Development of Feed-in Tariff for PV in the Kingdom of Saudi Arabia

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Abstract: Feed-in tariff (FIT) is the most commonly used strategy worldwide for promoting renewable energy. The FIT strategy mainly consists of three key elements—certain admission to the grid, long-term contracts (10 to 20 years), and reimbursement levels that are founded on the prices of renewable energy production. The most common renewable energy in the Kingdom of Saudi Arabia (KSA) is solar energy, and it can be incorporated into the main grid through a favorable feed-in tariff that will attract investment. This paper aims to review the FIT rates in Germany and the United States, then the design of FIT in these countries to study the results, which helps to determine the most appropriate FIT in the KSA for different regions with regard to investment costs, household electricity consumption, compatibility with the existing grid, period required for return on assets, and long-term benefits. This study will also explain the importance of interest rates for residential investors and the challenge created by the recent tariff increase to 0.18 SAR/kWh. Saudi Arabia has the advantage of being able to use this information to assess the best approach to the economic and environmental impacts of FIT.

Keywords: feed-in tariffs; renewable energy; tariff design; photovoltaic (PV)

1. Introduction

Over the past four decades, Saudi Arabia has witnessed tremendous economic development coupled with high population growth and urbanization, which is driven by crude oil revenues. High economic growth, as well as population and urban growth have led to huge growth in the electricity demand in the country. The electricity usage in Saudi Arabia has risen by about 7–8% annually over the last decade, with the summer peak demand increasing by 93% between 2004 and 2013 (from 28 to 54 GW) (ECRA, 2014). Between 2013 and 2020, the Saudi electricity demand is expected to increase by over 6% annually. This future electricity demand growth will require power generation capacity to increase to 120 GW by 2032 [1]. The current demand is usually met by the exploitation of conventional crude oil, heavy oil, and gas across the country.

Saudi Arabia is one of the main producers of oil with one of the world’s largest proven oil reserves and a unique role as the world’s top oil producer, giving the country considerable power to influence oil prices. Domestic consumption feeds on oil reserves that could otherwise have been exported, creating huge costs of oil export. The rate of oil consumption in Saudi Arabia is among the highest worldwide, representing 4% of the total daily oil consumption worldwide [2]. Another problem caused by high energy consumption in Saudi Arabia is the huge carbon effects, which are caused by burning fossil fuels. In 2017, the CO₂ emissions of Saudi Arabia increased to 1.75% of the global emissions [3].

Currently, Saudi Arabia relies on oil, and the oil resources are not sustainable. If the situation remains the same, the development will further affect the environment and climate, as well as the political economy, which may lead to social unrest and political instability. Instability in Saudi Arabia can have far-reaching consequences, leading to economic and political challenges to energy at regional...
and global levels. Far from being oblivious to the uncertain future of oil and the importance to adapt to the challenges posed by climate change, Saudi Arabia has launched the Saudi Vision 2030, a major plan aimed at reducing Saudi Arabia’s dependence on oil, diversifying its economy away from oil, and replacing it with renewable energy [4]. Renewable energy and energy efficiency are understood to be the twin pillars of energy sustainability [5,6]. According to Couture and Cory, renewable energy technologies are the most promising alternatives and will play a crucial role in providing more diverse energy supplies in the future [7].

In the context of obtaining a sound understanding of the kingdom’s consumption trends and peak loads, solar energy is the most ideal response in terms of addressing a factor that causes an electrical load to peak. For example, the daily afternoon peak coincides with the period when the sun is brightest and hottest, and the solar panels work best at that time. Similarly, solar panels are the most productive during such periods [8]. In this case, a core need that draws much energy from the grid system can be addressed using renewable resources such as solar energy. In this regard, the kingdom has an exceedingly high potential to develop wind and solar power projects to meet its goals as outlined in its 2030 vision. Hepbasli and Alsuhaibani noted that governments have developed policies to accelerate renewable energy deployments such as a renewable portfolio standard (RPS), tax incentives, and feed-in tariffs (FITs) [5].

2. Problem Statement

In Gulf countries such as Saudi Arabia, it is possible to invest in alternative sources such as solar, wind, and tidal energy and incorporate the energy into the main grid through a favorable FIT. In addition, the new rate for the residential category is 0.18 SAR/kWh and is more than a 200% increase for the customers in the lowest use group. With the current usage tariff rates being increased, the FIT rate needs to remain a large enough cost incentive to attract potential investors and have a reasonable impact on the energy use within the Kingdom of Saudi Arabia (KSA). Because the FIT policy in the KSA does not exist, the challenge is to examine how to invest in solar energy distributed to the main grid by applying a feed-in tariff policy, which attracts investment without increasing energy costs to the end consumer in the long term. The solution to this problem is to investigate possible application of a feed-in tariff for renewable energy in Saudi Arabia as part of the kingdom’s 2030 vision. The steps that must be taken to reach a solution involve reviewing the FIT rates in Germany and the United States, then the design of the FIT in these countries to study the results, which helps to determine the most appropriate FIT with regard to investment costs, household electricity consumption, compatibility with the existing grid, period required for return on assets, and long-term benefits. The investment costs need to be considered against the amount of energy that can be produced and the FIT rate. The FIT rate must be high enough to return the cost of the investment to the owner and continue to provide energy savings and monetary credits beyond the point of payback. It must also be low enough to allow the serving utility company to still profit from the delivered energy while maintaining the grid. Together, the customers/investors and the utility company can have an enormous impact on the environment and natural resources that exist in the KSA.

3. Feed-in Tariff

FIT is the most widely used application instrument to obtain renewable energy (RE) production globally [9,10]. A feed-in tariff is an incentive that pays owners of distributed energy systems (such as solar) a certain amount per unit of electricity that is sent to the grid. They are often fixed-price incentives that are locked in over a contract period of 10 to 20 years, providing property owners with distributed generation a long-term, stable incentive [10]. According to Butler and Neuhoﬀ, a comparison of support schemes for market-based deployment of renewable energy in the UK and Germany shows that the feed-in tariff reduces the costs to consumers and results in larger deployment [11]. In the European Union, FIT strategies have led to the arrangement of more than 15,000 MW of solar photovoltaic (PV) capacity and more than 55,000 MW of wind power between 2000 and the end of 2009. In general, FIT is
answerable for about 75% of worldwide PV and 45% of worldwide wind utilization. Nations such as Germany have established that FIT can be used as a controlling strategy tool for RE utilization and help meet joint energy safety and emissions reduction purposes. If the policy is designed and implemented carefully, the FIT can help policymakers target a variety of policy objectives [6,12].

The payment stages offered are per kilowatt-hours which can be distinguished by equipment type, scheme size, source quality, and scheme position to better reproduce actual scheme costs. Application designers can also regulate the payment levels so that installations in following years can be carried out at reduced costs, which will both pave the way for and encourage scientific alteration. In another method, FIT payments can be obtained as a fixed price or premium price [13,14].

FIT in Germany and the United States

Germany was the first European country to adopt a feed-in tariff program in 1991, with a tariff based on a percentage of the retail rate of electricity [15]. In 2000, Germany and Denmark altered their FITs to cost-based models, in which rates are set based on the cost of generation plus a reasonable rate of return. These governments mandated grid access for renewable energy, guaranteed payments for 20 years, and offered differentiated rates based on technology, project size, resource intensity, and application [16].

The first feed-in tariff (FIT) was implemented by the Carter administration in the United States in the late 1970s. The National Energy Act, as it was known, was meant to promote energy conservation along with the development of new, renewable sources of energy, such as solar and wind power. Since this time, FITs have been widely used, most notably in Germany, Spain, and other parts of Europe [17].

Table 1 shows the FIT and normal tariff rates for Germany and the United States, which will help the study to design the feed-in tariff.

| Country      | FIT Rate (£) | Normal Tariff |
|--------------|-------------|---------------|
| Germany      | 0.12        | 0.29          |
| United States| 0.165       | 0.20          |

4. Materials and Methods

The method of designing KSA FIT is to review the FIT rates in Germany and the United States and the design of FIT in these countries to study the results, which helps determine the most appropriate FIT in the KSA for different regions with regard to investment costs, household electricity consumption, compatibility with the existing grid, period required for return on assets, and long-term benefits. To design the FIT structure in the KSA, there are two important things that need to be calculated. These are the household electricity energy (HEE) (kWh/day) for each region (West, South, Central, and East) and the PV power for feeding the grid.

4.1. Household Electricity Energy

Household electricity energy is a required factor in determining the FIT structure for a given system. To use HEE as the basis of calculating FIT, it must be verified either through metering, or billing history and a study of the electrical system. Therefore, the calculations are in the form of three equations, as shown below:

\[ U_D = \frac{\text{HEE(kWh)}}{365 \text{ Days}} \]  

\[ Ah = \frac{U_D \times 1000}{48 \text{ Vdc}} \]  

\[ Ah_{KSA} = Ah + Ah_{ID} \]
where $U_D$ is the daily usage of household electricity energy, the multiplication between $U_D$ and 1000 is for converting from kWh to Wh; HEE is the yearly usage of household electricity energy; $Ah$ is the daily Amp hours at 48 Vdc; $Ah_{KSA}$ is the total daily Amp hours based on the KSA national annual average; $Ah_{ID}$ is total daily amp per hour that required for inverter power used on discharge.

### 4.2. PV Power

$P_{PV}$ is the annual energy output generated for feeding the grid by a photovoltaic solar power plant (kWh). The total $P_{PV}$ (kWh) will include some system losses. The approach should be to identify the possible losses through inefficiencies, minimize them, and mitigate them where possible. Furthermore, efficiencies should be applied where it is possible to incorporate them into the system. DC cable losses will not be included, assuming that the cables are oversized based on ampacity requirements of the system. High-efficiency inverters with superior performance are currently available through companies such as SolarEdge, who manufacture 98% efficient inverters producing only a 2% loss. Solar panels are available with a 3% power tolerance based on the listed rating. This loss will vary within the 3% range based on heat fluctuations and will average 1.5%. That is a total of 3.5% in losses through the panels and inverter. Additionally, in determining the output required for solar panels, it will also be considered that the batteries are Gel Cell type solar batteries and they are 90% efficient. The total losses are 13.5%. This will increase the output requirement for the solar panels. To increase the overall system performance and reduce project cost (PC), the system will be considered to have an MPPT type charge controller instead of a PWM controller. This will increase the overall efficiency of the system by 30%. The 30% efficiency for an MPPT control is the current industry standard and averages between 10% and 50% depending on many factors including the season of the year. Therefore, for calculating the PV power, three equations are required, as shown below:

\[
W = \frac{[(Ah_{KSA}/S) \times (1 + \eta_a) \times (1 + \eta_b)] \times E}{(1 + \eta_c)}, \quad (4)
\]

\[
PV = [P - (W/1000)] \times S \quad (5)
\]

\[
P_{PV} = PV \times 365 \quad (6)
\]

where $W$ is the total solar panel wattage that is required for HEE, $\eta_a$ is the panels and inverter losses, $\eta_b$ is the battery efficiency losses, $\eta_c$ is a gained efficiency from using an MPPT charger, $S$ is the typical hours of useful sun within a 24-hour day, $E$ is the voltage (Volt), $PV$ is the daily energy output generated for feeding in (kWh), $P$ is recommended system size based on instantaneous peak demand (kW), and $P_{PV}$ is the annual energy output generated for feeding the grid by a photovoltaic solar power plant (kWh).

### 4.3. FIT Structure

The FIT Structure calculation is based on household electricity energy and PV power and it is the final method to find the photovoltaics credits and savings amount throughout the 25-year period, as shown in Equation (7). The net savings over the 25-year period of the system are shown in Equation (8).

\[
PV_{CS} = (P_{PV} \times CI) + (HEE \times C) \quad (7)
\]

\[
Net \ PV_{CS} = (PV_{CS} \times N) - PC - OM \quad (8)
\]

where $PV_{CS}$ is the photovoltaics credits and savings, CI is the cost incentive (FIT rate) and C is current tariff, $N$ is the life time of the system, PC is the project cost (installed costs of solar panels, inverter, batteries, and wiring), and OM is the operation and maintenance (the battery is expected to be replaced once throughout the 25-year period).
5. Results

5.1. FIT in United States and Germany

5.1.1. FIT in Germany

Table 2 shows the initial installation costs for new equipment, where PRV is the photovoltaic plant price per kW (€/kW), Table 3 shows the PV plant installation, and Table 4 shows the rate of return on investment due to energy generation throughout the 25-year period, while light grey indicates the payback period and dark grey indicates the accumulative savings.

| Installed Solar (€/Watt) | Installed Wattage (W) | PC (€/kW) | Total PC (€) |
|--------------------------|----------------------|-----------|--------------|
| 2.00                     | 10,000               | 2000.00   | 20,000       |

Table 3. Photovoltaic plant installation (Germany).

| Daily Feed In (kWh) | PPV (kWh) | FIT Rate-CI (€) | Annual Feed in Credit (€) | HEE (kWh) | Current Tariff-C (€) | Annual Energy Savings (€) | PVCS (€) |
|---------------------|-----------|-----------------|--------------------------|-----------|---------------------|--------------------------|---------|
| 65.73               | 23,992.43 | 0.12            | 2879.09                  | 3512      | 0.29                | 1018.48                  | 3897.57 |

Table 4. The rate of return on investment due to energy generation throughout the 25-year period.

| Years | The Rate of Return (€) |
|-------|------------------------|
| 1 year| 3897.75                |
| 2 year| 7795.14                |
| 3 year| 11,692.71              |
| 4 year| 15,590.29              |
| 5 year| 19,487.89              |
| 6 year| 23,385.43              |
| 7 year| 27,283.00              |
| 8 year| 31,180.57              |
| 9 year| 35,078.14              |
| 10 year| 51,323.68          |
| 11 year| 56,456.05            |
| 12 year| 61,588.42            |
| 13 year| 66,720.78             |
| 14 year| 71,853.15             |
| 15 year| 76,985.52             |
| 16 year| 82,117.89             |
| 17 year| 87,250.26             |
| 18 year| 92,382.62             |
| 19 year| 97,514.99             |
| 20 year| 102,647.36            |
| 21 year| 107,779.37            |
| 22 year| 112,912.1             |
| 23 year| 118,044.46            |
| 24 year| 123,176.83            |
| 25 year| 128,309.20            |

5.1.2. FIT in United States

Table 5 shows the initial installation costs for 10 kW equipment, Table 6 shows the 10 kW PV plant installation, and Table 7 shows the rate of return on investment due to energy generation throughout the 25-year period, while light grey indicates the payback period and dark grey indicates the accumulative savings.
Table 5. The investment costs 10 kW equipment (USA-California).

| Installed Solar ($/Watt) | Installed Wattage (W) | Tax Rebate (%) | PC ($/kW) | Total Project Cost ($) |
|--------------------------|-----------------------|----------------|-----------|------------------------|
| 3.72                     | 10,000                | 30             | 2604.00   | 26,040.00              |

Table 6. Photovoltaic plant installation (USA-California).

| Daily Feed In (KWh) | PPV (KWh) | FIT Rate-CI ($) | Annual Feed in Credit ($) | HEE (kWh) | Current Tariff-C ($) | Annual Energy Savings ($) | PVCS ($) |
|---------------------|-----------|----------------|---------------------------|-----------|----------------------|--------------------------|----------|
| 51.06               | 18,635.8  | 0.17           | 3074.91                   | 10,339    | 0.20                 | 2057.46                  | 5132.37  |

Table 7. The rate of return on investment due to energy generation throughout the 25-year period.

| Years | The Rate of Return ($) |
|-------|------------------------|
| 1 year| 5132.37                |
| 2 year| 10,264.74              |
| 3 year| 15,397.10              |
| 4 year| 20,529.47              |
| 5 year| 25,661.84              |
| 6 year| 30,794.21              |
| 7 year| 35,926.58              |
| 8 year| 41,058.94              |
| 9 year| 46,191.31              |
| 10 year| 51,323.68             |
| 11 year| 56,456.05             |
| 12 year| 61,588.42             |
| 13 year| 66,720.78             |
| 14 year| 71,853.15             |
| 15 year| 76,985.52             |
| 16 year| 82,117.89             |
| 17 year| 87,250.26             |
| 18 year| 92,382.62             |
| 19 year| 97,514.99             |
| 20 year| 102,647.36            |
| 21 year| 107,779.37            |
| 22 year| 112,912.1             |
| 23 year| 118,044.46            |
| 24 year| 123,176.83            |
| 25 year| 128,309.20            |

5.2. KSA FIT Structure

5.2.1. Household Electricity Energy

According to the Electricity and Cogeneration Regulatory Authority (ECRA) and General Authority for Statics in the KSA, the annually national average HEE per year for the West is 8598 kWh; South is 6008 kWh; Central is 9013 kWh; East is 14,556 kWh. Table 8 shows the electrical usage for a 48 V solar plant in the KSA for different regions, which is important for calculating the battery bank.
Table 8. The electrical usage for 48 V solar plant in the Kingdom of Saudi Arabia (KSA) for different regions.

| Regions               | West (kWh) | South (kWh) | Central (kWh) | East (kWh) |
|-----------------------|------------|-------------|---------------|------------|
| Household Electricity Energy (HEE) | 8598       | 6008        | 9013          | 14,556     |
| Average Daily Usage (U_D) (kWh)  | 23.56      | 16.46       | 24.69         | 39.88      |
| Total Daily Amp Hours (Ah)   | 490.8      | 342.9       | 514.4         | 830.8      |
| Inverter on Discharge (ID) (Ah_ID) | 24         | 24          | 24            | 24         |
| Total Amp Hours/Day (Ah_KSA) | 514.8      | 366.9       | 538.4         | 854.8      |

5.2.2. PV Power

The average hours of daylight in the KSA are 12 hours at all locations monitored nationally. Peak sun producing hours are less than total hours of sun in a day. The total average hours are reduced by 25% for unknown factors including shade, cloudy days, geographical location, etc. There are 9 peak sun producing hours in the KSA. Table 9 shows the 10 kW PV plant calculation for four regions in the KSA.

Table 9. 10 kW photovoltaic (PV) plant calculation.

| Regions | Ah | S | η_a | η_b | η_c | W   | P   | PV   | P_PV |
|---------|----|---|-----|-----|-----|-----|-----|------|------|
| West    | 514.8 | 9 | 3.5%| 10% | 30% | 2404.51 | 10 | 68.36 | 24,951.18 |
| South   | 366.9 | 9 | 3.5%| 10% | 30% | 1713.71 | 10 | 74.58 | 27,220.48 |
| Central | 538.4 | 9 | 3.5%| 10% | 30% | 2514.74 | 10 | 67.37 | 24,589.07 |
| East    | 854.8 | 9 | 3.5%| 10% | 30% | 3992.57 | 10 | 54.07 | 19,734.40 |

Battery bank is sized to provide power for an average load for 15 hours with a recommended discharge depth of 60% to maintain the life of the batteries; 100% discharge is not recommended for the life of Gel Cell batteries. Table 10 shows the battery bank calculation in the KSA for different regions.

Table 10. The battery bank calculation for the KSA in different regions.

| Regions                          | West       | South     | Central   | East       |
|----------------------------------|------------|-----------|-----------|------------|
| Amp/hour that is required for HEE| 21.4       | 15.3      | 22.4      | 35.6       |
| Total Amp Hours require in 15 hours period | 321 | 229.5 | 336 | 534 |
| Recommended depth of discharge for sealed gel battery | 60% | 60% | 60% | 60% |
| Total adjusted capacity based on discharge depth | 535 | 382.5 | 560 | 890 |
| Battery capacity required per pack (Ah) | 550 | 400 | 575 | 900 |

The battery bank calculation is designed to find the battery capacity required for calculating the battery cost. The PV will work for 9 hours and the battery will feed the HEE for the rest of the day, i.e., 15 hours. After determining the total amp hours required in a period of 15 hours, it will be divided by 60% from the depth of discharge to calculate the battery capacity that needs to be installed.

5.2.3. KSA FIT Structure

Table 11 shows the investment cost for new equipment in the KSA for different regions, and Table 12 shows the 10 kW PV plant installation in the KSA for different regions. Table 13 shows the rate of return on investment due to onsite energy generation for different regions throughout the 25-year period, where the light grey indicates the payback period and dark grey indicates the continual accumulated savings for an individual region.
Table 11. The investment costs for new equipment in the KSA for different regions.

| Regions | Installed Solar Panel Cost (SAR) | Installed Inverter Cost (SAR) | Installed Battery Cost (SAR) | Installed Wiring Cost (SAR) | PC/kW (SAR) | Total PC (SAR) |
|---------|----------------------------------|-------------------------------|------------------------------|----------------------------|-------------|---------------|
| West    | 15,810.00                        | 3800.00                       | 4665.00                      | 3750.00                    | 2802.50     | 28,025.00     |
| South   | 15,810.00                        | 3800.00                       | 3266.00                      | 3750.00                    | 2662.60     | 26,626.00     |
| Central | 15,810.00                        | 3800.00                       | 4665.00                      | 3750.00                    | 2802.50     | 28,025.00     |
| East    | 15,810.00                        | 3800.00                       | 7465.00                      | 3750.00                    | 3082.50     | 30,825.00     |

Table 12. 10 KW PV plant installation in the KSA for different regions.

| Regions | Daily Feed In (kWh) | PPV (kWh) | FIT Rate-CI | Annual Feed in Credit (SAR) | HEE (kWh) | Current Tariff-C (SAR) | Annual Energy Savings (SAR) | PV_{CS} (SAR) |
|---------|---------------------|-----------|-------------|-----------------------------|-----------|------------------------|----------------------------|---------------|
| West    | 68.36               | 24,951.18 | 0.08        | 1996.09                     | 8598      | 0.18                   | 1547.64                    | 3543.73       |
| South   | 74.48               | 27,220.48 | 0.08        | 2177.64                     | 6008      | 0.18                   | 1081.44                    | 3299.08       |
| Central | 67.37               | 24,589.07 | 0.08        | 1967.13                     | 9013      | 0.18                   | 1622.34                    | 3589.47       |
| East    | 54.07               | 19,347.4  | 0.08        | 1578.75                     | 14,556    | 0.18                   | 2620.08                    | 4198.73       |

Table 13. The rate of return on investment due to energy generation in the KSA for different regions.

| Years   | Regions | West (SR) | South (SR) | Central (SR) | East (SR) |
|---------|---------|-----------|------------|--------------|-----------|
| 1 year  |         | 3543.73   | 3259.08    | 3589.47      | 4198.73   |
| 2 year  |         | 7087.46   | 6518.16    | 7188.94      | 8397.46   |
| 3 year  |         | 10,631.19 | 9777.24    | 10,768.41    | 12,596.19 |
| 4 year  |         | 14,174.92 | 13,036.32  | 14,357.88    | 16,794.92 |
| 5 year  |         | 17,718.65 | 16,295.40  | 17,957.35    | 20,993.65 |
| 6 year  |         | 21,262.38 | 19,554.48  | 21,536.82    | 25,192.38 |
| 7 year  |         | 24,806.11 | 22,813.56  | 25,126.29    | 29,391.11 |
| 8 year  |         | 28,349.84 | 26,072.64  | 28,715.76    | 33,589.84 |
| 9 year  |         | 31,893.57 | 29,331.72  | 32,305.33    | 37,788.57 |
| 10 year |         | 35,437.30 | 32,590.80  | 35,894.70    | 41,987.30 |
| 11 year |         | 38,981.03 | 35,849.88  | 39,484.17    | 46,186.03 |
| 12 year |         | 42,524.76 | 39,108.96  | 43,073.64    | 50,384.76 |
| 13 year |         | 46,068.49 | 42,368.04  | 46,663.11    | 54,583.49 |
| 14 year |         | 49,612.22 | 45,627.12  | 50,252.58    | 58,782.22 |
| 15 year |         | 53,155.95 | 48,866.20  | 53,842.05    | 62,980.95 |
| 16 year |         | 56,699.68 | 52,145.28  | 57,431.52    | 67,179.68 |
| 17 year |         | 60,243.41 | 55,404.36  | 61,020.99    | 71,378.41 |
| 18 year |         | 63,787.14 | 58,663.44  | 64,610.46    | 75,577.14 |
| 19 year |         | 67,330.87 | 61,922.52  | 68,199.93    | 79,775.87 |
| 20 year |         | 70,874.60 | 65,181.60  | 71,789.49    | 83,974.60 |
| 21 year |         | 74,418.33 | 68,440.68  | 75,378.87    | 88,173.33 |
| 22 year |         | 77,962.06 | 71,699.76  | 78,968.34    | 92,372.06 |
| 23 year |         | 81,505.70 | 74,958.84  | 82,557.81    | 96,570.79 |
| 24 year |         | 85,049.79 | 78,217.92  | 86,147.28    | 100,769.52|
| 25 year |         | 88,593.25 | 81,477.00  | 89,736.75    | 104,968.25|

The West KSA net PV_{CS} is 55,903.25 SAR, South KSA net PV_{CS} is 51,585 SAR, Central KSA net PV_{CS} is 57,046.75 SAR, and East KSA net PV_{CS} is 66,678.25 SAR. It was found when the projection cost is based on a higher than average demand of West 8598 kWh, South 6008 kWh, Central 9013 kWh, and East 14,556 kWh per year that a 10 KW system can payback within seven to nine years based on the FIT rate. If the usage is lower, then the 10 KW system will payback slower. However, more reasonably, investors who use less energy should offer a lower capacity system of 5 kW to 7 kW that can produce an effective payback within five to seven years as well. This can only occur if the current average FIT is increased and varies with the normal tariff rates.
6. Discussion

There are many benefits to the application of a suitable FIT that can be realized when considering various international examples outside of the KSA. When considering Germany and the USA, the FIT rates are high enough to speed up the payback, which is five to six years. Because Saudi Arabia currently does not have an FIT rate, the FIT rate is assumed to be 0.08 SAR. Furthermore, when considering California, USA, this state, like all US states, benefits from a 30% tax credit on the cost of installation, including parts and labor. While California does participate in a net metering program that measures the energy paid annually through anFIT, the separate localities offer further incentives. The city of San Francisco, California, for example, pays anywhere from $300 to $650/kW of solar power installed. The KSA is not currently offering tax credits of any kind to offset installation costs and there are no local incentives of any kind. The sole means of cost incentive in the KSA is the net metering program, which means that the FIT needs to be adequate to be effective.

The feed-in tariff, solar, and other renewable energy sources are greatly increasing their share in energy consumption in the KSA, further reducing the need for CO$_2$-emitting fossil fuel energy. In addition, the feed-in tariff policy is one of the best policies for attracting investors. When the feed-in tariff is applied in the KSA, the CO$_2$ emission will be reduced, the renewable energy will be widespread.

The significance of the FIT in the KSA is realized when considering the history of 28 separate nations within the European Union. The renewable energy sources (RES Directive), which was mandated to all 28 countries within the union set the goal to reduce greenhouse gas emissions by 40% from 1990 levels by 2030. It further defined mandatory percentages of solar, wind, and other renewable power sources in the energy profile to meet this goal. In doing so, similar plans were implemented that were similar to those in the USA to offer construction incentives based on specific technology, and a fixed FIT set for the duration of the contract based on current tariff rates. The governments regulated the amount of RE required for purchase by the electrical distributor through tradable green certificates (TGC). The plan then stipulated a quota required by the distributor for the number of TGCs acquired within a year.

In the southern countries, the sunniest countries, the FIT rates were, in turn, increased and subsequently, the normal tariff rates to the end consumers were raised due to the TGC requirements. Spain and Italy both reduced the incentives dramatically in 2011 as a result. Italy then stopped offering FIT incentives altogether in 2012. Bulgaria, Poland, and Romania have since lowered the TGCs. The KSA has an opportunity now that the normal tariff rates have been increased to mandate a suitable FIT that would be beneficial to consumers and distributors without causing a further increase to normal tariff rates as seen in Southern Europe. The normal usage tariff in the KSA is 0.18 Riyal/kWh and the FIT can be assumed to be 0.08 Riyal/kWh, meaning that if the FIT increased to 0.12 SAR, it still would be 0.06 Riyal less than the current commercial cost of electricity. This approach would allow the KSA to reduce the amount of energy produced from fossil fuels by a similar amount as Germany. Last year, 40% of Germany’s produced power was from renewable energy sources, with an overall goal of 80%, the current FIT in Germany is approximately 0.12 Euro/kWh.

To design the feed-in tariff in the KSA, the household electricity energy and the PV power need to be calculated. The previous results indicate that the feed-in tariff in the KSA is effective and attractive to investors. The higher the FIT rate, the more investors will be attracted to the system. The East region has the highest rate according to the household electricity consumption, which will make the total project cost expensive due to the battery installation cost, but it will save a lot of money compared to the normal tariff as it will achieve fast payback. The South region has the lowest rate according to the household electricity consumption, which will make the total project cost low due to the battery cost, but it will not save a lot of money compared to the normal tariff as it will make the payback is slow.

There are several solar power generation characteristics that have affected the worldwide market in the past 10 years. Solar power generation equipment has been on the market for more than 50 years and is no longer an experience but a commercial reality. Solar PV installation costs have fallen between 58% and 69% since 2010, driven by lower unit costs, reflectors, and higher unit efficiency. The cost is
expected to drop by 60% from current prices over the next 10 years. The global spread of solar energy has increased three-fold in the past decade, and this level of investment has led to the creation of an improved value-display chain.

7. Conclusions

Saudi Arabia is ahead of other countries in the GCC regarding the promotion of research and development of renewable energy technologies. A feed-in tariff is one of the most widely accepted economic policy options used for the acceleration of investment in renewable energies so that there is a guaranteed market for electricity generated from renewable energy sources. Hence, the application of the feed-in tariff policies is identified to speed up the development of renewable technologies, based on the experiences of countries all over the world. This study examines the benefits and challenges associated with the adoption of a feed-in tariff policy in Saudi Arabia.

The FIT rate in all the regions is 0.08 SAR/kWh. The point of payback on the system investment and maintenance was seven to eight years for all regions except the South, which is eight to nine years. Due to the recent usage tariff increases to 0.18 SAR/kWh, the rate of return on investment is slow and not lucrative enough to attract potential investors. The current cost of solar power installation is much lower now worldwide than it was 10 years ago. It is also expected to drop more over the next 10 years due to advances in technology. However, for the KSA to harness the sun as a source of renewable energy, it will be necessary to increase the current rates of FIT throughout all regions. If current usage rates remain at 0.18 Riyal/kWh, the FIT will need to be adjusted to 0.12 SAR/kWh to produce an approximately five-year payback and allow investors to continue to receive credits throughout the duration of their 20-year contract.

This approach would have the same economic impact as that which the USA has observed on the West Coast while providing the environmental impact that has been seen in Germany. If usage rates drop due to the offset of oil source energy with solar power, it would be reasonable to expect the FIT to drop. This is the reason that a variable premium FIT would be more suitable for the current state of the economy in the KSA instead of a fixed price FIT. Germany and Spain are both examples of countries currently and successfully using a variable premium FIT. A fixed price FIT will not work well for the KSA as it ignores other variable market values, most notably, fossil fuels.

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Symbols

| Symbol | Description |
|--------|-------------|
| HEE    | Yearly usage of household electrical energy |
| U_D    | Daily usage of household electrical energy |
| Ah_KSA | Total daily Amp per hour based on KSA national annual average |
| Ah_ID  | Total daily amp per hour that is required for inverter power discharge |
| S      | Typical hours of useful sun within a 24-hour day |
| η_a    | The panels and inverter losses |
| η_b    | The battery efficiency losses |
| η_c    | Gained efficiency from using MPPT charger |
| E      | Voltage |
| W      | The total solar panel wattage that is required for HEE |
| PV     | The daily energy output generated for feeding the grid by PV |
P The recommended system size based on instantaneous peak demand
PPV The annually energy output generated for feeding the grid by PV
PVCS Photovoltaics credits and savings
CI Cost incentive
C Current tariff
PC Project cost
OM Operation and maintenance
N Life system

Abbreviation
FIT Feed-in Tariff
RPS Renewable Portfolio Standard
RE Renewable Energy
ECRA Electricity $ Cogeneration Regulatory Authority
KSA Kingdom of Saudi Arabia
GW Giga Watt
MW Mega Watt
kW Kilo Watt
kWh Kilo Watt per hour
SAR Saudi Arabian Riyal
CO₂ Carbon Dioxide
MPPT Maximum Power Point Tracking
PV The daily energy output generated for feeding the grid by PV
P The recommended system size based on instantaneous peak demand
PPV The annually energy output generated for feeding the grid by PV
PVCS Photovoltaics credits and savings
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