouse gas emissions does not exceed the limit (Yi et al., 2019). The determination of the emission limit plays a vital role in this policy because if the limit is excessively large, the policy will be inefficient.

2.2 Carbon Tax

Carbon tax policy is being implemented and followed in some countries. In this scheme, industrial centers should pay tax for producing pollutant gases. In contrast to the CET scheme, there is no option for selling or buying carbon stock among firms in this approach. This scheme is currently being applied in Australia (Nelson, 2019). Hasudungan and Sabaruddin (2018) as a relevant study, using a hybrid CGE model to investigate the effects of promoting renewable energy production through two different FiT schemes ((a) paid by electricity consumers, and b) financed by a carbon tax adjustment) on Indonesia's economy. Their findings indicate because of the low shares of REs in the total electricity mix, the effects of both FiT schemes on macroeconomic and CO_2 emission are negligible. Results revealed current FiT regulation in Indonesia is insufficient to motivate national renewable energy production. Also, Yin et al. (2018) studied the impact of carbon pricing and renewables subsidy on the direct electricity generation cost in Chinese regions. The results of their regional generation cost evaluation model (RGCEM) showed that an increase of 9.5-11.6 Yuan per Ton CO_2 in carbon emission price has the same effect on achieving a given target of emission reduction as a 1% increase in the share of renewable energy.

2.3 CET Scheme

CET scheme is the subject of article 17 of the Kyoto protocol (Kuriyama & Abe, 2018). In this protocol, which was adopted by 37 industrial countries and European Union countries in 1997, the members committed to reducing their emissions of the six greenhouse gases, i.e., CO_2, N_2O, CH, SF, HFCS, and PFCS, in the period 2008-2012 to 5% lower than its amount in 1990 (Skjærseth & Wettestad, 2016). According to these agreements, each country or company has an upper bound for its carbon emission in such a way that firms that exceed their bound may purchase carbon credit from those who have unused credit (Diabat et al., 2012). In this way, this mechanism, on the one hand, with imposing a fine for exceeding their emission cap, and on the other hand, creating revenue from selling their surplus stock, makes the process of pollution reduction possible (Sarkis et al., 2011). The European Union emissions trading scheme (EUETS) is the most extensive scheme currently being performed and covers 11000 electricity power plants, industrial units, and airlines in 31 countries. This scheme is in the third phase (2013-2020) in the European Union. Liu et al. (2019) presented a comprehensive review of the real options theory in estimating a renewable energy investment. Besides explaining the limitations of the traditional methods for evaluating investment projects, they referred to the advantages of using the real options approach. Further, the application of the real options was examined in two scopes of evaluating renewable energy investments and policy assessment. Chen et al. (2019) studied the optimal energy storage subsidy for micro-grids using a real options game-theoretic approach. For this purpose, they proposed and solved an MLP model to estimate the optimal investment capacity concerning both parties' interests (government and investor). The price subsidy for storage more strongly affects the grid development compared with the initial investment subsidy. Furthermore, combining the two subsidies guarantees the investment value and reduces the initial cost of the project.

2.4 Renewable Energy Development Policies

The development of renewable energies requires defining the goals, determine the strategies to achieve them, an institutional framework based on which the government specifies the priorities, and an instrument to implement the strategy. Instruments used in the area of renewable energy development are generally divided into five main. Among them, the FiT policy is one of the most dominant instruments used to develop renewable energies. Investigation of the policies taken by the European Union shows that among the instruments mentioned, the FiT policy for the electricity generated by renewable energies is the most efficient and effective supportive program in the area of renewable energies. Several economic advantages and disadvantages are mentioned for the FiT policy. Some advantages include providing a secure and stable market for investment, significant stimulation and growth of local industries, and job creation. Additionally, we can refer to low trade costs, fair distribution of costs and benefits, resolving the uncertainty in access to the electricity grid, promoting the investors' access to the market, and providing an incentive mechanism for technologies at different maturity levels (Guillet & Midden, 2009).

Some disadvantages also have been referred to regarding the FiT policy. If this policy is not correctly designed, it may be economically inefficient. For example, if the subsidy paid is excessive, the actual consumers' price increases, or it may bring a cost burden for governments. This issue is more tangible when we face the development of technologies having a higher cost than others. On the other hand, this policy does not help reduce the costs of renewable energies directly. Still, it provides producers with the possibility of a depreciation of the costs only through providing a proper cash flow during a 15 to 25-year period. Therefore, fixed tariffs cause investors not to have sufficient motivation to reduce the costs or improve the production status (Alizamir et al., 2016).

Generally, when designing a FiT policy, first, the preferential tariff should be specified. Then, a guaranteed purchase agreement should be offered to the investor for a given period. Finally, the producer's access to the grid should be guaranteed. The key matter is that the establishment of a CET market can provide the possibility to reduce the tariffs without losing the motivation to generate electricity from renewable energies, and it provides the required incentive to managing the costs by producers (Glemarec et al., 2012).

As the most relevant studies, Tanil and Jurek (2020) assessed the RE policy adaption at the European and national level of governance for the Czech Republic. They found that the complex argumentation about the necessity of using RE is still mostly absent in the Czech Republic. Moreover, the proliferation of RE was financed mostly from EU sources. Ahmad Ludin et al. (2021) utilized a Cradle-to-Grave approach to analyze the environmental impact and (Levelized cost of energy) LCOE of solar PV systems in the Asia Pacific region and they found that rooftop PV systems recorded the lowest value of LCC and LCOE. Aghahosseini et al. (2018) focus on defining a cost-optimal 100% renewable energy system in Iran by 2030 using an hourly resolution model. Using a real policy option, a country-wide scenario, and an integrated scenario applied in this study.

2.5 Real Options Model and Investment Decision

Traditional approaches of the cash flow discount do not consider the flexibility caused by diversity in investors' decisions, leading to overvaluation of the investment (Martínez-Ceseña & Mutale, 2011). Changes followed by economic evolutions and increasing the complexities of the relevant activities lead to a new approach in financial and economic decision-making called real options (Smit & Trigeorgis, 2012). Stewart Myers first introduced the term of real options in 1987 by comparing financial options and real-world investments. In the real options theory, financial trade options were extended to non-financial assets, and it is a way to link the organization's financial affairs (often quantitative) with strategic planning (often qualitative) (Liu et al., 2019). Quantitative factors can be denoted by numbers and digits, while qualitative factors are not measurable or can be measured vaguely. Decision-makers often incorporate both qualitative and quantitative data into their decisions.

Real options analysis can bring these data types together, which are not consistent, to provide a comprehensive image of the decision-making (Hull et al., 2013). The real options approach is a systematic approach in which, using financial theory, operations research, economic analysis, statistics, decision theory, econometric modeling, and options theory, investment valuation as well as cost estimation of economic plans and projects and assets, and uncertain business environments as strategic investment decision-making (Maisel, 2009). The major distinction between the NPV, which is one of the most used traditional approaches, and real options is that the former considers uncertainty a risk to be minimized, while the latter regards uncertainty as an opportunity to maximize the project value.

For instance, Ritzenhofen and Spinler (2016) utilized the real options model to find the optimal tariff for renewable energies. Their results showed that the uncertainty of future regulatory regimes modifies or decreases renewable energy investments. Moreover, Mashhadizadeh et al. (2018) provided a framework to employ the fuzzy real options theory in evaluating photovoltaic plants. The results showed that investment value in the South of Isfahan plant is increased if real expansion and abandonment options are considered. (Gupta, 2021) proposed a real options approach to value India's renewable energy promotions. In this study, some RE-promoting policies are investigated by replacing coal with solar and wind under coal price uncertainty. Findings show the overall value of RE promotion policies to be sufficiently large.

To our best understanding, some novelties of the present research are: firstly, this article focus on the use of real options approach based on a Monte Carlo simulation to determine an incentive level of subsidy to create the motivation in the private sector to involve in solar energy investment in Iran using. Secondly, a CET scheme is considered a scenario, and the results are examined and compared in the case without CET. Moreover, to simulate uncertainty conditions, the sensitivity of the incentive subsidy to the changes in electricity price, CO_2 price, and variation, and the discount rate are analyzed.

3. The Study Model

Boyle et al. (1997) applied the Monte Carlo Simulation method to estimate the value of the options when being imposed. The Monte Carlo method generates thousands of simulation trials of assets value distribution in the future by which the probability distribution of the expected value of the stock in due date can be estimated. The greater the number of these trials is, the more the accuracy is. The Monte Carlo approach solves the real options problem as a simulation of the dynamic factors. In the Monte Carlo method applications in the real options technique, variables such as risk-free interest rate and asset value are defined in a given range, but they do not have certain values in a given time. The value of some investments (such as research and development investments) mainly is not specified with cash flows of the initial investment, but it is determined by future investment opportunities contributed by the main investment. Therefore, the value of these investments is specified by the main two components, i.e., first, through the initial investment opportunity and, second, through the value of investment opportunities (second investment) resulted from the initial investment. Accordingly, the issue of compound valuing arises. Geske (1979) proposed an extended solution for valuing this type of compound option (Perlitz et al., 1999). Fig. 1 represents the steps of the proposed model.

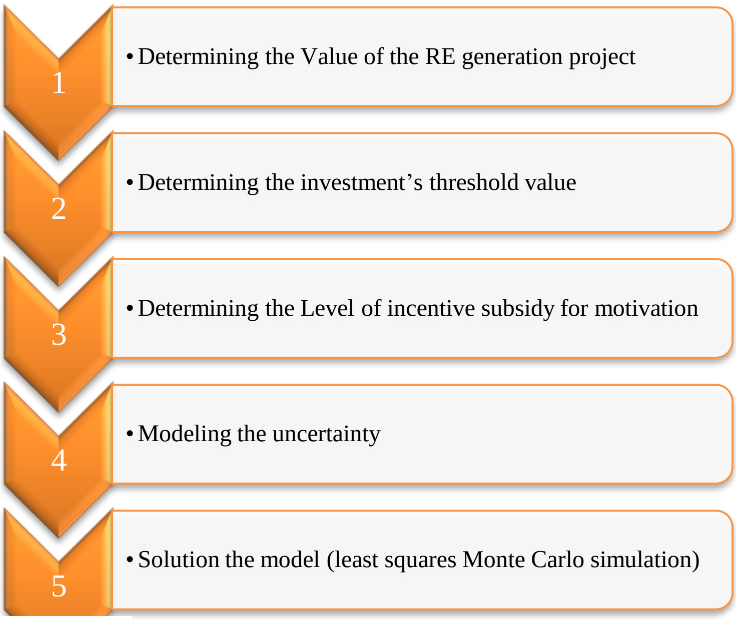

Figure 1. Steps of the proposed model

- **Value of the RE Generation Project**

Investors who invest in electricity generation from renewable (solar) energy get the value of project VP_t in year t ($1 \leq t \leq t_v$). According to Zhang et al. (2017), the project value can be stated in terms of the expected value of the project ($E(.)$) as equation 1.

$$VP_t = E\left[\sum_{i=t}^{t+LT} e^{-r(i-t)} CF_i - C_t^I\right] \quad (1)$$

Where r stands for the discount rate, CF_i is the cash flow in year i, LT represents the project lifetime, and C_t^I is the investment cost. Equation 2 is used to explain the cash flow of the project.

$$CF_t = RER_t + SF.CCR_t - C_t^{OM} - tc_t \quad (2)$$

In equation 2, CF_i represents the project cash flow, RER_t is the electricity revenue, CCR_t is the revenues from the sale of CO_2 emission credit, C_t^{OM} is the cost of operation and maintenance, tc_t is the cost related to the tax, and SF is a binary variable to represent the presence or absence of the CET scheme (Wang et al., 2014). The revenue from electricity sale in time t (RER_t) could be represented as equation 3:

$$RER_t = p_t^e.q_t^e.IC.(1 - r^h) \quad (3)$$

Where q_t^e denotes the unit generation capacity (kwh), p_t^e is the electricity market price (Rial/kwh), r^h is house service consumption rate (%), and IC

represents installed capacity (kw). The revenue from selling CO_2 emission allowances could be represented as equation 4:

$$CCR_t = p_t^c q_t^e IC(1 - r^h).k \tag{4}$$

Where, k is the share of tradable CO_2 emission allowance in total CO_2 emission reduction (%),p_t^c denotes CO_2 price (Rial/kwh). Also, the unit capacity in RE power generation may be decreased with d (%):

$$q_t^e = q_{t-1}^e(1 - d) \tag{5}$$

Operation and maintenance cost (COM) could be derived as equation 6:

$$C_t^{OM} = c_t^{uom}.q_t^e.IC \tag{6}$$

Where, c_t^{uom} denotes the unit COM (Rial/kwh). Moreover, considering the P_t^I as unit investment cost (Rial/kw), investment cost could be derived as equation 7:

$$C_t^I = P_t^I.IC \tag{7}$$

- **Determining the Investment's Threshold Value**

While the present value of the project is not less than zero, the investment project is viable and, otherwise, it is not viable and is avoided. According to the real options model, decision-making for investment is equivalent to a purchase. Based on this method, the investor can determine the best time for investment and earn the maximum profit (equation 8).

$$VP^* = F(VP) = max[max(VP_t, 0)] \qquad 1 \le t \le t_v \tag{8}$$

- **Level of Incentive Subsidy for Motivation**

The level of subsidy for motivation is defined as the difference between the NPV of the project and zero when the NPV is negative (Zhang et al., 2017). Contrarily, there is no need to pay a subsidy. According to the RO method, the subsidy equals the difference between the threshold value (VP^*) and value of the project (VP):

$$S^* = VP^* - VP \tag{9}$$

In the above equation, S^* is the incentive subsidy level that should be paid to the investor of electricity generation from renewable energies in the lifetime of the project (Rial/kw).

- **Modeling the Uncertainty**

Subsidy determination depends on several factors with uncertainty. Here, three uncertainty factors, i.e., the price of electricity (pe), CO_2 price (pc), and discount rate (dr^I), are included. Indeed, a change (variation) in the electricity price and CO_2 price fosters the uncertainty of the investment environment. In most previous research (such as Yang et al., 2008; Fan & Zhu, 2010; Lee & Shih, 2011), a Geometric Brownian Motion (GBM) process was used to describe the motion trend of the price of electricity. We assume that the three variables facing uncertainty (CO_2 price, the price of electricity, and discount rate) follow a Geometric Brownian Motion (GBM) process:

$$dp_t^e = \beta_e p_t^e dt + \gamma_e p_t^e dz_t^e \tag{10}$$

$$dp_t^c = \beta_c p_t^c dt + \gamma_c p_t^c dz_t^c \tag{11}$$
$$ddr_t^I = \beta_I dr_t^I dt + \gamma_I dr_t^I dz_t^I \tag{12}$$

Where p_t^e, p_t^c, and dr_t^I indicate the price of electricity, CO_2 emission price, and discount rate, respectively. Further, the parameters β_e, β_c, and β_I are applied to represent the drift, and γ_e, γ_c, and γ_I represent the variation. Finally, dz_t^e, dz_t^c, and dz_t^I are independent increases under the Wiener process.

$$dz_t^e = \varepsilon_{et}\sqrt{dt} \tag{13}$$
$$dz_t^c = \varepsilon_{ct}\sqrt{dt} \tag{14}$$
$$dz_t^I = \varepsilon_{It}\sqrt{dt} \tag{15}$$

In the above equations, ε_{et}, ε_{ct}, ε_{It} have a normal distribution with a mean of 0 and a standard deviation of 1.

- **Solution the Model**

The least squares Monte Carlo simulation method is an efficient method for valuing the actual capitals with several unknown variables and several real options. According to the study by (Pringles et al., 2015), the steps to conduct the estimation is as follows:

Step 1: Based on discrete approximations of uncertain factors, equations (16) to (18) simulate the paths of changes of uncertainty factors with w paths and N decision points in each path.

$$P^e(t+\Delta t) = P^e(t)\exp\left(\left(\beta_e - \frac{\gamma_e}{2}\right)\Delta t\right) + \gamma_e(\Delta t)^{1/2}\varepsilon_{et} \tag{16}$$
$$P^c(t+\Delta t) = P^c(t)\exp\left(\left(\beta_e - \frac{\gamma_c}{2}\right)\Delta t\right)\gamma_c(\Delta t)^{1/2}\varepsilon_{ct} \tag{17}$$
$$P^I(t+\Delta t) = P^I(t)\exp\left(\left(\beta_e - \frac{\gamma_I}{2}\right)\Delta t\right) + \gamma_I(\Delta t)^{1/2}\varepsilon_{It})) \tag{18}$$

Step 2: The project's expected value (VP_t) is calculated in each decision point of each path based on equation (1).

Step 3: The value of investment opportunity (threshold value to establishing the investment) is calculated.

$$F_{i,j} = max\{VP_{i,t}, 0\} \tag{19}$$

In each period ($1 \le t \le t_v$), investors should assess the continuation value of the project. The continuation value is obtained through the least squares regression in which the dependent variable is the optimal (incentive) value from the last period, and independent variables are investment cost (C^I), expected cumulative cash flow (CF) over the lifetime of the project.

$$F_{i,j} = max\{VP_{i,t}. e^{-r}E_t[F_{t+1}, j]\} \tag{20}$$

This recursive process continues, and the final threshold value is obtained by averaging all the paths. Then, the threshold value for the project (VP^*) can be determined as follows:

$$VP^* = F = \frac{1}{w}\sum_1^w e^{-rt}F_{t,j} \qquad j = 1, \dots, w \tag{21}$$

Step 4: After determining the threshold value for investment (VP^*), the optimal subsidy level can be calculated.

4. Empirical Results

This section presents an analysis of the empirical results. First, data and assumptions are introduced.

4.1 Data and Assumptions

In line with the research purpose, a small solar power plant with a capacity of 5 KW is considered in Iran to implement the model. Table 1 presents the information on the uncertainty parameters of the model, including initial values, units, and drift and variation parameters. Note that the initial values of the market price of electricity, investment unit cost for the Iranian economy, and CO_2 price are taken from China's CET market converted into Rials because the CET market has not been established in Iran.

Table 1. Parameters of model uncertainty factors

Parameters	Variables	Initial Value	Unit	Drift Rate(β)	Variation(γ)
Price of electricity (in the market)	p^e	1100	Rial/kwh	0.02	0.02
CO_2 price	p^c	720	Rial/kwh	0.02	0.03
investment cost of unit	p^l	110	Million Rial/kw	-0.06	0.04

***Source**: The drift and variation parameters have been taken from (Zhou et al., 2014).*

The main economic and technical parameters used for modeling are represented in Table 2.

Table 2. Main economic and technical parameters

Parameters	Variables	Value	Unit	Source
c_t^{uom}	c_t^{uom}	1200	Rial/kwh	Research assumption
Unit generating capacity	q^e	7500	kwh	Research assumption
Value added tax rate	r^v	9	%	Research assumption
Discount rate	dr	8	%	Research assumption
The validity period of investment	t_v	16	year	Research assumption
Lifetime of project	L	25	year	Research assumption
Decline rate of the unit generating capacity	d	2	%	Zhou et al., (2014)
Installed capacity	IC	5	kw	Research assumption
Share of tradable carbon in total carbon emission	K	0.9	-	Zhou et al., (2014)
Rate of internal demand	r^h	0	%	Zhou et al., (2014)

***Source**: Zhou et al., (2014), and research assumptions based on related project data in Iran*

4.2 Results from Scenarios

The amount of subsidy obtained by NPV and real options approaches for both the scenarios with and without the inclusion of a CET scheme is given in Table 3.

Table 3. Incentive subsidy in two different scenarios

Scenarios	Threshold	Project value	Subsidy (Based on NPV)	Subsidy (Based on Real Options)
Scenario 1: (without carbon emission trading) (unit: 1000Rial/kw)	1394.4	-47059.2	47059.2	48453.6
Scenario 2: (with carbon emission trading) (unit: 1000Rial/kw)	4932.2	-37494.3	37494.3	42426.5

***Source**: Research findings*

As shown in Table 3, the value of the solar project is -47059.2 (1000Rial/kw) in scenario 1, when CET isn't included. Hence, the required subsidy with NPV criterion should be at least 47059.2 (1000Rial/kw). Based on the real options model, the threshold value for motivating investment in solar projects is equal to 1394.4 (1000Rial/kw). So, the subsidy level must be at least 48453.6 (1000Rial/kw).[4] At subsidies below this level, the investor abandons the investment project. In scenario 2, when CET is included, the subsidy required to support solar energy investors is decreased based on both NPV and real option criteria. The level of required subsidy based on NPV and real options criteria are 37494.3, and 42426.5 (1000Rial/kw), respectively. This indicates a 20% and 12% reduction in the required subsidy compared to scenario 1, based on NPV and real option criteria. It is observed that by establishing and approving pollution allowance trading, the government can reduce the investors' subsidy (economic cost) substantially. This finding corresponds with the findings of (Cheng et al., 2015), and (Zhang et al., 2017). Besides providing the government's consent, this approach leads to investors' satisfaction by emission trading and brings a significant benefit for both parties and reduces pollution.

4.3 Sensitivity Analysis

This section analyzes the sensitivity of the subsidy paid by the government for electricity generation from solar energy to the changes in the variables of unit generating capacity, the market price of electricity, CO_2 price, and the discount rate. For this purpose, the sensitivity analysis is performed based on the two scenarios, i.e., scenario 1(without CO_2 emission trading), and scenario 2 (with CO_2 emission trading), to investigate the effect of the CET market on subsidy.

[4] This subsidy level (48453.6) is equal to the sum of the threshold value (1394.4) and project value (47059.2).

The comparative effects of the unit generating capacity in scenario 1 (without carbon trading) and scenario 2 (with carbon trading) can be seen in Fig 2. The subsidy has a decreasing trend. Further, when the CET is not considered, the project value is more than when the CET is considered. If the investors invest in solar energy generation, their major concern is the loss of capital. Compared with both scenarios, the CET scheme reduces the subsidy required. Also, in both scenarios, the project and threshold values increase when production capacity increases.

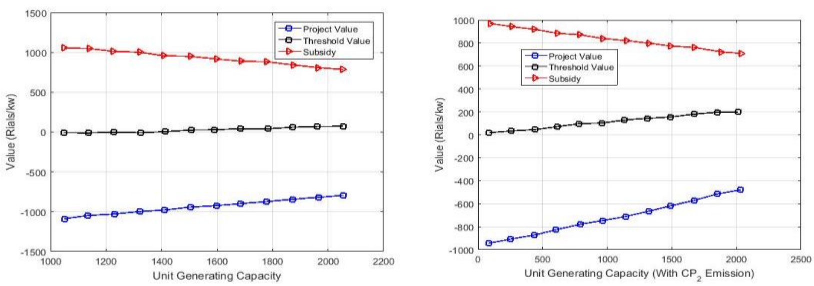

Figure 2. The effects of unit generating capacity on subsidy in different scenarios
***Source**: Research findings*

According to Fig 3, when the market price of electricity increases, the subsidy paid to the investors of electricity generation from solar energy decreases. In other words, with an increase in the market price of electricity, the need for a subsidy is reduced. Another finding is that including a CET market (scenario 2) reduces the need for a subsidy, compared with the case without a CET market. Also, with an increase in the market price of electricity, the project value and the threshold value increase in both cases because of an increase in the cash flow of the project (Fig 3).

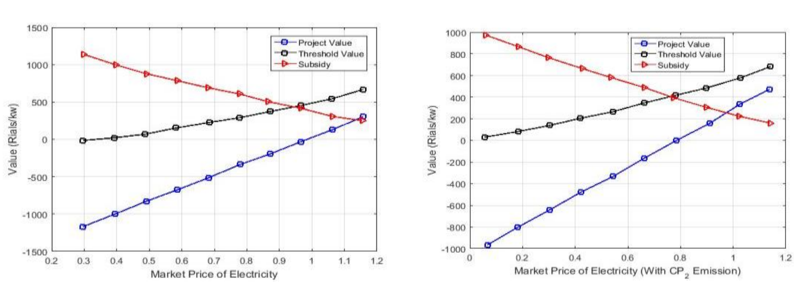

Figure 3. The effects of price electricity on subsidy in different scenarios
***Source**: Research findings*

Fig 4 represents the influence of the electricity price variation on the subsidy paid to the producers of electricity from solar energy. As seen, electricity price variation follows directly by an increase in subsidy required for electricity producers because electricity price variation leads to uncertainty among investors, causing a decrease in revenues from investments. This fact reflects an increase in the government's subsidy to keep the investors motivated. Comparing scenarios 1 and 2, we can see that the inclusion of a CET market caused the subsidy paid for electricity generation investment to be less than that in the case without a CET market.

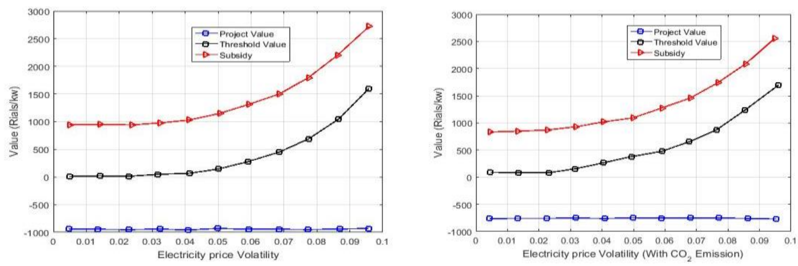

Figure 4. The effects of Electricity price variation on subsidy in different scenarios
***Source**: Research findings*

5. Concluding Remarks

Iran's energy mix is dominated by fossil fuels. To accelerate the energy transition, Iran must take motivate policies to promote renewable energy sources. Despite having great capacities (meteorological, geographical, and topographical) for development in this sector, renewable energies do not significantly affect Iran's energy basket. The FiT policy is an ordinary mechanism in the world for developing renewable energies that can increase investor certainty, reduce the risk, and raise the tendency to invest in renewable energies. However, continuing the current FiT policy significantly increases the government's expenditures to finance a guaranteed tariff policy in Iran (Table B.1). So, this research aimed to present a real options model to determine the incentive subsidy (FiT) required to support solar electricity generation investment in Iran under uncertainty. In this research, the incentive subsidy was calculated and analyzed in two scenarios with and without CET possibility. Further, electricity price, CO_2 price, and discount rate were entered into the analysis as the uncertainty variables, and the sensitivity of the subsidy determined to the changes in each variable was analyzed.

The results indicated that first, the CET scheme significantly helped to decrease the required subsidy. This result is in line with the result of (Zhang et al., 2017). Second, the subsidy measure by the real options approach was higher than that obtained by the NPV method because it could simultaneously incorporate net costs and opportunity costs. Therefore, the subsidy determined by the real options approach is more realistic. Third, an increase in unit production capacity and the electricity price can decrease the subsidy by reducing the difference between the threshold value and the project value. Nevertheless, increasing investment costs may increase the subsidy. Fourth, electricity price volatilities and CO_2 price volatilities can increase subsidy, while investment cost volatilities may slightly decrease subsidy. Fifth, when a CET scheme is considered, the subsidy may be easily affected by the relevant factors. These results support the findings of (Yin et al., 2018; Zhang et al., 2016; Zhang et al., 2017).

Considering the increasing amount and high intensity of carbon dioxide emissions in Iran and that electricity production has the largest share of greenhouse gas emissions in Iran, supporting electricity generation from renewable energy is essential. Given that financing the policy of guaranteeing electricity from renewable sources faces financial challenges, first, Given the legal requirements of the CET in Iran, it is suggested that the government establish an integrated emission trading market to motivate electricity producers from RE sources. Establishing a CET market instead of continuing the current FiT policy can more effectively support renewable sources in Iran.

Despite the effective role of the CET scheme in reducing emissions, some problems of its implementation are undeniable. These problems mainly arise from the issues related to improving its regulatory structure and less-accurate emissions measurement, reporting, and verification. Moreover, some CET schemes, like the case of Tokyo, give priority to local projects. These problems may reduce the efficiency of implementing this scheme.

Second, fostering the daily management of the carbon trading market and keeping the stability of the CO_2 price is important (Eltamaly et al., 2016; Mohamed et al., 2016). Third, emergency actions are necessary to maintain the stability of the electricity price.

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Conflicts of Interest:
The authors declare no conflict of interest.

Data Availability Statement:
The data used in the study were taken from
https://www.tavanir.org.ir/

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Appendix

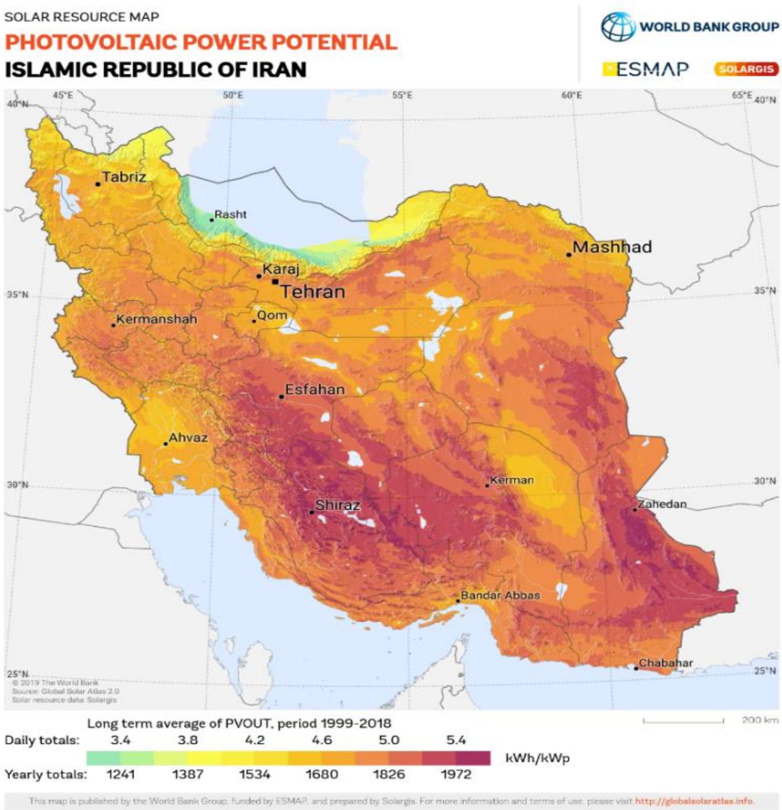

Figure. A.1. Iran's Photovoltaic Power Potential
***Source**: Global Solar Atlas*