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The environmental and economic analysis of grid-connected photovoltaic power systems with silicon solar panels, in accord with the new energy policy in Iran

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1. Introduction

Worldwide primary energy demand increased at a rate of 2.9% in 2018, nearly double its 10-year average of 1.5% from 2007 to 2017, which is the highest rate since 2010 [1]. Due to this increasing demand for energy and the burning of more fossil fuels, global warming has become one of the greatest consequential dilemmas facing human beings with considerable social, environmental, and economic outcomes. There are three outstanding ethical dilemmas, making difficult the climate change discussions: how to settle the rights and obligation of the developed and developing countries; how to estimate Geo-engineering schemes planned to slow or reverse climate change; and how to test our obligation to next generations who must struggle with an inferior climate we are changing today. In recent years, public awareness, the number of communities, national and international meetings about global warming have raised around the world. As prominent examples of international meetings, we can mention the Paris Agreement [2] and the Kyoto Protocol [3] as the two most important conventions by the United Nations on climate change.

At the same time, Worldwide carbon emissions from energy consumption increased by 2.0% in 2018, again the highest rate for seven years, with emissions rising by around 0.6 gigatonnes. To a significant extent, the increase in carbon emissions is clearly a direct outcome of the growth in energy consumption [1]. Due to the important role of coal in carbon dioxide (CO2) emissions, In 2016, more countries obligated to phasing out or moving away from the coal consumption for electricity production (e.g., Canada, France, etc.) [5,6] or do not more funding coal utilization (e.g., Brazil’s development bank) [7]. Opposing this trend, but several countries declared programs to increase coal production and utilization [4].

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However, in 2018 there was a significant move back to coal with both production (4.3%) and consumption (1.4%) [1].

In a large number of countries, the emission quotas referring to each power company are limited. With the emission trading pattern, they can determine the most preferred solution after achieving the Pareto solution set regarding different emission quotas. This technique is economically useful for countries with this ability [8]. The emission trading approach can be employed as a useful pattern by the power companies to maximize their profitability [9].

Comparatively low worldwide prices for coal, natural gas, and oil, keep challenging renewable energy markets, particularly in the heating and transport sectors [10,11]. Subsidies for fossil fuels, which stayed remarkably greater than renewable energy subsidies, also continued to influence renewable energy development. In 2017 over 50 countries had obligated to phasing out subsidies for fossil fuels due to international commitments [12]. Also, subsidy revisions were instituted in 2016 in several countries such as Brazil, Egypt, India, Iran, Nigeria, Saudi Arabia, Sierra Leone, Thailand, Tunisia, Ukraine, Venezuela [13].

In the energy sector, the world needs novel trends that are secure, sustainable, and favorable to all, and one of the most beneficial procedures is the utilization of sustainable energy resources instead of fossil fuels. The progression and consumption of sustainable energy resources are a fundamental alternative to climatic change and global energy demand. Utilization of sustainable, reliable, and inexpensive energy will determine the most standard aspects of life, in the future.

As of 2019, many countries directly provided renewable energy development and deployment with a broad range of policies. These policies prepare direct and indirect support, in an effort to economy-wide economic progression, environmental conservation, and national security. Technology developments, descending costs, and growing utilization of renewable energy resources are the results of these policies. In each country, authorities promote policies to merge renewable generation into their conventional national energy systems.

Due to the power sector is keeping to gain the most attention in energy subject, policymakers have introduced various support procedures and reformed existing policies to improve this sector by the utilization of renewable energy resources. These policies can be listed as follows:

- Feed-in tariff (FIT) policy is an energy-supply policy concentrated on supporting the progress of renewable energy plans by proposing long period purchase arrangements for the sale of renewable energy electricity. These arrangements propose purchasing every kilowatt-hour electricity for 10–25 years. The proposed payment levels for each kilowatt-hour can be distinguished by various factors such as project size, resource quality, technology type, and project location to properly cover main project costs. Policymakers can also arrange the payment levels to decrease for installations in the following years, which will both follow and encourage changes in technology. The two most ordinary FIT policies are the fixed FIT and the feed-in premium. In the fixed FIT, which is the most widely used FIT design, payment quantity stays independent of the market price for electricity, proposing a guaranteed payment for a clearly described period. In the feed-in premium, which is being increasingly used, the payment quantity is based on a premium proposed above the market price for electricity and this premium can either vary, dependent upon a sliding scale, or it can be constant.

Several countries, especially in Europe and Asia, have shifted away from FIT policies to auction and tender policies to support large-scale renewable energy project deployment. In spite of the fact that support for large-scale renewable energy projects is changing to a different mechanism in a growing number of countries, but FIT policies continue to be valid in many countries for the deployment of small-scale renewable energy installations. Policy designers continue to change FIT rates as the technologies become more cost-competitive in each country.

- Auctions and tenders are the most rapidly extending scheme of supporting mechanisms for the deployment of renewable energy projects and are becoming the preferred policy for supporting large-scale projects. Generally, they are on the basis of the cost of electricity generation; although in auctions, the price is the only factor to be considered, tenders may contain extra criteria.

- Net metering is a metering and billing agreement designed to compensate small-scale system owners for any electricity production that is exported to the grid. Net metering allows utility customers with on-site distributed energy generation to offset the electricity they extract from the utility grid during the billing cycle (e.g., one month) and they pay for the net electricity consumed from the grid. Net metering customers directly utilize the electricity produced on-site by their generation systems. If the amount of generation exceeds the utilized electricity, the excess electricity is exported to the utility grid. If a customer utilizes more electricity than the distributed energy generation system produces, he or she imports electricity from the utility grid and pays the full retail rate for that amount of electricity, exactly similar to a traditional utility customer.

- Renewable Portfolio Standard (RPS) policy is a regulatory mandate to raise energy generation from renewable resources and it’s also called a renewable electricity standard. The RPS procedure usually places an obligation on power supply companies to generate a clearly described fraction of their power production from renewable energy resources.

- Besides these main policies, some countries provided public funds by grants, loans or tax incentives to guide investment in renewable energy development. However, most of these incentives have been decreased or canceled in recent years in reaction to tightening fiscal budgets and/or reducing technology costs.

Although in recent years, policymakers in Iran have introduced different supporting policies for renewable energy resources but there is no collective and updated survey from this point of view. This study examines the country’s background from energy outlook and some of its important policies for energy subject and introduces current supporting policy for various renewable and clean energy resources. Due to the serious CO₂ emissions and air pollution in large cities of the country alongside with the high solar energy harvesting potential and growing trend of utilization of PV technology in Iran, we investigate environmental and economic aspects of two different scales of PV systems, 20 kW as a candidate for small-scale (for residential and commercial users) and 1 MW as a candidate for large-scale (utility-scale) grid-connected PV power systems in Tehran, Iran, using RETScreen software based on the new feed-in tariff policy.

2. Country background and energy policy

2.1. Iran

Iran, an Asian country, is the 18th largest and 17th most populated country in the world. In this territory, population and
technology growth has driven to the necessity for more energy production; while electricity production is mainly controlled by its fossil fuel resources. This country has the second-largest proven natural gas reserves (33.5 trillion cubic meters) and the fourth-largest proven crude oil reserves (158.4 thousand million barrels) in the world, around 18% and 9.3% of the world's total reserves, respectively [14,15].

It has an outstanding regional occasion because it is surrounded by several countries that are more opportune for international economic progression due to their vast and various energy resources, tourism market, passenger and freight transportation. This occasion could be managed more appropriately in the energy field with a suitable energy business strategy to accomplish electrical, gas pipeline, and crude oil pipeline loops between neighboring countries and Iran [16].

2.2. Energy policy

However, Iran's immense fossil fuel energy resources alongside subsidization, have resulted in the growing consumption of energy without seriously being worried about energy efficiency and the negative influences on the environment. During recent years, it has embarked on several policies for the production and consumption of energy. Four remarkable policies that have affected energy demand, can be mentioned as:

I. The first and the most prominent energy policy in Iran is the large energy consumption subsidization, particularly in households and transport sectors. There are several distinctive approximations for energy subsidies in Iran (between 0.5 and 12% of GDP); However, it is accepted that Iran's energy subsidies are one of the top-ranking energy subsidies in the world.

II. The second policy is assigning of oil production capacity in accord with the OPEC endorsements. Meanwhile, faced with capital restrictions, Iran identified the important role of international investment in the oil sector to develop new fields and improve the recovery factor in the existent fields, hence presented a “buy-back” contract to international investors. This contract permitted international companies to finance in oil and gas fields in Iran and to share profits with the domestic counterparts.

III. The third prominent energy policy in Iran has been the noticeable consumption and progression of natural gas fields from the 1990s so far. This policy reinforced, especially when Iran discovered its share of the South Pars gas field, the world's largest gas reservoir, which is located in the Persian Gulf. Iran has been using most of its ever-growing gas production to replace relatively cheap and environmentally friendly natural gas for domestic consumption of crude products in various sectors. In 2018, its energy consumption based on natural gas was 193.9 million tonnes of oil equivalent (Mtoe) [1].

IV. The fourth important energy policy in Iran is providing rural areas with electricity by new transmission lines. This policy has assisted a lot of rural communities to receive clean and cheap energy and decrease environmental problems like for example deforestation.

Some other prominent policies in the energy sector in Iran can be listed as follows:

✓ Establishment of two organizations by the Ministry of Energy for studying and expanding investment in renewable energy resources. These two organizations are SABA (Iran Energy Efficiency Organization in 1994) and SUNA (Renewable Energy Organization of Iran in 1995). These organizations have conducted several projects on the wind, solar, and geothermal energy resources in Iran.

✓ National Iranian Oil Company established IFCO (Iranian Fuel Conservation Company) in 2000 with the aim to regulate fuel consumption in various sectors. IFCO has audited several manufacturing industries and recommended different procedures for energy conservation in those units. Substituting pollutant and inefficient old taxis with new autos in cities and using compressed natural gas (CNG) as a replacement for gasoline are samples of the plans by IFCO in recent years.

✓ Iran has tried to improve the consumption of nuclear energy by finishing the Bushehr nuclear plant (which started in the 1970s and become operational in 2013) and investing in other new plants. In 2018, its energy consumption based on nuclear energy was 1.6 Mtoe [1].

✓ Although high-impact low-probability (HILP) events such as earthquakes, hurricanes, and consequent flooding have a prominent influence on power generation companies [17] and the number of these natural disasters has increased in recent years in Iran, but there is not a comprehensive and clear policy for these situations. Generally, the government decides based on the event impact on local people life and, for example, provide them with free fuel and power for a certain period of time. As another example of the emergency situation, during the COVID-19 crisis in the world, the authorities in Iran have postponed the payments due for water and power bills in the country.

2.3. Renewable energy policy

Similar to other countries in the world, there has been a growing trend toward the utilization of sustainable energies in Iran, too. Besides enormous fossil fuel reserves, Iran enjoys a perfect potential of using renewable energies (energy resources that are naturally inexhaustible and replenished) such as solar, wind, geothermal, biomass, and hydropower. In Iran, electrical customers participate in an electricity market and buy electricity generated from fossil fuels. Due to the current Levelized cost of electricity (LCOE) prices, the production of electric power based on renewable energy resources is not economical on its own yet. Therefore, the progression of the renewable energy division in Iran is leaned upon the government incentive attitude and its encouraging policy on this subject. From the environmental aspects, noticeable troubles in Iran are CO₂ emissions and air pollution. In 2018, CO₂ emissions in Iran were 656.4 million tonnes, increased by 5.5% growth rate per annum that is above double its 10-year average of 2.6% from 2007 to 2017 [1]. So recently, the authorities have paid basic investment in harnessing renewable energies and laid down the new supporting policies to inspire people to use clean energy resources. Due to the huge investments in hydropower, a large share of renewable power generation in Iran is hydropower, around 2.4 Mtoe in 2018 [1]. Although in recent times, it has been financing on others, such as wind and solar power, too.

Solar energy as a worthwhile renewable energy source has attracted a lot of attention nowadays. Living things, including human beings, depend on solar energy for warmth and food. However, human beings also harness solar energy in many distinctive ways. They use solar energy either indirectly as the form of fossil fuels, biomass, wind, hydropower, and ... or directly by utilization solar thermal technology (using solar energy to generate low-cost, environmentally friendly thermal energy) and PV technology. PV devices or solar cells directly convert energy from the sunlight into electricity by the PV effect quietly, with no pollution or
moving parts. A PV system is working differently than most electric-generating systems because it generally doesn't need a technician to be on-site for daily direct management due to its automated operation, and it just needs insignificant and slight oversight, monitoring, and maintenance. These systems are designed modularly and can be built on different scales.

Fortunately, solar energy is broadly achievable in most areas of Iran, specifically in the southern and central regions (Fig. 1). This country is potentially one of the best regions for solar energy harvesting because located in the global Sunbelt, and experiences three hundred sunny days per year on over two-thirds of its land area, according to SATBA (renewable energy and energy efficiency organization), the ministry of energy, Iran [19]. The radiation distribution varies between 2.8 kWh/m² in the southeast part to 5.4 kWh/m² in central parts. In a country-wide analysis of irradiance, it is estimated that on 80% of Iran’s land area, solar irradiance is between 1640 and 1970 kWh/m²/year [20]. The calculations show that the applicable solar radiation hours in Iran surpasses 2800 h per year [21,22]. According to the reports, by covering only 1% of the deserts in the country by solar collectors, the output energy would be five times greater than its annual gross electricity output [15,23].

Besides Iran’s solar energy harvesting potential, several factors such as the price of fossil fuels in electricity generation and the import of expensive PV instruments have limited applying PV technology in Iran. As mentioned above, new supporting policies such as different feed-in tariff and subsidies have been described to stimulate using of renewable energies and turn them into competitive technologies with common electricity production methods based on the burning of fossil fuels. According to the new supporting policy of the government, the latest prices for electricity based on the feed-in tariff by offering long-term contracts to renewable energy resources are shown in Table 1 [24]. The selected currency in this study is the Iranian Rial (IRR) which can be converted to US Dollar (USD) easily (1 USD = 42,000 IRR). According to Table 1, the government will buy electricity from the producers at two prices: during the first 10 years, the purchasing price is relatively high to investors gain their investment as soon as possible. However, during the second 10 years, the price will be decreased to 70% of the prime bid for all resources except the wind systems (the price will be calculated according to their capacity factors), and after 20 years the electricity can be sold in energy exchange. So, investments in different renewable and clean energy resources (especially PV technology) with different scales, are fostered by the new feed-in tariff to decrease consumption of fossil fuels in Iran.

3. Simulation

Regarding the growing trend in using PV technology around the globe, there is a considerable requirement for relatively simple, and user-friendly software packages, for the designing and performance assessment of PV systems by installers particularly during the
date the new feed-in tariff to support renewable and clean energy resources in Iran.

| Energy type | Specification | IRR/kWh (USD/kWh) |
|-------------|---------------|-------------------|
| **The first decade** | | |
| Biomass | Landfill | 2700 (6.43) |
| | Anaerobic digestion of livestock and agriculture wastes and sewage sludge | 3500 (8.33) |
| | Waste Incineration and gasification | 2450 (5.83) |
| Wind | More than 50 MW<sup>a</sup> | 3700 (8.81) |
| | ≤50 MW | 3400 (8.10) |
| | < 1 MW | 4200 (10.10) |
| Solar | More than 30 MW<sup>a</sup> | 3700 (8.81) |
| | ≤30 MW | 3400 (8.10) |
| | ≤10 MW | 5700 (13.57) |
| | ≤100 kW | × (0.4–1)<sup>b</sup> |
| | < 20 kW | × (0.4–1)<sup>b</sup> |
| Small hydropower (≤ 10 MW) | On the rivers and peripheral equipment for dams | 3200 (7.62) |
| | On the water pipeline transport | 4000 (9.52) |
| Geothermal | including drilling and equipment | 4900 (11.67) |
| WHRU | Production of electricity from the waste heat recovery unit | 7000 (16.67) |
| Fuel cells | – | 8000 (19.05) |
| Turboexpander | Known as turbo-expander or expansion turbine | 1600 (3.81) |
| **The second decade** | | |
| | | 1890 (4.5) |
| | | 2450 (5.83) |
| | | 2590 (6.17) |
| | | 2240 (5.33) |
| | | 2800 (6.67) |
| | | 3440 (8.17) |
| | | 4900 (11.67) |
| | | 5600 (13.33) |
| | | 1470 (3.5) |
| | | 1050 (2.5) |
| | | 3430 (8.17) |
| | | 2030 (4.83) |
| | | 1463.6 (8.25) |
| | | 1120 (2.67) |

<sup>a</sup> The highest level capacity for the wind and solar farms will be determined by the policy of the ministry of energy on renewable and clean energy development policy, which is following up to 2000 MW in a year by the private sector.

<sup>b</sup> During the second decade, the contract fee will calculate based on the capacity factor. For wind farm with capacity factors >40% and ≤20% during the first 10 years, the prime fee will multiply in 0.4 and 1, respectively. For capacity factors between 20 and 40%, the prime fee will multiply in a number proportionally.

The investigated case of the PV installation is the grid-connected PV system with easy installation, and in locations with trustworthy grid power, it generally doesn’t need the battery equipment for backup power. After installation, these systems do not need extra care and service, do not generate CO₂ and air pollution, and they are as quiet as the sun. A schematic diagram of the simulated grid-connected PV power system is shown in Fig. 2.

RETScreen software is provided with NASA’s Satellite-derived Meteorological Data (developed by NASA’ Langley Research Center in collaboration with CanmetENERGY) for any location and the NASA Prediction of Worldwide Energy Resource (POWER) project. This data set is a helpful option when there is no access to ground-based data or itemized resource maps for the project location; It is calculated from data collected for a 20-year period starting in July 1983, applying a 1-degree cell (at mid-latitudes (45°) the cell dimensions is around 80 × 110 km). Solar radiation parameters are derived using satellite data of the atmosphere and Earth’s surface. The other meteorological values are adapted from Goddard Earth Observing System (GEOS) meteorological analysis by the NASA’s Global Modeling and Analysis Office (GMAO). The selected site for this simulation is Mehrabad national airport which its elevation, latitude, and longitude coordinates are 1191 m, 35.68° and 51.3° respectively. Climate data for this site is gathered from the weather station and NASA database in RETScreen (Table 2).

The capacity factor of the PV module (the ratio of the average power produced by the power system over a year to its rated power capacity) is vital for selecting a proper site and solar system, and its quantity is 22.30% for the fixed solar array in Tehran [15].

We used Yingli Silicon Solar PV Modules (Mono-Si-Panda-YL250C-30b) 250Wp with a module efficiency of 15.3% for this simulation. The numbers of PV modules for 20 kW and 1 MW PV power plants are 80 and 4000 modules, respectively. According to the PV market in Iran, the estimated initial and periodic costs (due to the inverter replacement) for these two systems are shown in Table 3. Several factors such as site location, type of PV technology, maintenance, and … may affect these estimated prices.

4. Results and discussion

4.1. 20 kW PV power plant

The first case, 20 kW PV power plant, is a candidate for small-scale PV power plants. A small-scale PV system is normally mounted on places like residential or commercial roofs, the ground in backyards, or facade of the building, etc. Along with the grid, these systems can take advantage of the battery equipment for backup power during a power outage, or while the sun is not shining. However, this advantage comes with intensified complexity, price, and maintenance. Hence, in locations with trustworthy grid power, ignoring the battery backup system is the logical choice.

As mentioned before, global warming has become one of the greatest consequential dilemmas facing the human being in this century, thereby researching on GHG emissions is necessary for any power project. An emissions analysis worksheet is provided in RETScreen to help studies on the GHG emissions mitigation potential of renewable energy projects.

The main GHGs are water vapor, CO₂, methane (CH₄), nitrous...
oxide (N₂O), ozone (O₃) and Fluorinated gases. GHGs that are considered for energy project analysis are CO₂, CH₄, and N₂O which are expected in the RETScreen emission reduction analysis. Results from the GHG equivalence tool in the RETScreen are presented in terms of the annual amount of CO₂ that would be equivalent to the total emission reduction, regardless of the actual gases. and it’s done by converting CH₄ and N₂O emissions to the equivalent CO₂ emissions based on their global warming potential.

In Table 4, one can find interesting data about 20 kW PV power plant from the net annual GHG emissions reduction outlook. In this table, important equivalent cases from the environmental perspective, such as the number of cars & light trucks that are not

### Table 2
The climate data of Mehrabad national airport, Tehran, Iran.

| Month | Air T (°C) | Earth T (°C) | Relative humidity | Daily solar radiation — horizontal (kWh/m²/d) | Atmospheric pressure (kPa) | Wind speed (m/s) |
|-------|------------|-------------|-------------------|-----------------------------------------------|---------------------------|-----------------|
| Jan.  | 3.0        | 1.0         | 60.1%             | 2.44                                          | 88.5                      | 35              |
| Feb.  | 5.3        | 2.5         | 51.6%             | 3.33                                          | 88.3                      | 50              |
| Mar.  | 10.3       | 7.3         | 46.4%             | 4.08                                          | 87.9                      | 64              |
| Apr.  | 16.4       | 15.7        | 41.6%             | 5.42                                          | 87.5                      | 71              |
| May   | 22.1       | 21.9        | 34.2%             | 6.42                                          | 87.3                      | 72              |
| Jun.  | 27.5       | 26.9        | 27.6%             | 7.64                                          | 86.8                      | 67              |
| Jul.  | 30.4       | 29.1        | 29.8%             | 7.50                                          | 86.5                      | 55              |
| Aug.  | 29.2       | 28.1        | 29.0%             | 6.92                                          | 86.8                      | 49              |
| Sept. | 25.3       | 23.1        | 31.6%             | 5.75                                          | 87.3                      | 47              |
| Oct.  | 18.5       | 16.0        | 39.2%             | 4.25                                          | 87.9                      | 47              |
| Nov.  | 11.6       | 8.7         | 49.8%             | 2.92                                          | 88.3                      | 39              |
| Dec.  | 5.6        | 2.9         | 61.2%             | 2.25                                          | 88.5                      | 35              |
| Annual| 17.2       | 15.3        | 41.8%             | 4.92                                          | 87.6                      | 53              |

### Table 3
Estimated costs for two PV power plants in Iran.

| Capacity | Initial cost: IRR (USD) | Periodic cost: IRR (USD) |
|----------|-------------------------|--------------------------|
| 20 kW    | 12000000000 (38,571)    | -12 2600000000 (6190)    |
| 10 MW    | 50000000000 (1190476)   | -12 10750000000 (255,952) |

### Table 4
Equivalent cases substitute for 20 kW PV power plant based on net annual GHG emissions reduction in Iran.

| Equivalent cases                     | Value |
|--------------------------------------|-------|
| Cars & light trucks not used         | 4     |
| Liters of gasoline not consumed      | 9496  |
| Barrels of crude oil not consumed    | 51.4  |
| People reducing energy use by 20%    | 22.1  |
| Acres of forest absorbing carbon     | 5.0   |
| Hectares of forest absorbing carbon  | 2.0   |
| Tons of waste recycled               | 7.6   |
| Annual GHG emissions reduction       | 22.06 tCO₂ |
| Annual electricity exported to the grid | 39 MWh |
used, liters of gasoline not consumed, barrels of crude oil not consumed, people reducing energy use by 20%, acres of forest absorbing carbon, hectares of forest absorbing carbon, tons of waste recycled are mentioned. According to this simulation, the annual GHG emissions reduction and the annual electricity exported to the grid for 20 kW PV power plant are 22.06 tCO₂ and 39 MWh, respectively.

A financial analysis worksheet in RETScreen is provided to aid the feasibility investigation of renewable energy projects. By considering a new supporting policy of the government for renewable energy resources, a financial analysis was carried out based on the new feed-in tariff for PV electricity in Iran (Table 1) and estimated initial and periodic costs for 20 kW PV power plant (Table 3). The cumulative cash flows from the simulation are plotted versus time in Fig. 3.

According to this figure, the estimated initial cost for 20 kW PV power plant is 1.2 bIRR based on the PV market in Iran. After starting operation, the gained annual interest income is above 300 MIRR so the payback period for the initial investment is between 3 and 4 years. The change in the linear trend of this plot is related to the estimated periodic costs (260 MIRR) for replacing invertors and other necessary services after 12 years. Following this payment, the same annual interest income can be gained until 20 years. The average annual interest rate for this investment is about 8.75% over 20 years, base on the new feed-in tariff for this scale of the PV power plant.

4.2. 1 MW PV power plant

The second case, 1 MW PV power plant, is a candidate for large-scale PV power plants. Large-scale (utility-scale) PV power plants, also known as solar parks, farms, or ranches (particularly when they are located in agricultural areas) are power stations that provide a considerable amount of electrical energy to great numbers of consumers. Large-scale PV power plants are ground-mounted, usually with fixed tilted solar panels instead of utilizing expensive tracking systems.

A similar examination was carried out on 1 MW, same as 20 kW PV power plant. First, the GHG emissions mitigation was studied and related data are presented in Table 5. According to this simulation, the net annual GHG emissions reduction and the annual electricity exported to the grid for 1 MW PV power plant are 1103 tCO₂, and 1953 MWh, respectively.

A financial analysis was carried based on the new feed-in tariff (Table 1) for 1 MW PV power plant, too. The cumulative cash flows from the simulation are plotted versus time in Fig. 4. According to this figure, the estimated initial cost for 1 MW PV power plant is 50 bIRR and after starting operation, the obtained annual interest income is above 1 bIRR so the payback period for the initial investment is about 5 years. The change in the linear trend of this plot is related to the estimated periodic costs (10.75 bIRR) for replacing invertors and other necessary services after 12 years. Following this payment, the same annual interest income can be gained until 20 years. The average annual interest rate for this investment is about 3% over 20 years, base on the new feed-in tariff for this scale of the PV power plant.

We have simulated two different scales of the PV power plant and investigated them from the environmental and economic aspects based on CO₂ emissions, and the cumulative cash flows after the new feed-in tariff, respectively.

From the environmental (CO₂ emissions) and electricity generation perspective, a comparison between these two scales of PV power plant shows us that CO₂ emissions and the annual electricity exported to the grid, have a linear relationship with the scale of the power plant. We can reduce the quantity of CO₂ emissions by using PV technology as multiple small-scale PV power plants (by residential and commercial users), or a large-scale PV power plant (by the governments) in the same impact. From the economic outlook, there isn’t a linear relation in cumulative cash flows rate and the average annual interest rate with the scale of the PV power plant. With a comparison between these two cases, as candidates for small-scale and large-scale PV power plants, we can realize that

| Equivalent cases                          | Value   |
|------------------------------------------|---------|
| Cars & light trucks not used              | 202     |
| Liters of gasoline not consumed           | 473,928 |
| Barrels of crude oil not consumed         | 2565    |
| People reducing energy use by 20%         | 1103    |
| Acres of forest absorbing carbon          | 251     |
| Hectares of forest absorbing carbon       | 101     |
| Tons of waste recycled                    | 380     |
| Annual GHG emissions reduction            | 1103 tCO₂ |
| Annual electricity exported to the grid   | 1953 MWh |
this difference comes from various amounts of the feed-in tariff for different scales of PV power plants in Iran. According to the supposed initial costs, the payback period for the initial investments are between 3 and 4, and 5 years for 20 kW and 1 MW PV power plants, respectively.

Hence, in accord with the high initial costs for PV power plants, the ministry of energy in Iran has formulated an incentive and supporting policy to persuade people, spatially residential or commercial users, or private sector to invest in small-scale PV power plants. Therefore, residential and commercial customers will have considerable long-term benefits, from taking part in an electricity market and selling their PV systems output. While those PV systems generally do not need a technician to be on-site for daily direct management due to its automated operation, and they just need insignificant and slight oversight, monitoring, and maintenance. On the other hand, the government itself has taken the responsibility to set up large-scale PV power plants around the country. By focusing on these two procedures in PV subject, Iran takes its first steps in lessening reliance on fossil fuel consumption and its related environmental issues. In future research, we will examine the various feasible renewable energy projects in Iran, for different scales from the environmental and economic aspects in terms of this new feed-in tariff for each technology categories and scales. Also, the authors will try to provide data from available operational cases to check the impacts of this supporting policy in reality.

5. Conclusions

In conclusion, this paper intends to give a brief and comprehensive survey on various energy policies and provide a technical outlook from the environmental and economic aspects for two different scale grid-connected PV power systems according to the new supporting policy for renewable energy resources in Iran. We have presented clear and efficient simulations on 20 kW and 1 MW grid-connected PV power plants using RETScreen software to illustrate the mentioned aspects based on the net GHG emissions reduction, the annual electricity exported to the grid, the cumulative cash flows, and the payback period for the initial investment.

From the environmental (CO₂ emissions) and electricity generation perspective, a comparison between these two scales of PV power plant demonstrates that CO₂ emissions and the annual electricity exported to the grid, have a linear relation with the scale of the power plant. From the economic outlook, due to varying amounts of the feed-in tariff for different scales of PV power plants, there isn’t a linear relation in cumulative cash flows rate with the scale of the PV power plant. According to the supposed initial costs, the payback period for the initial investments are between 3 and 4, and 5 years for 20 kW and 1 MW PV power plants, respectively.

Hence, in accord with the high initial costs for PV power plants, the ministry of energy in Iran has formulated an incentive and supporting policy to persuade residential and commercial users, and private sector to invest in small-scale PV power plants. Furthermore, the government has taken the responsibility to set up large-scale PV power plants around the country. It can be concluded that, by focusing on these two procedures in PV subject, Iran takes its first steps in lessening reliance on fossil fuel consumption and its related environmental issues.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Mostafa Farangi: Conceptualization, Formal analysis, Investigation, Methodology, Software, Writing - original draft, Writing - review & editing. Ebrahim Asl Soleimanl: Conceptualization. Mostafa Zahedifar: Formal analysis, Writing - original draft, Writing - original draft. Omid Amiri: Formal analysis, Writing - original draft. Jafar Poursaafari: Formal analysis, Writing - original draft.

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Reference to any special commercial product, trademark, manufacturer, and so on, does not necessarily infer or insist on its confirmation, or approval by the writers.

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