The Effect of Retail Electricity Price Levels on the Financial Indicators of Smart-Grid Rooftop Solar Power Systems: A Case Study in the Central Highlands of Vietnam

Tran Thi Lan
Prince of Songkla University
Sopin Jirakiattikul
Prince of Songkla University
Niem Duc Le
Tay Nguyen University
M. S. Chowdhury
Prince of Songkla University
Dilawer Ali
Prince of Songkla University
Kuaanan Techato (kuaanan.t@psu.ac.th)
Prince of Songkla University https://orcid.org/0000-0002-9178-8416

Original article

Keywords: Economic Efficiency, Central Highlands, Solar Power, SG rooftop PV, Vietnam

Posted Date: July 6th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-36197/v1

The Effect of Retail Electricity Price Levels on the Financial Indicators of Smart-Grid Rooftop Solar Power Systems: A Case study in the Central Highlands of Vietnam

Tran Thi Lan[1,2], Sopin Jirakiattikul[3], Le Duc Niem[2], M. S. Chowdhury[1,4,5], Dilawer Ali[5], Kuaanan Techato[1, 4,5,*]

[1]Faculty of Environmental Management, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand

[2]Faculty of Economics, Tay Nguyen University, Vietnam

[3]Faculty of Economics, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand

[4]Environmental Assessment and Technology for Hazardous Waste Management Research Center, Faculty of Environmental Management, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand

[5]Program Sustainable Energy Management, Faculty of Environmental Management, Prince of Songkla University 90112, Thailand

* Corresponding author*:* **Kuaanan Techato**, E-mail*:* kuaanan.t@psu.ac.th.

Tel*:* +**66(0) 8 1841 8962** *https://orcid.org/0000-0002-9178-8416*

Abstract

Background: There are many constraints on the use of fossil fuels and, many countries have, therefore, conducted research relating to alternative energy resources to replace conventional fuels. On 31 January 2019, the Vietnamese Ministry of Finance enacted a preferential policy relating to the installation of under-50kWp rooftop solar projects. The Central Highlands of Vietnam has a high potential for solar power generation due to the duration of sunshine it enjoys, and the development of both rooftops solar and solar farms is appropriate for the region. The study reported investigated the economic efficiency of smart-grid rooftop solar electricity systems (SG rooftop PV) in the Central Highlands of Vietnam in light of the different levels of retail electricity pricing in Vietnam and

the implementation of a feed-in-tariff system. The research reported in this paper will be useful for many groups of stakeholders, including electricity consumers who intend to install rooftop solar panels on their houses, companies who supply SG rooftop PV, and policymakers, who can use the findings relating to SG rooftop PV to adjust the retail price of electricity during different periods.

Method: Financial indicators were calculated based on the net present value, payback period, internal rate of return, and the number of hours of sunshine in the Central Highlands of Vietnam

Result: The study's results show that the electricity price level affects the economic efficiency of SG rooftop PV. In particular, SG rooftop PV installed to satisfy higher levels of electricity consumption, which attract a higher retail electricity price, result in greater benefits, especially when domestic electricity consumption exceeds 400 kWh, at which level the retail electricity price is at the highest level. In this case, people who install SG rooftop PV and use all the electricity to satisfy domestic consumption will recoup their investment in only 4 years and thereafter will enjoy free electricity.

Conclusion: All the financial indicators derived from this research show that people in the Central Highlands of Vietnam can derive benefit from installing SG rooftop PV, whether they sell all the electricity output to the grid or use the power output to satisfy their domestic demand.

Keywords: Economic Efficiency, Central Highlands, Solar Power, SG rooftop PV, Vietnam.

Background

Conventional resources account for the majority of energy consumed by people throughout the world. According to the World Energy Council, expenditure on power from conventional resources accounted for over 85 % of the total power generation during the period 2005-2015 [1]. However, there are many constraints in using fossil-fuel resources. Firstly, these will be exhausted in the future due to the rapidly increasing energy demand [2], and Shafiee and Topal (2009) forecasted that crude oil stocks would be exhausted in around 35 years from 2005

with natural gas stocks being exhausted in 37 years, whereas coal stocks would be exhausted in 107 years. Therefore, after 2042, coal will be the only fossil fuel available up to 2112 [3]. Moreover, the burning of fossil fuels is one of the major sources of the emissions which are causing global warming and climate change [4] and also entails risks for people's health [5]. Therefore, many countries have conducted research relating to alternative energy resources to replace conventional fuels [6].

Over 90 % of the electricity in Vietnam is currently generated from hydropower, coal, and gas, with hydropower occupying 37.6 % of total electricity generation [7]. Hydropower dams have given people many benefits, including electricity supply, control of floods, and irrigation of the land. However, the construction of dams can threaten ecosystems [8, 9], and there are some negative effects on society and the environment. In particular, local people must uproot themselves from the areas where dams are constructed [10–12]. In Vietnam, the construction of hydropower dams has necessitated the appropriation of 133,930 hectares of land and the relocation of over 200,000 people involving the evacuation of 44,557 homes [13]. The generation capacity of hydropower energy also entails a loss of forests, and deforestation can reduce river discharge and thus decrease the power-generating capacity [14].

Moreover, the demand for power is growing rapidly and by the year 2035, energy demand in a business-as-usual scenario in Vietnam will be nearly 2.5 times higher than it was in 2015 [15]. Therefore electricity shortages are likely to happen, particularly in the hot season, especially from 2020 onwards [16].

The government of Vietnam has therefore shown interest in solar generation, wind energy, and biomass power and while there is a great potential for wind and biomass-generated energy, the development of solar power generation facilities is particularly appropriate for Vietnam and especially so in the Central Highlands and Southern areas [17]. The total duration of sunshine in the Central Highlands is from 2000 to 2600 hours per year [18], and 1kWp of solar energy will generate at least 2000kWh electricity per year. The Vietnamese Government has therefore adopted a policy of encouraging the development of solar energy as well as wind and biomass energy, and solar power has the second-highest price in the feed-in-tariff)FIT(system after electricity from the direct combustion of biomass [15].

In addition, the government is also encouraging the construction of solar farms, and users of rooftop solar panels can sell electricity to the grid at the same FIT price as that paid to solar farms, 9.35 US Cents/per kWh, with the duration of the current FIT being 20 years [19]. On 31 January 2019, the Vietnamese Ministry of Finance enacted a preferential policy relating to the installation of under-50kWp rooftop solar projects. Based on this policy, rooftop-solar-generated electricity is not subject to the levy of special consumption tax, and the personal income tax and VAT rates are zero if the investment income is less than 100 million VND, with the personal income tax rate 0.5 %, and VAT rate, 1 % if the investment income is greater than VND100 million. Further, rooftop solar power projects with a capacity of less than 50kWp are exempted from the need for an electricity operation license [20].

SG rooftop PVs are common in Vietnam because they are cheaper than off-grid systems, and users do not have to replace the battery every 2 to 5 years. They are also easy to use in the Central Highlands because over 95 % of households in this area have grid electricity in their houses [21]. Moreover, rooftop solar is considered as self-consumption electricity that helps decrease the dependent on the national grid [22].

The retail electricity price for residential consumption is divided into six different levels: 0-50kWh, 50-100kWh, 101-200kWh, 201-300kWh, 301-400kWh, and more than 400kWh. The price increases with the level of electricity consumed, thus, consumers who use more electricity have to pay a higher price than those who use less electricity. Therefore households that can generate power by installing a rooftop solar power system can reduce the amount that they pay every month for electricity not only by reducing the amount of power they consume from the grid but also by bringing themselves into a lower consumption band attracting a lower price for the electricity they purchase.

This paper assesses the potential benefits of installing rooftop solar panels based on three indicators, net present value)NPV(, payback period)PBP(, and internal rate of return)IRR(which are important financial indicators that can help people to decide whether or not to invest in a project. The conditions which render a project acceptable are an NPV greater than zero or an IRR higher than the discount rate. A project with a longer PBP is usually associated with a higher risk to the investors, thus a shorter PBP is preferable [23].

The research reported in this paper will be useful for many groups of stakeholders: firstly, for electricity consumers who intend to install rooftop solar panels on their house, who need to understand the benefit of rooftop solar generation, and in particular over how many years they will recoup their investment and whether their investment over the project lifetime would match the return by way of the interest they would generate by depositing their money in a bank. Secondly, companies that supply SG rooftop solar systems can use the findings of the research to advise people, who are considering installing smart rooftop solar power systems to generate electricity for their own consumption as well as selling any excess generated to the grid through the FIT. Finally, policymakers can use the findings relating to SG rooftop solar power to adjust the retail price of electricity during different periods.

In fact, all residents are affected by the same price of electricity level consumption whether they operating entirely during the day or night. However, SG rooftop PV can generate electricity only in the day. Therefore, this research focus only on the customers who install SG rooftop PV to sell all electricity to the grid or consume all electricity during the day for specific fields such as individual business households or families whose production and business activities take place mainly during the day

Literature review

Geographical location of the Central Highlands of Vietnam

There are five provinces in the Central Highlands of Vietnam, namely, Gialai, Kontum, Daklak, Daknong and Lamdong (Figure 1), which account for 16.5 % of the area and approximately 6.1 % of the population of Vietnam [24]. As mentioned above, the area has a high annual sunshine duration, which is suitable for the exploitation of solar energy.

Financial supporting ways from governments toward the power that generated from rooftop solar electricity systems.

Net-metering (NM) and net-billing (NB) are two groups of supporting ways that many countries have been applied with the excess electricity from rooftop PV. NM calculates the net electricity consumption from the national grid and rooftop PV (in kWh), while NB calculates separately the power from the two parts [25].

The excess power from rooftop PV that feeds to the grid may not be received any compensation from the government. For example, the Pilot project in Thailand's 100MW rooftop PV in 2016, in which the government encouraged people for self-consumption and no payment for any excess electricity load into the national grid [22].

Recently, the Vietnamese government has changed the way it deals with electricity generated from rooftop PV. In 2017, the Vietnamese Government assigned the Electricity Power Corporation of Vietnam (EVN) to buy electricity from SG rooftop PV based on a net-metering policy [19]. However, from 20th March 2019, EVN will buy electricity from independent SG rooftop PV based on a net-billing policy [26].

Smart grid definition

A smart grid (SG) is known as a smart power/ electrical grid, future grid, intelligent grid, or inter grid that is an expansion to the electricity grid of the 20th century. The conventional power grids are usually used to transfer electricity to a vast number of users of customers from a few central generators. In comparison, the SG makes use of two-way power and information to build an integrated and distributed advanced energy supply network [27].

In Vietnam, SG development was enacted by the government in 2012 with the decision 1670/QĐ-TTg, October 2012, which encourage the investor into renewable energy and SG. SG allows two-way powers. Therefore, customers can sell excess electricity from their renewable energy resources to the grid and buy electricity from the grid [28].

Smart-grid rooftop solar electricity systems

SG rooftop PV can be installed on the roofs of houses, offices or other commercial or industrial buildings. In contrast to other types of solar electricity systems, SG rooftop PV offers a bidirectional exchange, in which, power can be directed either to the customer from the power utility or in the opposite direction when the customer's system generates more electricity than the customer consumes. An SG rooftop PV helps the solar electricity system to operate stably and smoothly in the following ways: [29].

- When the capacity generated by the system < the customer's needs, the inverter will withdraw the power required from the grid

- When the capacity generated by the system = customer's needs, the power generated from the rooftop solar electricity system will be used to meet the customer's requirements.

- When the capacity generated by the system > The customer's needs, the surplus power will be sent to the grid

The process of assessing the relationship between power generation and the customer's needs, and directing the flow of electricity occurs constantly and automatically without the need for the user's intervention. In Vietnam, from July 1^{st,} 2019, the surplus electricity from domestic solar power systems and the power required from the grid is measured by two-way-meter. However, customers can sell electricity to EVN at the FIT price of 9.35USD/1kWh independently of the electricity which they buy from the grid. Based on the recent Decision No. 02/2019/QD-TTg, of the Prime Minister of Vietnam, the former net-metering mechanism has been replaced by a two-way calculation, whereby, the electricity from SG rooftop PVthat people sell to the grid and electricity purchased from the grid in times of high consumption, when their solar power system cannot provide enough electricity to cover their consumption, will be calculated independently. Moreover, if they so wish, people can sell all the electricity generated by the system to the grid [26]. In this research, the data was estimated based on two cases, customers selling all the electricity generated to EVN, or using all the electricity for their consumption.

Smart grid solar rooftop systems are highly appropriate for the Central Highlands because 95,17 % of households in this area are already connected to the electricity grid [21]. The advantages of SG rooftop PVare the lower cost of installation and the fact that customers do not have to replace the battery every 2 to 5 years. Unused solar power can be sold to EVN at a reasonable price. However, when power outages occur on the grid, the system stops supplying power to the grid to maintain the safety of the system.

Economics of solar power (PV) system

The basic economics of the PV system is related both to the efficiency and the optics. On markets, PV system often sold by cost per square meter or a cost per watt that may be generated under peak form of solar lights (cost per watt peak (Wp)), 1kWp=1000Wp. In other words, Wp is used to predict the electricity generated and to evaluate the performances of the PV

system in an optimum sun condition [30]. For example, rooftop PV with 1kWp will generate a maximum of 1kWh for one hour in an optimum sun condition. Therefore, if the optimum sun is 5 hours per day, then 1kWp will produce up to 5kWh power.

The equation to change the square meter and cost per watt peak are as following:

$$\$/\text{Wp}=\frac{\$/_{m^2}}{\mu.1000\,{}^{Wp}/_{m^2}}$$

μ: Solar convert efficiency.

For example, a PV module has 12% efficiency with \$400/m^2 will cost \$3.33/Wp [30].

Methodology

Calculating the NPV, IRR, and PBP of the rooftop solar system

*** *NPV***

NPV is the present valuation of all cash flows in the future, and NPV is calculated in order to make investment decisions. The following formula is used to calculate NPV [23]:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+R)^t} \qquad)1($$

Where: Bt: Benefit at year t

Ct: Cost at year t

R: Discount rate

n: Project lifetime

If NPV>0, the investment is acceptable because the discounted benefit is higher than the discounted cost, and the project will produce a surplus over the investment.

If NPV<0, the investment is not acceptable because the discounted benefit is lower than the discounted cost, and the project will produce a loss from the investment.

If NPV=0, the acceptance of the project will depend on the investors' decision.

*** *IRR***

The IRR is the discount rate that renders the NPV equal to zero. Thus, an investor will earn a return on investment if the IRR is exceeded when the project operates.

The following formula is used to calculate IRR:

$$0 = \sum \frac{B_t - C_t}{(1+IRR)^t} \quad (2)$$

If IRR ≥ cost of capital, the project is acceptable but

If IRR < cost of capital, the project is not acceptable.

To calculate IRR the Microsoft Excel function, IRR)value,]guess[(was used in this study and the values obtained were incorporated in column Bt-Ct in Tables 5 and 7, with *guess* being the option validity)since this was unknown, the *guess* was assumed to be 10 %(

**** PBP***

PBP is the amount of time that a project will require to recoup the investment in it from the income it generates. PBP does not take into account the value of money over time as do NPV and IRR

A project with a longer PBP is usually associated with a higher risk to the investor.

Cost (Ct), Benefit (Bt), and the discount rate of rooftop solar energy

**** Cost***

The cost of rooftop solar power includes the installation cost, taxes, and fees.

Ct=C0+tax+ fees (3)

Where C0: Cost of investment

In cases where people sell the electricity output to the grid, rooftop solar energy is not subject to the levy of special consumption tax and personal income tax and VAT rates are zero if the investment income is less than VND 100 million, with the personal income tax rate, 0.5 %, and VAT, 1 % if the investment income is greater than 100 million VND)equivalent to USD4,244(. Further, rooftop solar power projects with a capacity of less than 50kWp)< 01MW(are exempted from the requirement for an electricity operation license [20].

According to Vietnam's Ministry of Finance Circular 302/2016/TT-BTC, there is no excise fee on investments with an income below VND100 million. The fee on projects where the income per year is between VND100 and 299.999 million)equivalent to USD4,244 to 12,732.8(is VND299,999)equivalent to USD12.37(. On an income of VND300-499,999 million)equivalent to USD12,732.9 to 21,221.4(the fee is VND500,000)equivalent to USD21.22(, and

for an income of VND500-1000 million)equivalent to USD21,221.5 to 42,443(the fee is VND1,000,000)equivalent to USD42.44([31].

If all the electricity generated is used by the consumers themselves, they will not have to pay tax or other fees on the value of the electricity generated. Further, the maintenance cost will be zero during the guarantee period of 12 years [32] or more. The lifetime of a rooftop solar system is around 25 years, the lifetime of the inverter is around 10 years and the expected maintenance cost after the guarantee period was also assumed to be zero)see detailed calculation in Tables 5 and 7(.

**** Benefit***

The benefit is the electricity that is extracted from the system. If people use all the power output to meet their own electricity needs, the benefit is based on the retail electricity price. If they sell the electricity output to the grid, the benefit calculation is based on the FIT price of 9.35 US cents/per kWh.

The hours of sunshine in the Central Highlands range from 2000 to 2600 hours per year, with the sunshine duration being different among years and months. Table 2 shows the sunshine duration of Daklak Province [33], which is located in the middle of the area and is known as the metropolis of the Central Highlands [24].

In this study, a low sunshine duration of 2000 hours/per year was chosen when generating the data used in the analysis to ensure that the output power assumed for SG systems would be commensurate with the least favorable climatic conditions. Based on that assumption, the benefits of the rooftop solar energy in the Central Highlands were calculated as follows:

- The hours sunshine per month are at least 2000/12= 166 hours, thus, 1kWp solar electricity will generate at least 166kWh electricity per month
- On the assumption that the power output will reduce over time, from 100 % to 90 % in the first ten years and from 90 % to 80 % for the last 15 years [32], the % photo-voltaic capacity)Bt(in this research was calculated based on 90 % of the maximum electricity generation capacity for the first ten years and 80% of the maximum for the final 15 years)see detailed calculation in Table 5(.

284 **** Discount rate***

285 The discount rate for the NPV calculation in this study was based on the highest deposit
286 interest rate at commercial banks in Vietnam in January 2019, 8.6 %. [34].

287 ***Retail electricity price***

288 In Vietnam, the electricity price is different among residential, commercial, and
289 industrial consumers. This study refers only to domestic electricity users, thus, the retail price in
290 Table 1 was relevant to residential (household) users [35][36][37].

291 The cost of electricity to households is based on the level of electricity consumed. The
292 amount paid every month for electricity is shown in Figure 2.

293 ***Survey to suggest policies implication***

294 In this study, a part of the results of the survey on the intention to install SG rooftop
295 solar power was used to suggest the policy implication for the discussion. A sample of 300
296 household heads in the Central Highlands was surveyed by the authors from May to July 2019.
297 None of the households who answered the questionnaire had installed SG rooftop solar systems
298 on their houses, although their houses' roofs were suitable for the installation of such a system.
299 The survey consists of 2 parts, part 1 with questions related to factors affecting the intention to
300 install the system, and the question of the binary dependent variable, and one question about the
301 household's suggestion for promoting the development of SG rooftop solar. Part 2 covers
302 demographic questions of the households. However, in this study, the results obtained from the
303 question of household's suggestion for SG rooftop solar promotion and levels of electricity
304 consumption was applied. The question and answers were as follows.

305 1) Would you please recommend the Vietnamese Government to enhance SG rooftop
306 solar beside the FIT 9.35 US cent?

307 □ Support 10% installed cost

308 □ Support 20% installed cost

309 □ Support 30% installed cost

310 □ Recommend commercial banks to give preferential rate loans

311 □ Give 5 million VND bonus for people who install the system

312 Other……

2) Level of electricity consumption?

□ From 0-50kWh □ From51-100kWh □ From 101-200kWh

□ From 201-300kWh □ From 301-400kWh □ Over 400 kWh

Estimating the kWp rooftop solar energy capacity appropriate for each level of electricity consumption

As mentioned above, a sunshine duration of 2000 hours/per year was applied in deriving the data for this study. On that basis, the electricity output from a 1kWp rooftop solar power system would be 2000kWh per year)equivalent to 166.67kWh per month(. The kWp rooftop solar energy appropriate for each level of electricity consumption was therefore calculated as follows.

$$kWp\ Rooftop\ Solar\ Energy = \frac{Level\ of\ Electricity\ Consumption\ Per\ Month}{166{,}67} \qquad (4)$$

The cost of installing the system was based on the price quoted for high-quality household SG rooftop PV, as quoted by companies who supply them in Vietnam. The lifetime of an inverter is only 10 years, and the inverter would thus need to be replaced during the lifetime of the SG rooftop PV. The cost of replacing the inverter was, therefore, taken into consideration. A breakdown of the cost of the SG rooftop PV and the inverter is shown in Table 3.

The quoted installation cost of a rooftop solar system in Vietnam ranged between USD850 and over 1200 per kWp. In this research, the cost of USD1200 per kWp was adopted. This high initial level of cost for the system and inverter was adopted to ensure that in establishing the economic performance of SG rooftop PV, households could be expected to choose high-quality equipment and also to replace the inverter every 10 years' use. Based on equation)4(, the monthly cost of electricity and the kWp of a SG rooftop PV appropriate for each level of electricity consumption, the installation cost including the cost of replacing the inverter is illustrated in Table 4 for each level of electricity consumption shown in Figure 1

Results

Because SG rooftop PV generate power only in the day, thus, the calculations in this section is true only with the residents who sell all electricity to the grid or use all electricity in the daily time.

Estimated NPV, IRR, and PBP for each level of electricity consumption where all electricity

output is used for domestic consumption

When all the electricity output from a rooftop solar power system is used to satisfy domestic consumption, as shown in Table 4, the kWp of the rooftop solar power system can be estimated based on the level of electricity consumption, and the cost of electricity will represent the benefit derived from the system. In this scenario, the consumer does not have to pay tax. However, the inverter will have a maximum life of 10 years, thus the cost will be enhanced by the cost of the inverter (NB there is no battery) every 10 years' use. On that basis, the cost-benefit analysis for the first level of electricity consumption)50kWh(is as shown in Table 5, where the capacity of the system installed is 0.3kWp, with an installation cost of USD360 the cost of electricity is USD 3.9 per month and the cost of replacing the inverter every 10 years is 111USD; the NPV, IRR, and PBP appear in Table 6.

As mentioned above, the efficiency of a rooftop solar power system decreases over time. Therefore, the benefit)Bt(every year for the first ten years can be estimated based on 90 % of the cost of electricity every month multiplied by 12, with the same calculation incorporating a figure of 80 % for the last 15 years.

Bt)level 1-first ten years(= 3.9*12*90% = USD42.12 per year

Bt)level 1-last 15 years(= 3.9*12*80% = USD37.44 per year

(This calculation is based on the lifetime of a rooftop solar system being around 25 years with the expectation that the maintenance cost both during and after the guarantee period will be zero. The inverter will be replaced in year 10 and year 20 of the system).

Based on the estimate in Table 5, the economic efficiency of a 0.3kWp rooftop solar system appropriate for the first level of electricity consumption)50kWp(with a discount rate of 8.6 % is as follows:

$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+R)^t}$ = USD9.12

To determine the payback period, as can be seen from Table 5, the accumulated Bt-Ct is greater than zero in the 12th year of the project, which means that the initial investment can be recouped after the first 11 years of operating the system.

The IRR was calculated using the Microsoft Excel, IRR)value,]guess[(function based on the values in column Bt-Ct of Table 5 with a *guess* based on the option validity)since this was unknown, *guess* was assumed to be 10 %(. From that calculation, the IRR is 9.04 % per year

The same calculations were conducted for other levels of electricity consumption, and the resulting financial indicators are shown in Table 6 and illustrated in Figures 3 a, b, and c.

It is therefore clear that people should invest in SG rooftop PV at all six levels of electricity consumption because the NPV is greater than zero and the IRR is greater than the discount rate. Moreover, the higher kWp required to satisfy higher levels of electricity consumption will bring more benefits than those accruing to consumers using less electricity. An SG solar power system with a capacity of 3.33 kWp has a PBP of only 4 years, while that of a system appropriate for the first level of electricity consumption is 11 years. The IRR increases from 9.04 % to 23.66 % between levels 1 and 6, and the NPV also increases from USD9.12 to USD2,618.86, respectively.

These scenarios assume that all the electricity generated is used for domestic consumption, and the electricity price level has a significant effect on the economic efficiency of SG rooftop solar power systems.

Financial indicators for each level of electricity consumption based on the sale of power at the FIT price.

According to Decision No. 02/2019/QD/TTg, of the Prime Minister of Vietnam, the electricity generated from solar power cells can be sold independently to the grid. If it is assumed that all the electricity generated from a rooftop solar power system is sold to the grid, the Bt is the revenue that people derive by selling the electricity output to the grid at the FIT price of 9.35 US Cents per kWh.

In this scenario, in a similar way to that dealt with in the case of people using all the electricity generated for domestic consumption, the lifetime of a rooftop solar system was taken to be 25 years, and the maintenance cost was assumed to be zero, but in this case, people have to pay both tax and an excise fee. Thus:

Cost per year:

$$Ct = C0 + Tax + Fee \quad (3)$$

where C0: Total cost of investment

However, only when the revenue from the power output)Bt(exceeds VND100 million)equivalent to USD4,244(per year, will people have to pay 0.5 % personal income tax, 1 % VAT [20], and as noted above, an excise fee each year)USD12.37 for revenue from USD4,244 to 12,732.8 per year, USD21.22 for revenue from USD12,732.9 to 21,221.4 per year, and USD42.44 for revenue from USD21,221.5 to 42,443(.

The Bt, Ct, NPV, IRR, and PBP for a 3.3 kWp solar system appropriate for level-6 electricity consumption)500kWh(, the capacity of which is 3.33 kWp, and the installation cost, USD3,960 with an electricity cost per month of USD56.1 were then calculated. The same assumptions as were used in the first case were made regarding the efficiency of the system (i.e., 90 % in the first ten years 80 % for the last 15 years [32]. The inverter would also need to be replaced in year 10 at a cost of 885USD for level-6 electricity consumption. Therefore, the benefit each year for the first ten years was estimated at 500kWh multiplied by the FIT price of 9.35 US cents (or USD 0.0935)/per kWh(multiplied by 12 and then multiplied by 90 %, for the first 10 years, and by 80 % for the last 15 years as shown below:

Bt)level 6-FIT-first ten years(= 500*0.0935*12*90%= USD504.9 per year

Bt)level 6- FIT- last 15 years(= 500*0.0935*12*80%= USD448.8 per year

The benefit per year in this situation is still well under the threshold of USD 4,244 per year, and would, therefore, attract no personal income tax, nor VAT [20], and no excise fee. The calculation is illustrated in Table 7.

In a scenario where all the electricity output is sold to the grid at the FIT price of 9.35 US cents per kWh, the economic efficiency indices for a 3.33kWp rooftop solar system appropriate for level-6 electricity consumption)500kWp(with a discount rate of 8.6 % is as follows.

$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+R)^t}$ = USD717.40

To determine the PBP, as shown in Table 7, the accumulated Bt-Ct exceeds zero in the 8th year of the project, which means that the investment in the system is recouped after the first 7 years of the system's operation. Further, based on Microsoft Excel's IRR function, the IRR is

11.60 % per year. Similar calculations for all six levels of electricity consumption are shown in Table 8.

The indicators in Table 8 show that the installation of rooftop solar power systems appropriate for every level of electricity consumption, with all the electricity output being sold to the grid, will produce a benefit at all levels. However, the highest level (level 6) entails the lowest IRR. These indicators are compared in Figures 4 a, b, and c.

It can be seen that there are differences in the SG rooftop solar financial indicators between using the power output to satisfy domestic consumption and selling it to the grid, among the six levels of electricity consumption. At levels 1 and 2, the retail price of electricity is lower than that at higher levels, and therefore people who install SG rooftop solar power systems and sell all the electricity generated will derive more benefit than by using the electricity for their consumption. The benefit of the two scenarios is nearly the same at levels 3 and 4, but at levels 5 and 6, people gain greater benefit by using all the electricity generated to satisfy their consumption since this will bring much greater benefit than at lower levels of consumption. This is particularly so at level 6 where the retail electricity price is highest. Households that consume electricity at level 6 who install an SG rooftop solar power system will recoup their investment with only a 4-year PBP with an NPV of around three times that derived from the sale of electricity to EVN. Moreover, the IRR is also higher for level 6 by using all the power generated for domestic consumption than for all the other levels.

The consumption-based level of the retail price of electricity in Vietnam, therefore, benefits those who install rooftop solar systems and use higher levels of electricity since they will derive better economic efficiency from such a system, especially, when the system generates more than 400 kWh electricity per month. However, if consumers who depend on the grid for electricity consumption use more electricity in the hot season, this will threaten the safety of the electricity sector. According to EVN)2018(, in April, May, June, and July 2018, the number of customers who used more than 400kWh electricity increased to around 600,000 per month compared to 385,000 customers in March that year [38]. When electricity demand increases suddenly in the summer months, this can lead to the overloading of the grid in some areas, which represents a hazardous situation for the electricity grid [39]. Moreover, electricity generation in Vietnam

fluctuates depending on the season because the electricity from hydropower accounts for a very high percentage of the total electricity generated. This means that the electric supply is not stable, and fluctuations and power outages frequently occur in the dry summer season [40]. Recently, this issue has always been resolved every year and the System Average Interruption Duration Index)SAIDI(, which demonstrates the median yearly period of power cuts for each power buyer, decreased significantly from 2,281 to 1,651 minutes between 2015 and 2016. The System Average Interruption Frequency Index)SAIFI(, which indicates the mean quantity of electricity outages suffered per buyer in a year, also fell from 13.36 times per buyer in 2015 to 10.6 times per buyer in 2016 [7, 41]. However, there is still instability in Vietnam's electricity delivery and consumption because the 500kV electricity line, which underlies the main electricity network of the country, has to convey an enormous volume of electricity from the North to the South of Vietnam since the major hydropower plants are located mostly in the North-West of Vietnam, and the major coal-fired plants are located close to the coal mines in the North-East of the country with only gas turbines located in the South [42]. Therefore, the installation of rooftop solar systems is the best means by which people can combat the problem of unstable electricity supply in the hot season.

Finally, a survey relating to customers' intention to install SG rooftop solar systems was conducted as mention in the methodology section. Out of the 300 households who responded, 99 (33 %) wanted to install a rooftop system, whereas 201 households (67 %) did not want to do so for various reasons, for example, they could not afford the capital cost of installing such a system. All 300 households consume electricity at level 2 to level 6, in which, a total of 68.7% belonging to level 3 and level 4. As the analysis of this paper, people can get more benefits from SG rooftop solar electricity with a high level of electricity consumption (level 3 to level 6). The customer used electricity as levels 5 and 6 are also high that occupied 10.3% and 4.7% respectively (Table 9). This report is meaningful if the incentive of government applied to the right customer and help them used alternative energy resource, reduce power shortage in the hot season and guarantee the national energy security. All of the respondents agreed that they would be willing to install SG rooftop PV and would encourage other people to do so if there were suitable support from the government, and recommended the forms of support set out in Table 9.

The largest group of households (39.3%) suggested that 30 % of the initial costs should be provided by the government, with 27 % of suggesting that the government should arrange finance through preferential loans from commercial banks. Other methods of encouraging the installation of SG rooftop PV suggested by the remainder included staggering initial payments over a period of 3 to 5 years with interest being payable, supporting 50 % of the initial cost, or providing better information about SG rooftop solar electricity systems.

Discussion

Research limitations

This study calculated the financial indicators of SG rooftop PV for only one customer group (people using residential solar PV). Therefore, the subsidies mentioned here are applicable only for that group of customers. Moreover, the study only considered the cases of people using all the electricity generated for their consumption in the daily time or selling all the electricity generated to the grid. Future research should study other cases, where a part of the power output during the day is sold to the grid while at times of higher consumption, e.g., during the evening, some electricity is bought from the grid.

How to encourage SG rooftop PV development in the area studied

Although the results show that people will obtain a profit from their investment in rooftop solar electricity systems, the initial cost of rooftop solar systems still presents a barrier for ordinary people. The Vietnamese Government should, therefore, provide incentives to encourage people to use renewable energy by installing SG solar rooftop electricity systems. The Vietnamese government budget comes from many resources such as taxes, fees, the income of the national company, income from the national resource, and foreign aid. The budget has been used for many purposes, in which, renewable energy development is one of the purposes of the government.

At present, the only incentive offered by the Vietnamese Government is the FIT price (9.35 US cent/kWp). However, increases in the retail electricity price following Decision No 648/QD-BTC of 20 March 2019 may encourage people to find alternative sources of electricity. Nevertheless, to enhance the development of renewable resources, for instance, through the

511 installation of rooftop solar panels by domestic users, the researchers suggest that the
512 government of Vietnam should apply some of the following incentives.

513 • Exempting people from tax (VAT) when people install SG, off-grid, or hybrid PV
514 systems and when they sell electricity to the grid.
515 • Providing preferential interest rate loans for green energy, where the interest rate is
516 lower than that applying to other loans.
517 • The government giving a monetary gift (e.g., 5 million VND) when people choose to
518 install a rooftop solar system on their house.
519 • Supporting 10-30 % of the initial cost of installation of domestic rooftop solar systems
520 as well as similar support to companies who install such systems in the same way that
521 the Indian government has been doing in their PV rooftop program [43].

522 On 27 March 2019, EVN held a "Seminar on Promotion of Roof-Top Solar Energy in
523 Vietnam" in Hanoi [44]. The participants in the seminar included the World Bank, Bank aus
524 Verantwortung, the Japan International Cooperation Agency, Agence Francaise de
525 Development, Green Innovation, and Development Centre of Vietnam, SolarBK of Vietnam,
526 Amplus Solar of India, the Korea Electricity Power Corporation, experts in the energy industry
527 and members of EVN's Board of Directors. During the seminar, EVN proposed various means
528 of encouraging the installation of rooftop solar power systems in some areas with high potential
529 for generating solar energy. Firstly, EVN suggested that the Vietnamese Government should
530 support part of the initial cost incurred by households in installing rooftop solar electricity
531 systems. Secondly, the Ministry of Industry and Trade was requested to promulgate a new
532 circular relating to the FIT arrangements to replace circular 16 relating to the net-metering
533 mechanism) [45], to make it clear that EVN can sign electricity contracts with customers based
534 on decision 02/2019/QD-TTG of the Prime Minister of Vietnam. Moreover, EVN requested
535 banks, investors, producers, international organizations, and domestic organizations to
536 participate in the rooftop solar energy market. The hope was expressed that support from all
537 stakeholders in the Vietnamese electricity market would be forthcoming in the future.

538 The authors' opinion about the Vietnamese Government subsidies would be based on the

opinion of people in the Central Highlands. Therefore, in the long term development of energy in Vietnam, the Vietnamese government should consider those suggestions set out in Table 9 and adjust their policies to encourage people to install SG rooftop PV as an alternative power resource to minimize the hazards to the electricity grid which result from high levels of consumption in the hot season in Vietnam.

Conclusions

In conclusion, all the financial indicators derived in this research show that people in the Central Highlands of Vietnam can derive benefit from installing SG rooftop PV, whether they sell all the electricity output to the grid or whether they use the power output to satisfy their domestic demand during the day. Based on the different levels of the retail electricity price applied to different levels of electricity consumption, SG rooftop PV brings the following benefits to households in the area:

- The IRR is higher than the discount rate)8.6 %(and ranges from 9.04 % to 23.66 %)Figure 4a(
- The NPV is greater than zero and ranges from USD9.07 to 2,618.86)figure 4b(
- The PBP is shorter for higher-level consumers of electricity, where all the electricity generated is used to satisfy their domestic consumption)Figure 4c(.

The differential level of the retail electricity price renders higher levels of electricity consumption proportionately more expensive than lower levels. However, if people install SG rooftop PV to satisfy higher levels of electricity consumption, they will derive more benefit from the power output of the system. In particular, when people's electricity load is at level 6)401 to 500kWh(, and they install an SG rooftop PV, they will enjoy free electricity after 4 years of installation.

Abbreviations

Bt	Benefit
Ct	Cost
EVN	Electricity Power Corporation of Vietnam
FIT	Feed-In-Tariff

IRR	Internal Rate of Return
kWh	Kilowatt-hour
kWp	Kilowatt peak
MW	Megawatt
NB	Net-billing
NM	Net-metering
NPV	Net present value
PBP	Payback Period
PV	Solar power system
SG	Smart-grid
USD	United States Dollar
VAT	Value Added Tax
VND	Vietnam Dong

Declarations

Acknowledgments

The authors are most grateful for supporting grants from the Prince of Songkla University)PSU(Graduate School and Interdisciplinary Graduate School of Energy Systems. The authors also give many thanks to English native speaking editor from the Research and Development Office (RDO), Prince of Songkla University who edited English for this manuscript.

Funding

The manuscript is funded by a research grant of the Ph.D. program of Sustainable Energy Management - Prince of Songkla University (No. TEH-AC 048/2018).

Availability of supporting data

All the data used in this research are from Electricity Power Corporation of Vietnam and extract from a survey relating to customers' intention to install SG rooftop solar systems as mention in the methodology section. The detail information of data resources are also shown in the references.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Conflicts of interest

The authors declare there are no conflicts of interest.

Authors' contributions

S.J, L.D.N provided valuable research insights into the analysis; T.T.L, S.J & K.T designed the framework of the paper and the research questions. T.T.L. analyzed data and wrote the paper, M.S.C & D.A edited the paper, S.J, K.T, L.D.N supervisor, M.S.C sent the paper to be edited by the Publications Clinic at the Research and Development Office at Prince of Songkla University.

References

1. World Energy Council (2016) World Energy Resources, London. https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf Accessed 15 Oct 2017.
2. Ellabban O, Abu-Rub H, Blaabjerg F (2014) Renewable energy resources: Current status, future prospects, and their enabling technology. Renew Sustain Energy Rev 39:748–764. https://doi.org/10.1016/j.rser.2014.07.113.
3. Shafiee S, Topal E (2009) When will fossil fuel reserves be diminished? Energy Policy 37:181–189. https://doi.org/10.1016/j.enpol.2008.08.016.
4. Tang X (2013) Depletion of fossil fuels and anthropogenic climate change — A review. Energy Policy 52:797–809. https://doi.org/10.1016/j.enpol.2012.10.046.
5. Hales AJMREWS (2006) Climate change and human health: present and future risks. Lancet 367:859–869. https://doi.org/10.1016/S0140-6736(06)68079-3.
6. Dincer I (2000) Renewable energy and sustainable development: a crucial review. Renew Sustain Energy Rev 4:157–175. https://doi.org/10.1016/S1364-0321(99)00011-8.
7. EVN (2017) Vietnam Electricity Annual Report 2017. In: The Electricity Power Corporation of Vietnam. Available via DIALOG https://en.evn.com.vn/userfile/User/huongbtt/files/2018/2/AnnualReport2017.pdf. Accessed 10 Aug 2018.
8. Sun Sheng Han, Kim Trang Vu (2008) Land Acquisition in Transitional Hanoi, Vietnam. Urban Stud 45:1097–1117. https://doi.org/10.1177/0042098008089855
9. Manyari WV, de Carvalho OA (2007) Environmental considerations in energy planning for the Amazon region: Downstream effects of dams. Energy Policy 35:6526–6534. https://doi.org/10.1016/J.ENPOL.2007.07.031

10. Lerer LB, Scudder T (1999) Health impacts of large dams. Environ Impact Assess Rev 19:113–123. https://doi.org/10.1016/S0195-9255(98)00041-9
11. Tilt B, Braun Y, He D (2009) Social impacts of large dam projects: A comparison of international case studies and implications for best practice. J Environ Manage 90:249–S257. https://doi.org/10.1016/j.jenvman.2008.07.030
12. Scudder T (2001) The World Commission on Dams and the Need for a New Development Paradigm. Int J Water Resour Dev 17:329–341. https://doi.org/10.1080/07900620120065110
13. Bui TMH, Schreinemachers P (2011) Resettling Farm Households in Northwestern Vietnam: Livelihood Change and Adaptation. Int J Water Resour Dev 27:1–17. https://doi.org/10.1080/07900627.2011.593116
14. Stickler CM, Coe MT, Costa MH, et al (2013) Dependence of hydropower energy generation on forests in the Amazon Basin at local and regional scales. Proc Natl Acad Sci 110:9601–9606. https://doi.org/10.1073/pnas.1215331110
15. Vietnamese MOIT (2017) Vietnam Energy Outlook Report. In: Danish Energy Agency. Available via DIALOG https://ens.dk/sites/ens.dk/files/Globalcooperation/Official_docs/Vietnam/vietnam-energy-outlook-report-2017-eng.pdf. Accessed 18 Oct 2018
16. VEA (2018) Sustainable development and environmental protection in Vietnam, Vietnam Energy Association. http://nangluongvietnam.vn/news/vn/bao-ton-nang-luong/phat-trien-nang-luong-ben-vung-va-bao-ve-moi-truong-tai-viet-nam.html. Accessed 24 Mar 2019
17. Polo J, Bernardos A, Navarro AA, et al (2015) Solar resources and power potential mapping in Vietnam using satellite-derived and GIS-based information. Energy Convers Manag 98:348–358. https://doi.org/10.1016/j.enconman.2015.04.016
18. EVN (2019) Solar potential in the Central Highlands of Vietnam, The Electricity Power Corporation of Vietnam. https://www.evn.com.vn/c3/evn-va-khach-hang/Tin-nang-luong-tai-tao-141-17.aspx. Accessed 23 Mar 2019
19. Decision No. 11 /2017/QD-TTg (2017) On the Support mechanisms for the Development of Solar Power Projects in Vietnam. In: The Vietnamese Prime Minister. http://vanban.chinhphu.vn/portal/page/portal/chinhphu/hethongvanban?class_id=1&_page=1&mode=detail&document_id=189336. Accessed 15 Oct 2017
20. Instruction No.1534/BTC-CST (2019) Preferential policy toward under 50kWp rooftop solar project. In: The Vietnamese Ministry of Finance. Available via DIALOG https://thuvienphapluat.vn/cong-van/Tai-chinh-nha-nuoc/Cong-van-1534-BTC-CST-2019-chinh-sach-uu-dai-doi-voi-du-an-dien-mat-troi-duoi-50kw-410737.aspx. Accessed 19 Apr 2019
21. Nguyen NH (2015) Vietnam Power Report 2015. In: The Electricity Power Corporation of Vietnam. Available via DIALOG www.fpts.com.vn. Accessed 20 May 2017

22. Tongsopit S, Junlakarn S, Wibulpolprasert W, et al (2019) The economics of solar PV self-consumption in Thailand. Renew Energy 138:395–408. https://doi.org/10.1016/j.renene.2019.01.087
23. Abraham A (2014) Project planning and management: an aspect of development. Anchor Academic Publishing, Hamburg, Germany.
24. The Vietnamese Government (2019) Site map of Vietnam. In: Vietnam Government Portal. Available via DIALOG http://www.chinhphu.vn/portal/page/portal/chinhphu/Sitemap. Accessed 15 April 2019
25. Dufo-López R, L.Bernal-Agustín J (2015) A comparative assessment of net metering and net billing policies. Study cases for Spain. Energy 84:684–694. https://doi.org/https://doi.org/10.1016/j.energy.2015.03.031
26. Decision No. 02/2019/QD-TTg (2019) Adjusted and added some terms of the Decision No. 11/2017/QD-TTg of the Government for solar energy development. In: The Vietnamese Prime Minister. Available via DIALOG http://vanban.chinhphu.vn/portal/page/portal/chinhphu/hethongvanban?class_id=1&mode=detail&document_id=195869. Accessed 20 Mar 2019
27. Fang X, Misra S, Xue G, Yang D (2012) Smart grid - The new and improved power grid: A survey. IEEE Commun Surv Tutorials 14:944–980. https://doi.org/10.1109/SURV.2011.101911.00087
28. Decision No 1670/QĐ-TTg (2012). In: Vietnamese Government. Available via DIALOG http://vanban.chinhphu.vn/portal/page/portal/chinhphu/hethongvanban?class_id=2&_page=1&mode=detail&document_id=164399
29. Feyza O. and Suat Y. O. (2016) A fog computing based smart grid model. In: 2016 International Symposium on Networks, Computers, and Communications, ISNCC 2016, IEEE, pp 1–6, 17 November 2016.
30. Smestad GP (2011) The basic economics of photovoltaics. Opt InfoBase Conf Pap. https://doi.org/10.1364/solar.2008.stuc8
31. Circular 302/2016/TT-BTC (2016) Guideline of excise. In: The Vietnamese Ministry of Finance. Available via DIALOG http://vbpl.vn/botaichinh/Pages/vbpq-van-ban-goc.aspx?ItemID=118657. Accessed 19 Apr 2019
32. BKSolar (2018) Brochure of BigK Product. In Irex Energy Joint Stock Company - Vietnam.
33. Statistic office of Daklak (2019) Yearbook statistics of Daklak Province, Vietnam. Statistic publishing, Hanoi, Vietnam.
34. Vietnambiz (2019) The comparative bank interest rate in Vietnam in January 2019. https://vietnambiz.vn/so-sanh-lai-suat-ngan-hang-thang-12019-lai-suat-tiet-kiem-tai-ngan-hang-nao-cao-nhat-115884.htm. Accessed 2 Mar 2019

35. Decision No. 648/QD-BCT (2019) Adjusted the average retail price and the selling price of electricity. In: The Vietnamese Ministry of Industry and Trade. Available via DIALOG https://www.evn.com.vn/d6/news/Quyet-dinh-so-648QD-BCT-ngay-2032019-ve-dieu-chinh-muc-gia-ban-le-dien-binh-quan-va-quy-dinh-gia-ban-dien-9-130-23316.aspx. Accessed 22 Mar 2019
36. Decision No. 2256/TQD-BCT (2015) The Regulation of Electricity Price. In: The Vietnamese Ministry of Industry and Trade. Available via DIALOG http://vbpl.vn/bocongthuong/Pages/vbpq-van-ban-goc.aspx?ItemID=70476. Accessed 18 May 2017
37. Decision 4495/QD-BCT (2017) Electricity retail price from 1st December 2017. In: The Vietnamese Ministry of Industry and Trade. Available via DIALOG https://www.evn.com.vn/d6/news/Quyet-dinh-4495QD-BTC-quy-dinh-ve-gia-ban-dien-tu-ngay-1122017-6-12-20990.aspx
38. EVN (2018) Electricity bill would increase in the hot and sunny months. The Electricity Power Corporation of Vietnam. https://www.evn.com.vn/d6/news/Hoa-don-tien-dien-se-tang-cao-trong-cac-thang-nang-nong-6-14-21947.aspx. Accessed 23 May 2019
39. MOIT (2018) Electricity demand increases in the hot seasons, The Vietnamese Ministry of Industry and Trade. http://moit.gov.vn/tin-chi-tiet/-/chi-tiet/nang-nong-dien-rong-keo-dai-dan-đen-tieu-thu-đien-tang-vot-evn-tiep-tuc-khuyen-cao-triet-đe-tiet-kiem-đien-11996-23.html. Accessed 24 May 2019
40. Lerch E (2014) Stability Study and Modernization Roadmap for Expanding Vietnamese Power System. Power Technology.
41. EVN (2016) Vietnam Electricity Annual Report 2016. In: The Electricity Power Corporation of Vietnam. Available via DIALOG https://www.evn.com.vn/userfile/files/2017/3/AnnualReport2016.pdf. Accessed 10 Aug 2018.
42. Hai NS, Huu NT (2011) Operational Problems and Challenges in Power System of Vietnam. In: 2011 EPU-CRIS International Conference on Science and Technology, IEEE, pp 1–5, November 2011.
43. MNRE (2017) National Solar Mission - Grid Connected Solar Rooftop Program in India. In: Ministry of New and Renewable Energy-Government of India. Available via DIALOG https://solarrooftop.gov.in/notification/Notification-24012017.pdf. Accessed 29 Mar 2019
44. EVN (2019) Seminar on promoting rooftop solar energy in Vietnam. In: The Electricity Power Corporation of Vietnam. Available via DIALOG https://evn.com.vn/d6/news/Tai-lieu-Hoi-thao-Thuc-day-phat-trien-dien-mat-troi-ap-mai-tai-Viet-Nam-ngay-2722019-141-170-23168.aspx. Accessed 25 Mar 2019
45. Circular 16/2017/TT-BCT (2017) Regulation of project development and electricity sale

contract apply for a rooftop solar energy project. In: The Vietnamese Ministry of Industry and Trade. Available via DIALOG http://vbpl.vn/bocongthuong/pages/vbpq. Accessed 25 Mar 2019

TABLES

Table 1. Retail electricity price for domestic consumption)exclusive of 10 % VAT(

Retail electricity price for domestic consumption)USD(	**From March 2015 to 30 November 2017** [36]	**From 01 December 2017 to March 2019** [37]	**From 20 March 2019** [35]
Level 1. 0-50kWh	0.063	0.066	0.071
Level 2. 51-100kWh	0.065	0.068	0.074
Level 3. 101-200kWh	0.076	0.079	0.085
Level 4. 201-300kWh	0.095	0.099	0.108
Level 5. 301-400kWh	0.106	0.111	0.120
Level 6. 401kWh or more	0.110	0.115	0.124
The average price)exclusive of VAT(	0.069	0.073	0.079
VAT)%(	10 %	10 %	10 %

Note: Exchange rate as at 2 March 2019, VND/USD = 23,561)State Bank of Vietnam, 2019(

Table 2. Duration of sunshine in Daklak Province, in the Central Highlands

	2010	**2015**	**2016**	**2017**	**2018**
TOTAL SUNSHINE DURATION (HOURS)	**2,498.90**	**2,880.20**	**2,433.80**	**2,291.80**	**2,431.30**
January	267.70	296.50	276.70	189.70	221.90
February	269.70	271.90	214.00	210.70	269.10
March	269.90	304.90	305.90	275.50	264.00
April	264.60	285.80	277.60	216.70	274.10
May	263.70	263.70	219.00	201.80	206.50
June	243.50	195.50	163.80	223.30	138.80
July	193.30	168.30	220.10	124.60	122.90
August	162.50	218.90	177.60	201.70	122.50
September	187.10	195.50	149.50	203.30	188.90
October	119.00	234.80	134.30	150.70	248.40
November	81.70	208.70	191.70	137.00	206.20
December	176.20	235.70	103.60	156.80	168.00

Source: [33]

Table 3. Detailed price quotation per 1kWp for SG rooftop solar generating systems for households including replacing the inverter, appropriate for each level of electricity consumption quoted by companies in Vietnam (price/ web address of the company who provide the products)

Price converted to USD

	Price of 1kWp SG	Price of 300w inverter	Price of 600w inverter	Price of 1000w inverter	Price of 2000w inverter	Price of 3000w inverter	Price of 4000w inverter
1	1061 – 1273 http://vuphong.vn	80.6 http://www.pinnangluongmattroi.vn	123 https://www.lazada.vn	282 http://www.pinnangluongmattroi.vn	318 http://www.pinnangluongmattroi.vn	368 http://www.pinnangluongmattroi.vn	657 https://vioa.com.vn
2	1018-1273 https://vogiasolar.com	111 https://diensach.com	80.6 https://www.sendo.vn	200 http://giaongay247.com	393 https://diensach.com	316 https://www.sendo.vn	673 https://diensach.com
3	971 https://bigk	65.8 https://ww	75 https://ww	140 https://w	331 https://techwa	289 https://ww	552 https://shop

	.vn/	w.sendo.vn	w.sendo.vn	ww.lazada.vn	y.vn	w.lazada.vn	ee.vn
4	850 https://vioa.com.vn	86.6 http://solarking.vn	129 http://solarking.vn	151 http://solarking.vn	327 http://giaongay247.com	360 http://giaongay247.com	885 http://giaongay247.com
5	1061 https://lithaco.vn	82.8 https://techway.vn	62 https://shopee.vn	191 https://www.sendo.vn	324 http://nhamaydienmattroi.com	433 http://ungdungdientu.com	802 http://nhamaydienmattroi.com
The cost assumption used in this study	1200	111	129	282	393	433	885

Note: VND to USD, exchange rate as at 2 March 2019, VND/USD = 23,561)State Bank of Vietnam, 2019(

Table 4. The size (kWp) of rooftop solar energy systems appropriate for each level of electricity consumption

1. Level of electricity consumption	**Level 1: up to 50kWh**	**Level 2: up to 100kWh**	**Level 3: up to 200kWh**	**Level 4: up to 300kWh**	**Level 5: up to 400kWh**	**Level 6: more than 401 kWh)500kWh(**
2. Electricity cost each month)USD(	≥3.9	≥ 8.0	≥ 17.4	≥ 29	≥ 42.4	≥ 56.1
3. Capacity of rooftop system for)1(per equation 4/166.67)rounded up kWp(-	0.3	0.62	1.24	1.85	2.47	3.33
4. Assumed SG system installation cost (USD( ])3(* 1200[	360	744	1,488	2,220	2,964	3960
5. Assumed cost of the inverter	111	129	282	393	433	885

Source: calculations based on the assumptions set out below and on the electricity cost appropriate for different level users.

Note: the assumptions adopted were the sunshine duration (Table 2), and a detailed price quotation per 1kWp for a domestic SG rooftop solar system quoted by companies in Vietnam (Table 3). A low sunshine duration of 2000 hours/per year and a high system cost were adopted to ensure that the economic indicators derived would be based on realistic levels of both sunshine and installation cost rather than average or optimistic levels.

774 **Table 5.** Cost-benefit analysis for a SG rooftop PV appropriate for level 1 electricity
775 consumption

Year	Bt)USD(	C0)USD(	Tax	Excise Fee	Ct	Bt-Ct	Accumulation of Bt-Ct	1+r^t	Bt-Ct/)1+R(^t
1	42.12	360	0	0	360	-317.88	**-317.88**	1.09	-292.71
2	42.12	0	0	0	0	42.12	**-275.76**	1.18	35.71
3	42.12	0	0	0	0	42.12	**-233.64**	1.28	32.89
4	42.12	0	0	0	0	42.12	**-191.52**	1.39	30.28
5	42.12	0	0	0	0	42.12	**-149.40**	1.51	27.88
6	42.12	0	0	0	0	42.12	**-107.28**	1.64	25.67
7	42.12	0	0	0	0	42.12	**-65.16**	1.78	23.64
8	42.12	0	0	0	0	42.12	**-23.04**	1.93	21.77
9	42.12	0	0	0	0	42.12	**19.08**	2.10	20.05
10	42.12	111	0	0	0	-68.88	**-49.80**	2.28	-30.19
11	37.44	0	0	0	0	37.44	**-12.36**	2.48	15.11
12	37.44	0	0	0	0	37.44	25.08	2.69	13.91
…….....									
20	37.44	111	0	0	0	-73.56	213.60	5.21	-14.13
21	37.44	0	0	0		37.44	251.04	5.65	6.62
22	37.44	0	0	0		37.44	288.48	6.14	6.10
23	37.44	0	0	0	0	37.44	325.92	6.67	5.61
24	37.44	0	0	0	0	37.44	363.36	7.24	5.17
25	37.44	0	0	0	0	37.44	400.80	7.87	4.76
								Sum	9.12

776 Source: calculations based on the assumptions shown below Table 4 and the level of electricity
777 cost appropriate for users at this level of consumption.
778
779 **Table 6**. Financial indicators of SG rooftop PV appropriate for each level of electricity
780 consumption

1. Grid electricity used monthly	**Level 1)up to 50kWh(**	**Level 2)up to 100kWh(**	**Level 3)up to 200kWh(**	**Level 4)up to 300kWh(**	**Level 5)up to 400kWh(**	**Level 6)400kWh: 401kWh-500kWh)**
2. Cost of electricity per month)USD(	3.9	8.0	17.4	29	42.4	56.1
3. Capacity of rooftop system for (1(per equation 4 /166.67)rounded up - kWp(	0.3	0.62	1.24	1.85	2.47	3.33
4. Assumed SG instalation cost)USD( ])3(* 1200[	360	744	1,488	2,220	2,964	3960
5. Assumed cost of replacing inverter after 10 years' use	111	129	282	393	433	885
6. The expected financial indicators if all output power used to meet domestic electricity consumption based on current EVN retail electricity price						
PBP (years)	***11***	***10***	***7***	***7***	***6***	***4***
NPV	***9.12***	***75.81***	***283.88***	***761.08***	***1,461.47***	***2,618.86***

IRR (%/per year)	*9.04*	*10.69*	*11.71*	*14.14*	*16.46*	*23.66*

Source: calculations based on the assumptions set out below Table 4 and the level of electricity cost appropriate for each level of consumption.

Table 7. Cost-benefit analysis of an SG rooftop PV appropriate for level 6 electricity consumption where all electricity output sold to the grid.

Year	Bt (USD (	C0)USD(	Personal income tax, VAT& Excise fee	Ct	Bt-Ct	Accumulation of Bt-Ct	1+r^ t	Bt-Ct/)1+R) ^t
1	504.90	3,960	0	3,960.00	-3,455.10	**-3,455.10**	1.09	-3181.4
2	504.90	0	0	0	504.90	**-2,950.20**	1.18	428.10
3	504.90	0	0	0	504.90	**-2,445.30**	1.28	394.20
4	504.90	0	0	0	504.90	**-1,940.40**	1.39	362.98
5	504.90	0	0	0	504.90	**-1,435.50**	1.51	334.24
6	504.90	0	0	0	504.90	**-930.60**	1.64	307.77
7	504.90	0	0	0	504.90	**-425.70**	1.78	283.40
8	504.90	0	0	0	504.90	79.20	1.93	260.96
9	504.90	0	0	0	504.90	584.10	2.10	240.29
10	504.90	885	0	0	**-380.10**	204.00	2.28	-166.57
11	448.80	0	0	0	448.80	652.80	2.48	181.10
12	448.80	0	0	0	448.80	1,101.60	2.69	166.76
13	448.80	0	0	0	448.80	1,550.40	2.92	153.56
.....								
20	448.80	885	0	0	436.20	3,807.00	5.21	-83.77
21	448.80	0	0	0	448.80	4,255.80	5.65	79.36
22	448.80	0	0	0	448.80	4,704.60	6.14	73.08
23	448.80	0	0	0	448.80	5,153.40	6.67	67.29
24	448.80	0	0	0	448.80	5,602.20	7.24	61.96
25	448.80	0	0	0	448.80	6,051.00	7.87	57.06
			Total					**717.40**

Source: Calculation base on the assumptions set out below Table 4 and the level of electricity cost appropriate for this level of consumption

Table 8. Financial indicators for SG rooftop solar PV where all electricity sold to the grid

1. Grid electricity used monthly	**Level 1)up to 50kWh(**	**Level 2)up to 100kWh(**	**Level 3)up to 200kWh(**	**Level 4)up to 300kWh(**	**Level 5)up to 400kWh(**	**Level 6)more than 401kWh(500kWh**
2. Cost of electricity per month)USD(	3.9	8.0	17.4	29	42.4	56.1
3. Capacity of rooftop system)same as table 6(	0.3	0.62	1.24	1.85	2.47	3.33
4. Assumed SG instalation cost (same as table 6(	360	744	1,488	2,220	2,964	3960
5. Assumed cost of	111	129	282	393	433	885

replacing inverter every 10 year's use						
6. The expected economic indicators if all power output is sold to the grid at the FIT price of 9.35 US Cents per kWh						
PBP (years)	***7***	***7***	***7***	***7***	***7***	***7***
NPV	***90.7***	***217.93***	***420.74***	***661.07***	***1,079.45***	***717.41***
IRR (%/per year)	***12.90***	***13.30***	***13.20***	***13.41***	***14.21***	***11.6***

Source: calculations based on the assumptions set out under Table 4 and the level of electricity cost appropriate for each level of consumption.

Table 9. Level of electricity consumption and recommended forms of support from the Vietnamese Government

	Number of households	Percent
Level of electricity consumption		
Level 1 (From 0-50 kWh)	0	0
Level 2 (From 51-100 kWh)	49	16.3
Level 3 (From 101-200 kWh)	119	39.7
Level 4 (From 201-300 kWh)	87	29.0
Level 5 (From 301-400 kWh)	31	10.3
Level 6 (Over 400 kWh)	14	4.7
Recommended forms of support from the government		
Support 10% initial cost	51	17.0
Support 20% initial cost	29	9.7
Support 30% initial cost	118	39.3
Recommend commercial banks to give preferential rate loans	81	27.0
Give 5 million VND bonus for people who install the system	8	2.7
Other	13	4.3
Total	300	100.0

Source: Survey of 300 households in the Central Highlands of Vietnam about their intention to install an SG rooftop PV.

FIGURES

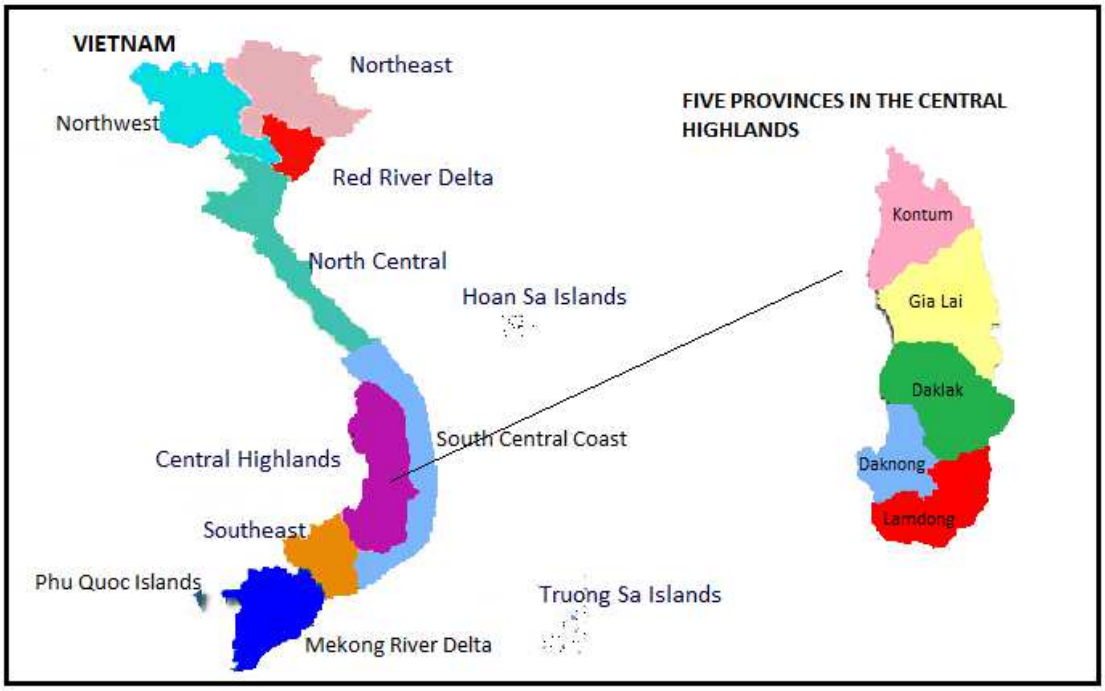
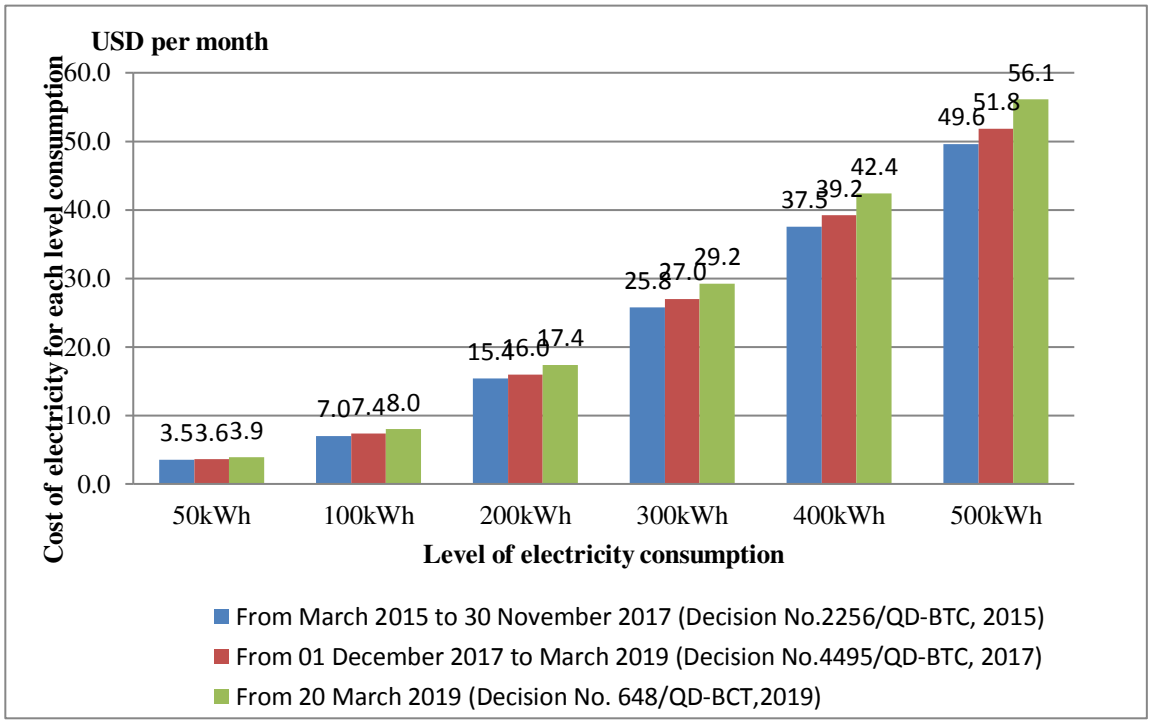


Figure 1. Geographical location of the Central Highlands of Vietnam
Source: [24]



Note: All decisions made by the Vietnamese Ministry of Finance

Figure 2. Cost of electricity for each level of electricity consumption

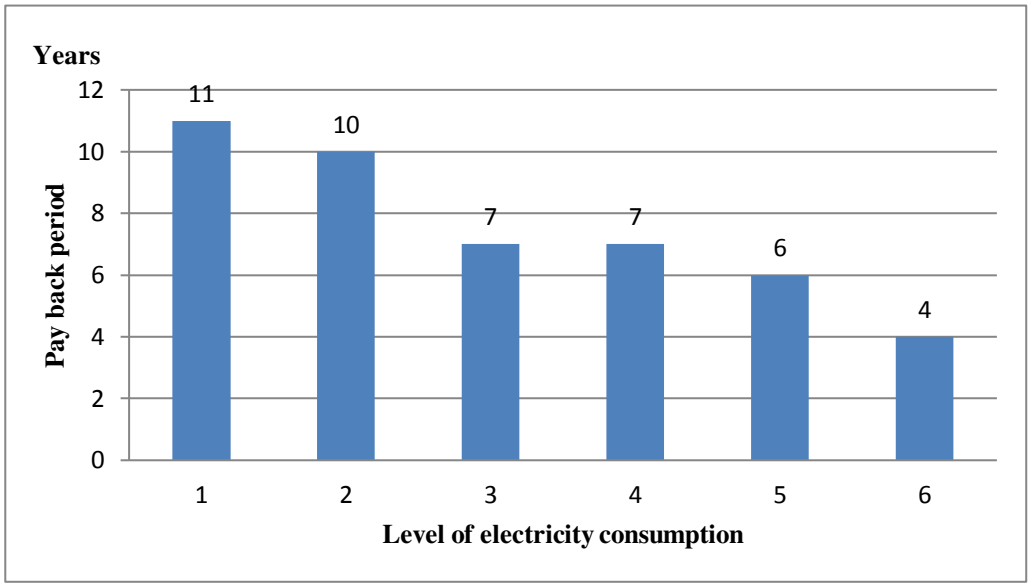


Figure 3a. PBP of SG rooftop PV appropriate for each level of electricity consumption

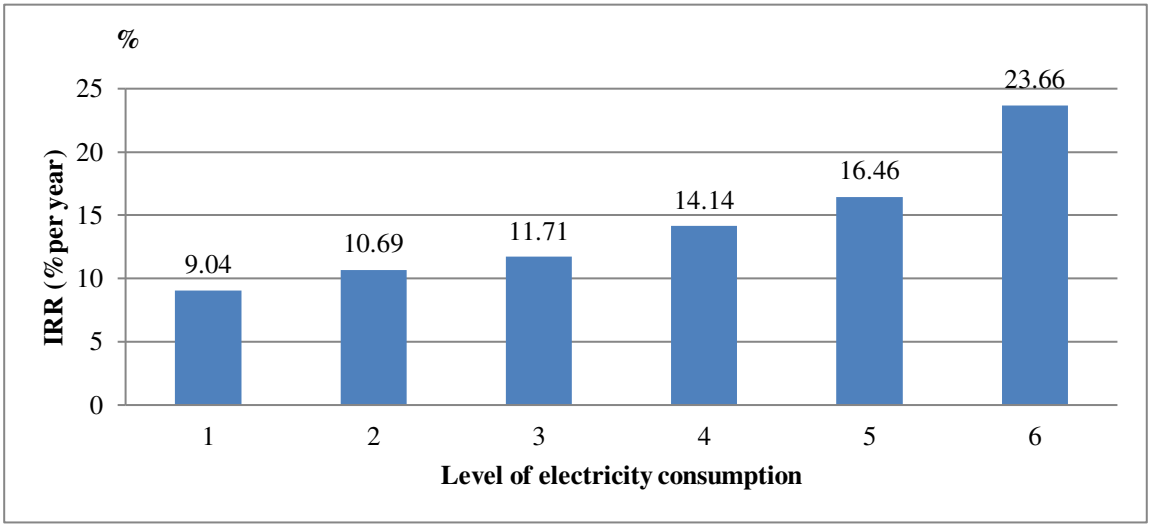


Figure 3b. IRR of SG rooftop PV appropriate for each level of electricity consumption

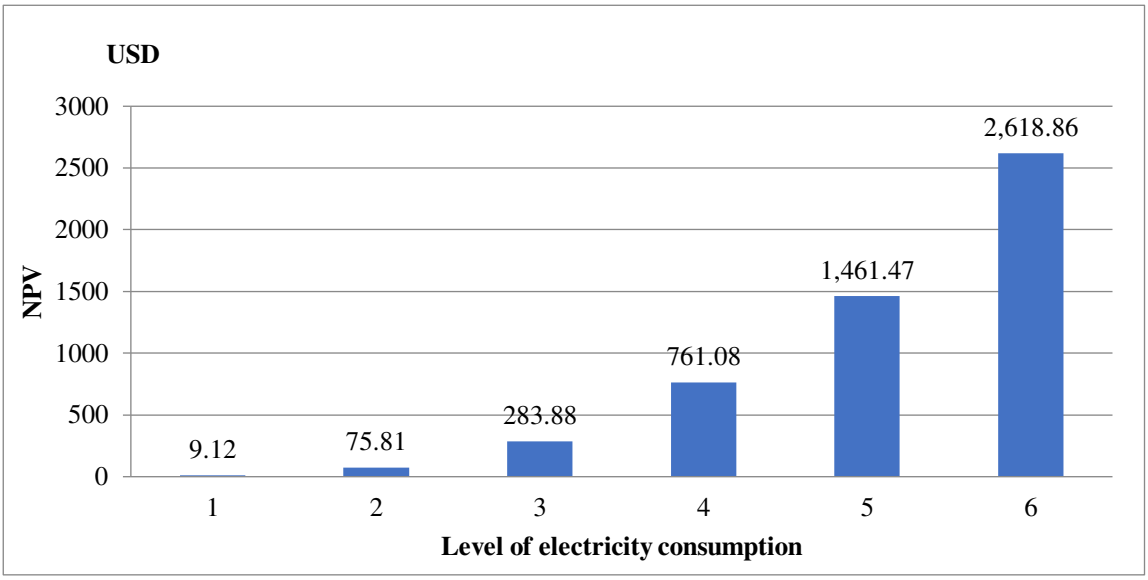


Figure 3c. NPV of SG rooftop PV appropriate for each level of electricity consumption

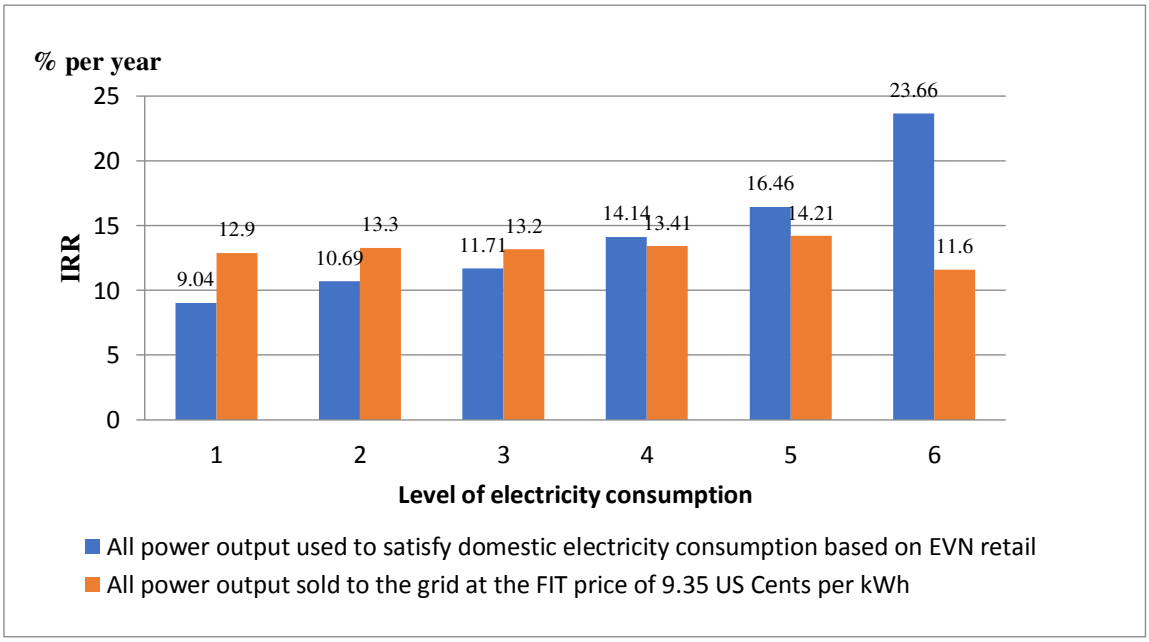


Figure 4a. IRR comparison of the SG rooftop PV where all electricity output used for domestic consumption vs. all electricity output being sold to the grid**.**

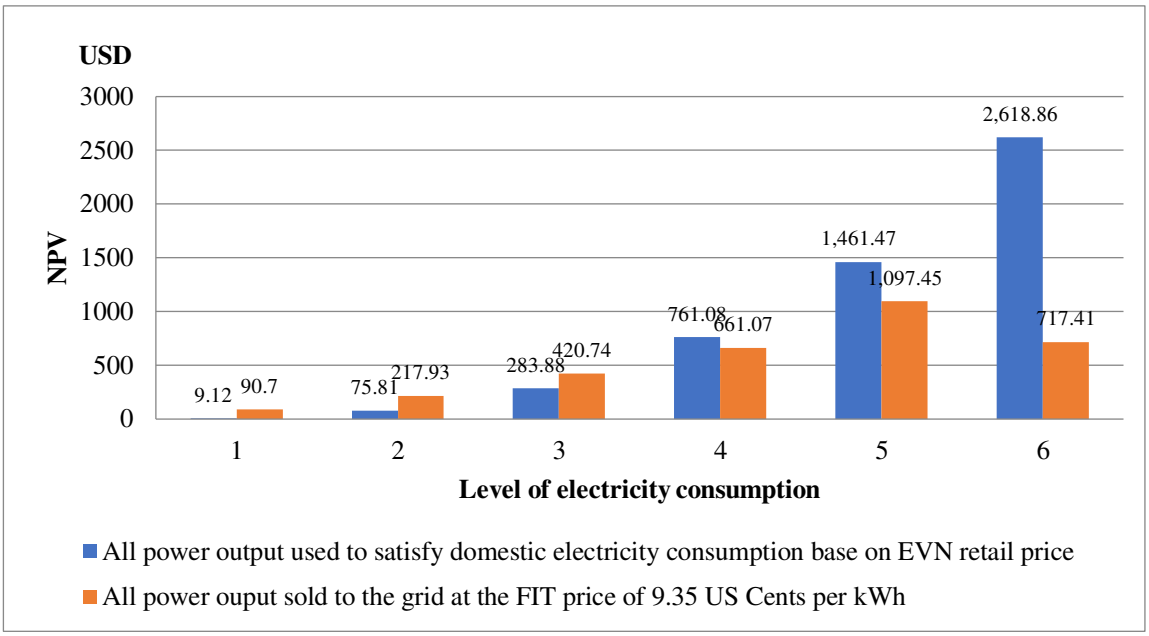


Figure 4b. NPV comparison of the SG rooftop PV where all electricity output used for domestic consumption vs. all electricity output being sold to the grid**.**

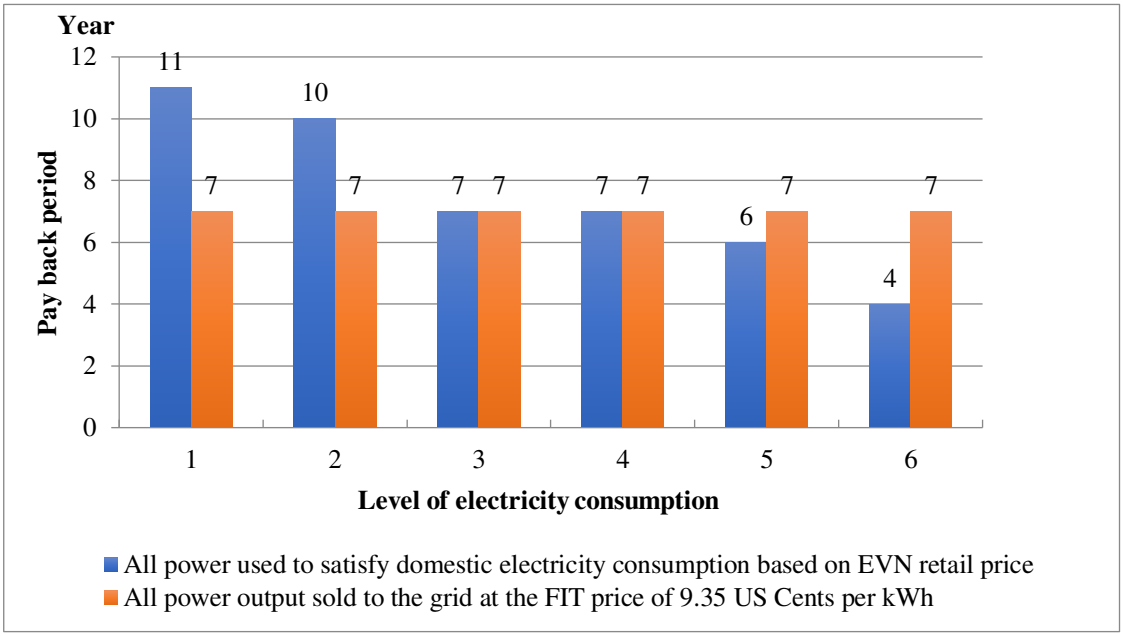


Figure 4c. PBP comparison of SG rooftop PV where all electricity output used for domestic consumption vs. all electricity output being sold to the grid**.**

Figures

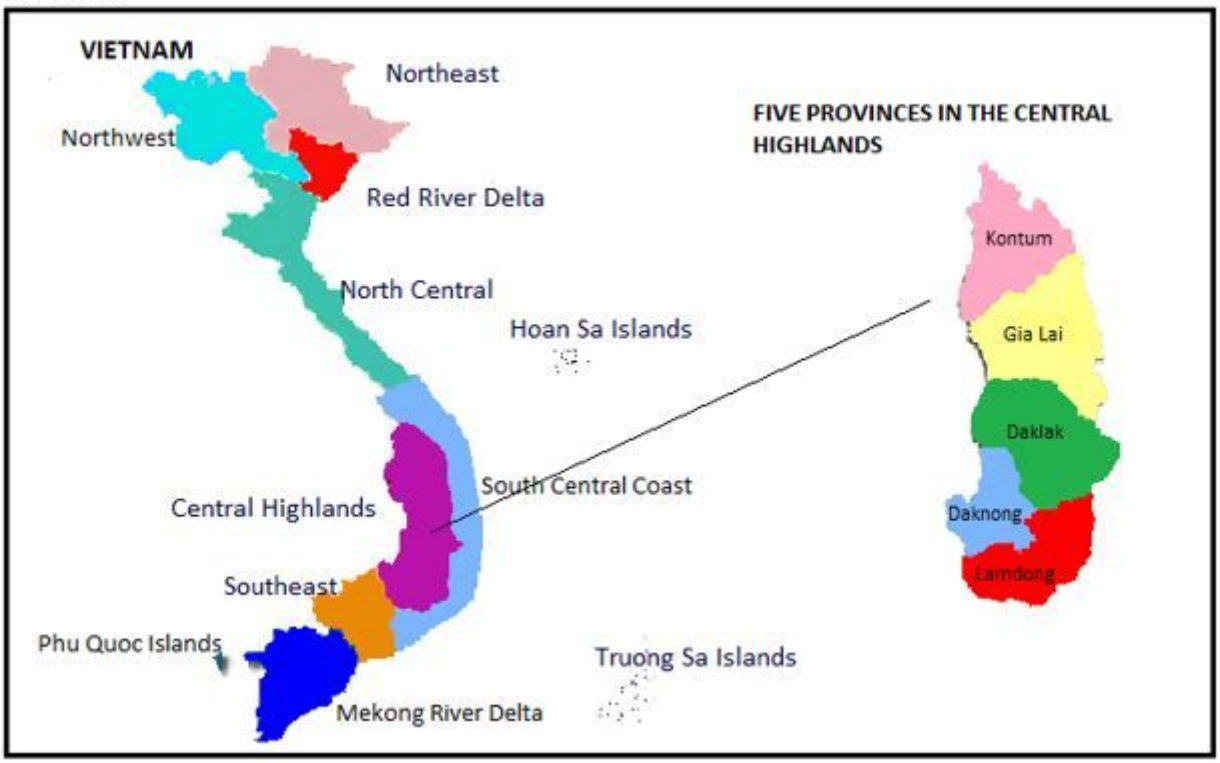
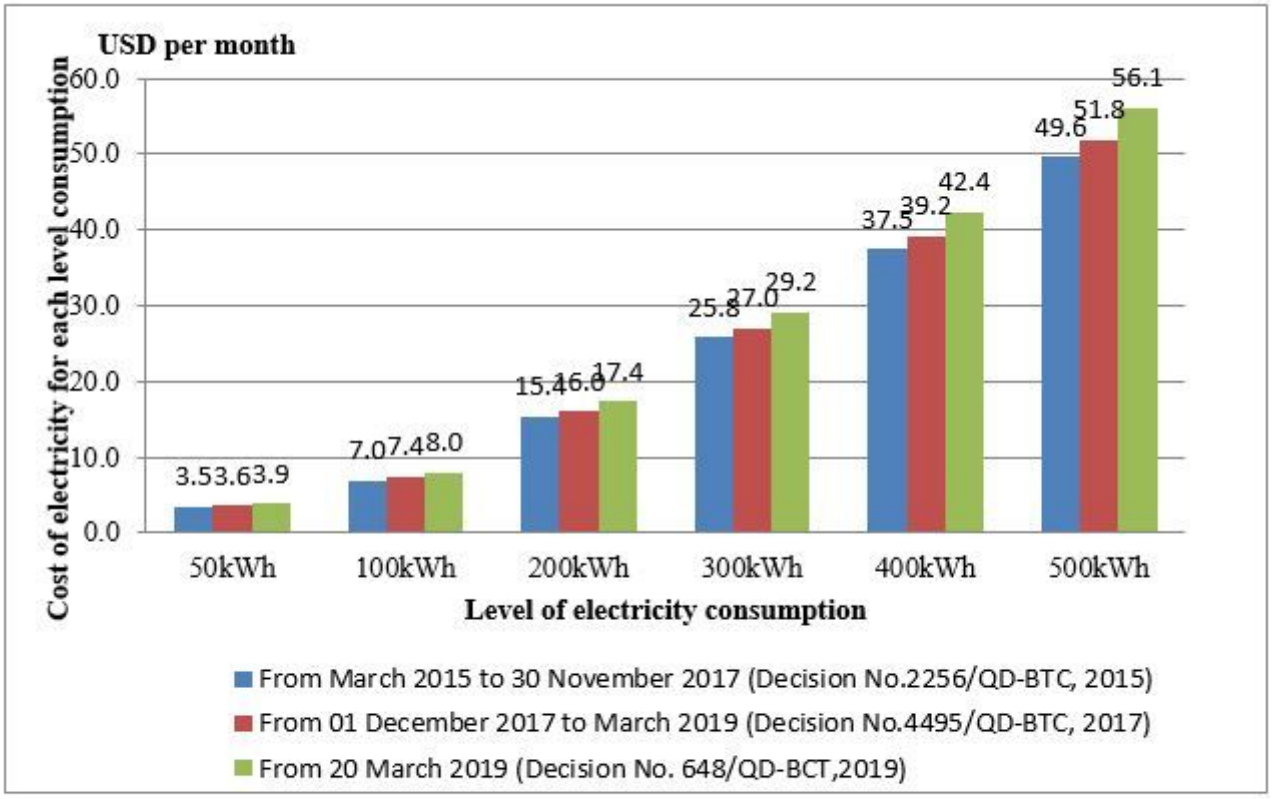


Figure 1

Geographical location of the Central Highlands of Vietnam Source: [24]



Note: All decisions made by the Vietnamese Ministry of Finance

Figure 2

Cost of electricity for each level of electricity consumption

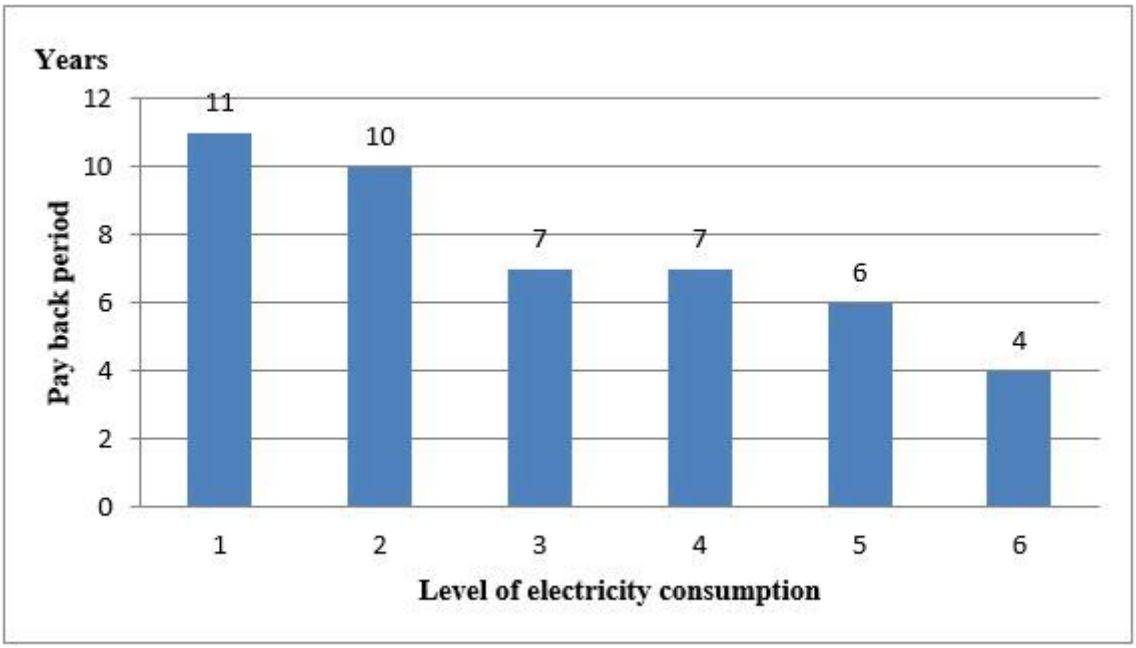


Figure 3

3a. PBP of SG rooftop PV appropriate for each level of electricity consumption

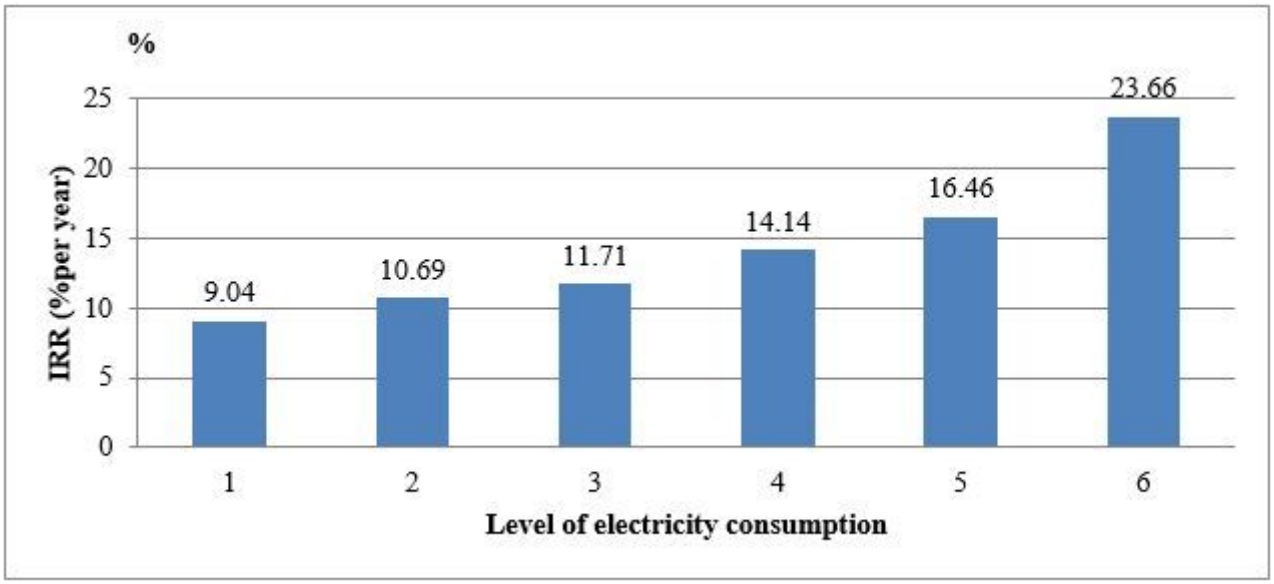


Figure 4

3b. IRR of SG rooftop PV appropriate for each level of electricity consumption

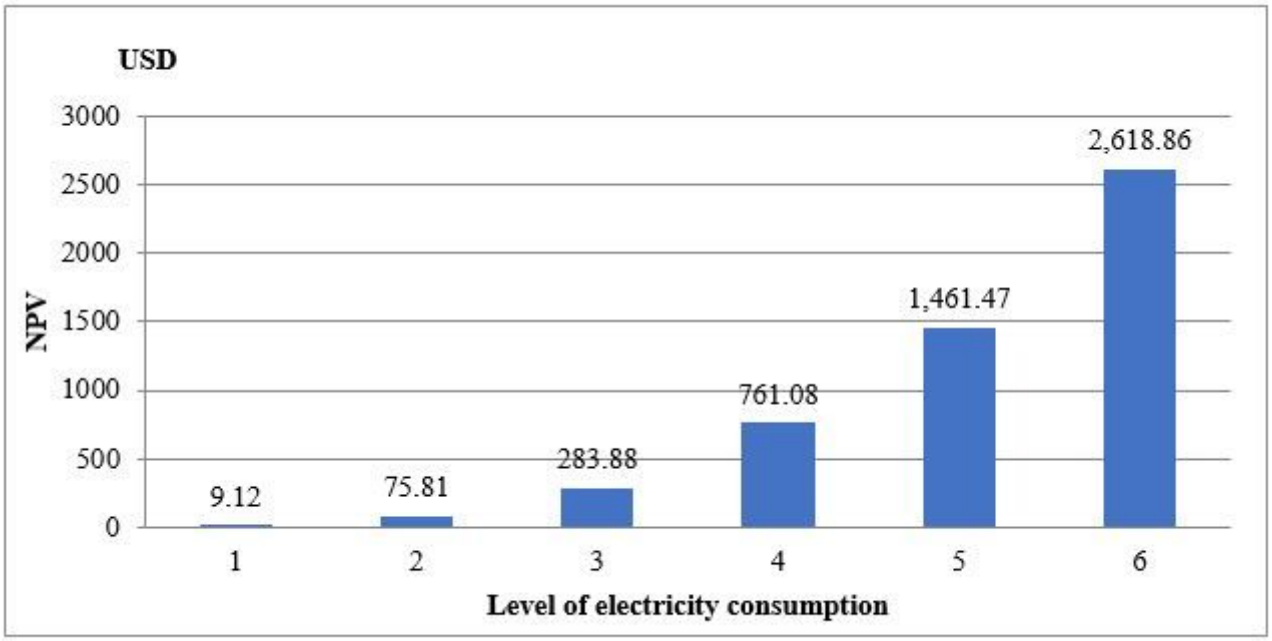


Figure 5

3c. NPV of SG rooftop PV appropriate for each level of electricity consumption

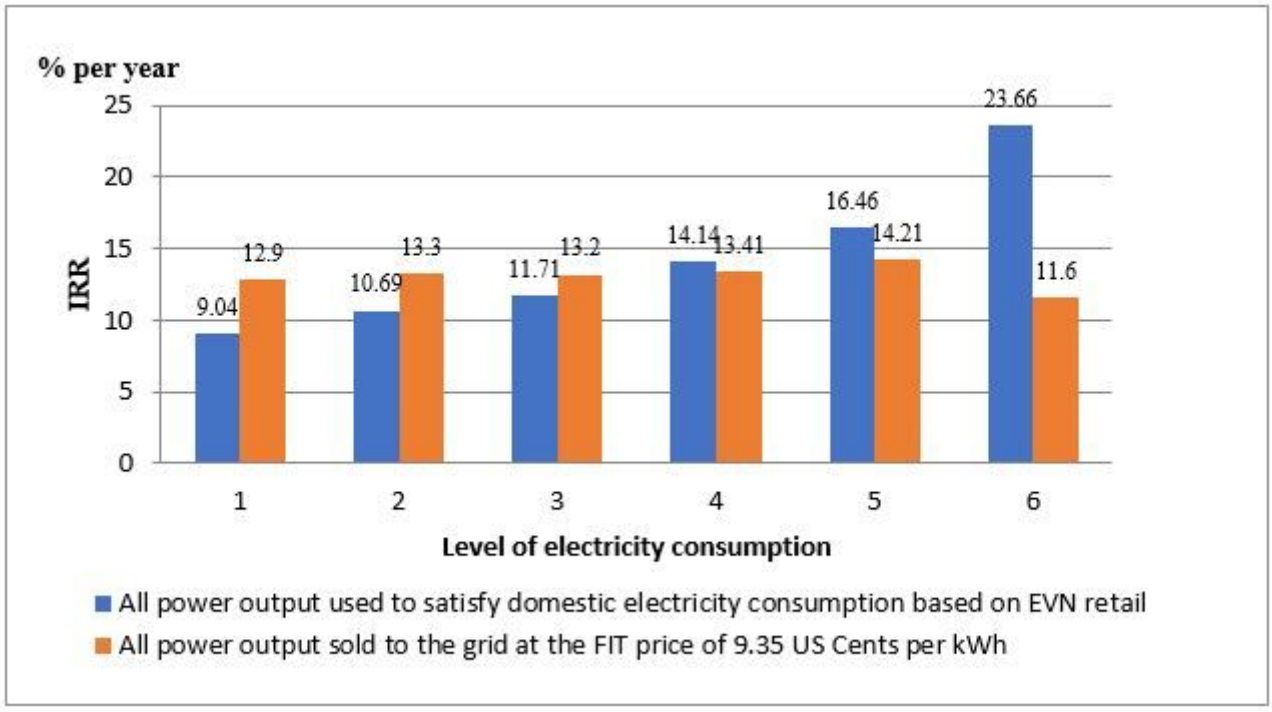


Figure 6

4a. IRR comparison of the SG rooftop PV where all electricity output used for domestic consumption vs. all electricity output being sold to the grid.

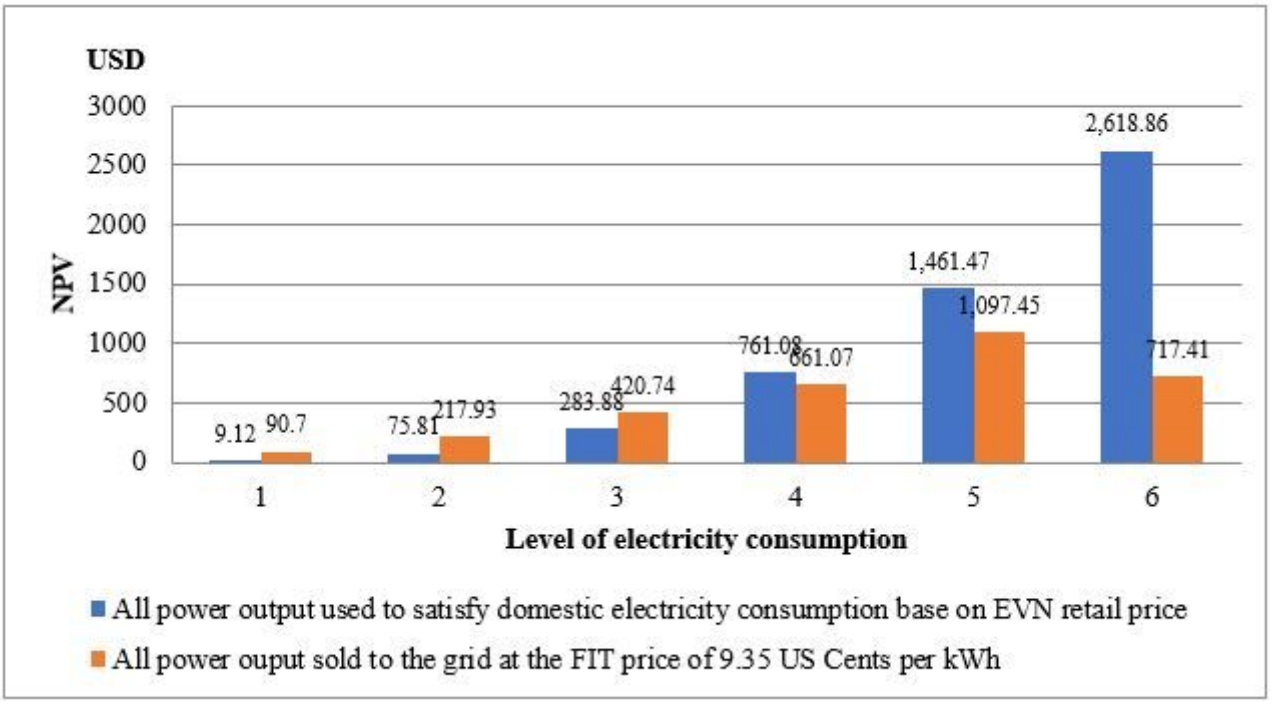


Figure 7

4b. NPV comparison of the SG rooftop PV where all electricity output used for domestic consumption vs. all electricity output being sold to the grid.

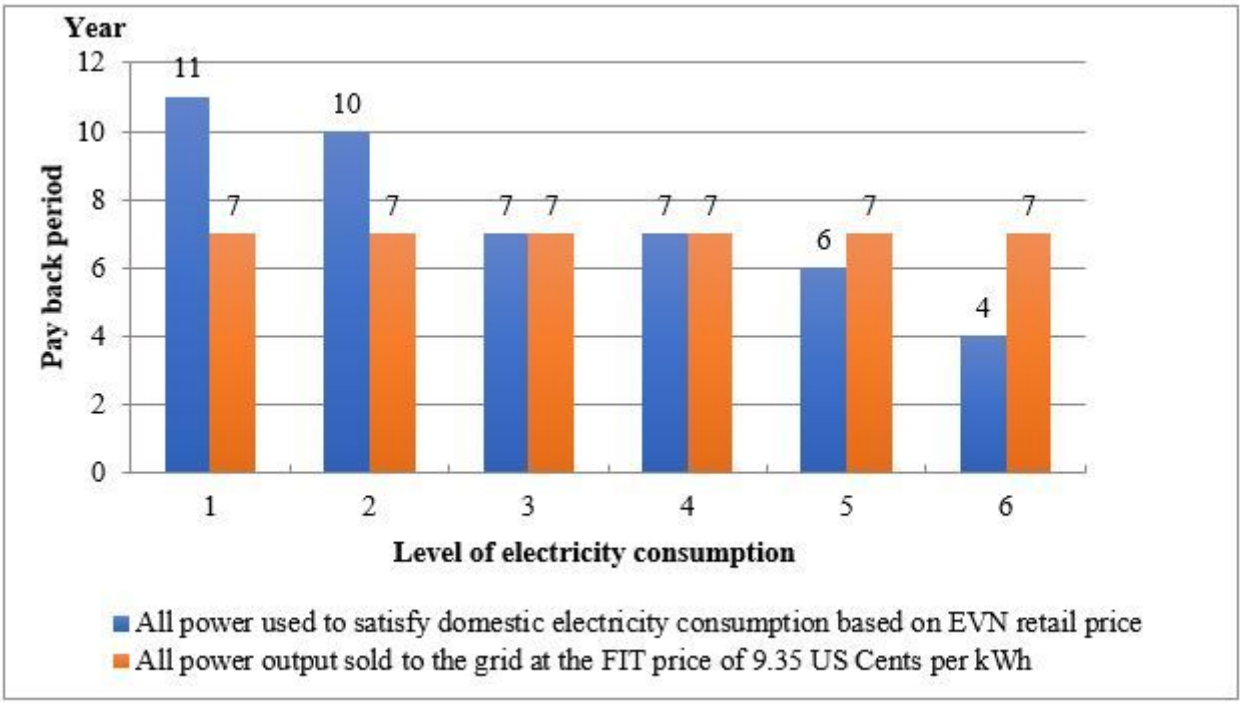


Figure 8

4c. PBP comparison of SG rooftop PV where all electricity output used for domestic consumption vs. all electricity output being sold to the grid.