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Pol. J. Environ. Stud. Vol. 32, No. 5 (2023), 4219-4227
DOI: *10.15244/pjoes/166349*

Original Research

The Development of Solar Electric Power in Vietnam From Economy and Policy Analysis

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DOI: *10.15244/pjoes/166349* ONLINE PUBLICATION DATE: 2023-07-24

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Received: 9 April 2023
Accepted: 20 May 2023

Abstract

Vietnam has pledged to reduce methane emissions by 30%, increase renewable energy utilization, and decrease coal-based electrical power, with a goal of achieving net-zero carbon dioxide emissions by 2050. Among renewable energy sources, solar energy has gained attention due to Vietnam's favorable location near the equator. This study aims to evaluate the economic feasibility of solar energy generation in Vietnamese households, focusing on the north, middle, and south regions. Using the Ecotect software, the study assesses the potential for solar energy production, while also examining the country's solar power policy for electricity production. Through this analysis, the research aims to identify any weaknesses in the current policy and recommend possible solutions to maximize the economic benefits of solar energy development. The findings of this study are expected to provide insights into the economic feasibility of solar energy generation in Vietnamese households, as well as inform policymakers about the shortcomings of the current solar power policy. Ultimately, this research aims to support Vietnam's transition towards a sustainable and prosperous future, in line with the country's long-term goals for reducing carbon emissions and increasing the utilization of renewable energy.

Keywords: Autodesk Ecotect, solar heat water system, governmental policy, greenhouse gas

Introduction

In recent years, Vietnam has taken steps to reduce its greenhouse gas (i.e., Carbon dioxide -CO_2, methane, nitrous oxide and fluorinated gases) emissions and transition towards a more sustainable energy system. At the COP26 conference in Scotland, Vietnam committed to reducing methane emissions by 30%, reducing coal-based electrical power, and increasing the use of renewable energy by 2030. The country also aims to reach net zero CO_2 emissions by 2050 [1]. However, achieving these goals will require overcoming many challenges, including the formulation and implementation of effective solar energy policies.

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The largest contributor to this is coal-fired power, which is being phased out due to its inefficiency in converting only 30% of heat energy to electricity. To address this, the shift towards renewable energy and the implementation of effective policies will be accelerated to achieve net zero CO_2 emissions [2].

Fortunately, Vietnam's geographic location near the equator (from 8°27' to 23°23' North) provides abundant and nearly unlimited solar energy potential around 5 kWh/m^2 per day. The country experiences an average of 2000 hours of sunlight each year [3]. Thus, solar energy can be utilized in various industries. As a result, solar energy can be utilized in various industries, including agriculture, where solar drying can help reduce energy demand in the process of drying agricultural products such as rice, fruits, and vegetables [4]. This system works by having sunlight penetrate a glass cover and heat up the collector, which then transfers the heat to raise the air temperature. Different collector shapes, such as flat, finned, and triangle-finned, can be employed to increase the amount of solar energy collected [5]. Additionally, solar energy can be used to generate hot water, which involves capturing solar radiation to heat up the collector containing water, thereby raising its temperature [3]. Electricity can also be generated through photovoltaic means, using materials that can convert sunlight into electricity.

However, on rainy days or during nighttime, the amount of solar radiation is in-sufficient. To overcome this, an electric heater was used to supplement the heat. This means that electric energy is used to increase water temperature. To conserve energy, a heat pump can be used as an alternative to a traditional electric heater [6, 7].

In addition to solar thermal applications, electricity can also be generated through photovoltaic means. Photovoltaic cells (PV) are made from materials that can convert sunlight into electricity [2].

Currently, silicon mixed with impurities forms two layers: one with an excess of electrons and one with a deficiency of electrons. When exposed to photons, free electrons flow through an external circuit to the layer with a deficiency of electrons, creating an electric circuit. There are three commonly used types of PV cells: single-crystal silicon cells, multi-crystal silicon cells, and thin-film cells. Single-crystal silicon cells have the highest efficiency (16-22%) but are the most expensive, while multi-crystal silicon cells have a lower efficiency (14-17%) and thin-film cells have the lowest efficiency (7-12%). The application of PV cells has been widely researched by various scientists. Gangopadhyay (2017) [8] conducted a study on a photovoltaic (PV) plant located at the National Institute of Advanced Studies in India. The purpose of this study was to examine the electrical generation capacity, economic viability, and maintenance requirements of the plant. The results of the study were compared to a similar rooftop PV power project in Vietnam. Mah et al. (2018) [9] implemented a study on photovoltaic (PV) power in Hong Kong by conducting 57 interviews with residents. The aim of their research was to understand the benefits and challenges of policies related to PV power and to evaluate them. Oliva (2017) [10] studied the impact of the existing electricity tariffs on the financial viability of PV systems and energy efficiency by obtaining real data from households in Sydney. They reported that inappropriate tariffs could have a negative effect on the benefit of PV grid usage for both households and their service suppliers.

According to Shukla et al. (2016) [11], the design of a photovoltaic (PV) power system is influenced by factors such as location, amount of solar radiation, weather patterns and energy needs. The authors outlined a step-by-step approach to designing the system and utilized simulation software to assess its performance, the economic feasibility of a rooftop PV system also investigated. Chandel et al. (2019) [12] briefly introduced the operation and behaviour of PV power and the basic equation. Subse-quently, they simulated a 50 W solar panel using MATLAB Simulink/PSIM to predict the effects of solar radiation and cell temperature on output current and power characteristics. These results, compared with the manufacturer's date sheet and published curves, show the signed agreement with their simulation. Kumar and Singh (2018) [13] conducted a simulation for PV cells to display the I–V and P–V graphs of solar PV modules. Their objective is to provide a comprehensive understanding to engineers, social communities, and broad knowledge to researchers, manufacturers, and social gatherings. It is clear that most simulations of PV cells focus only on creating I-V and P-V graphs using MATLAB Simulink/PSIM [12, 13] or PVSYST [2]. These software programs do not consider the impact of shading from surrounding buildings on PV cells, especially in developing countries like Vietnam. In contrast, most practical solar engineering is familiar with Autodesk Ecotect, which has successfully evaluated power production in some developing areas [14, 15]. Overall, regardless of limitations, these studies focused primarily on technical aspects, proving that the use of PV cells to generate electricity can bring economic benefits to society.

Despite the positive results from technical studies on PV cell technology, the practical implementation of this advanced technology requires comprehensive national regulations and laws. In Vietnam, the current solar energy policy falls short in meeting the country's 2050 net-zero carbon dioxide emissions target, with inconsistent policies resulting in pricing challenges for investors and consumers [3]. This study utilizes Ecotect software to evaluate the solar energy production of households in Ho Chi Minh, Danang, and Hanoi, while also critically examining the country's PV cell policy to identify weaknesses and provide recommendations for maximizing the economic potential of solar energy in the future.

Methodology

When sunlight hits a photovoltaic cell, electrons flow and generate direct current (DC) electricity. The PV system is then connected to the main power grid. When the power output from the PV system is lower than the demand or during the nighttime, power is taken from the grid. On sunny days, any surplus power from the PV cells can be sent back to the grid, providing benefits to both power companies and PV owners. Energy demand is typically higher during the day due to factors such as air conditioning and production, so power companies do not have to invest in additional generators to meet this demand [15]. In Vietnamese households (4 people), the use of electricity for hot water accounts for 16-21% of daily electricity consumption, which ranges from 1.8 kWh/day to 2.5 kWh/day, thereby this study selected a daily electricity consumption of 11590 Wh for calculation purposes.

In the simulation, a 28 square meter photovoltaic (PV) cell with an electrical efficiency of 12% was used. Under ideal conditions with a solar radiation of 1000 W/m^2, the 28 m^2 cell is capable of producing 3.36 kWp. However, in real conditions, the amount of solar radiation varies based on location and time, meaning that the amount of electricity produced cannot reach 3.36 kWp. This paper analyzed three cities in Vietnam: Ho Chi Minh (10.75^{o}N,106.415^{o}E), Da Nang (16.071^{o}N, 107.9^{o}E), and Ha Noi (21^{o}N, 105.8^{o}E) to determine the impact of location on solar energy production [16, 17].

This simulation utilized a weather library constructed by the Joint Research Centre (JRC) and relied on data from METEOSAT satellites covering Europe, Africa, and Asia [18]. The weather data and solar radiation were obtained by capturing images every 15 or 30 minutes and comparing them to clear sky conditions to calculate radiation during cloudy weather. This method showed good agreement with the ground measurements. This weather library was used in the Ecotect simulation. Three models of PV panel were designed with three different titlangle (11^{o}, 16^{o}, 21^{o}) corresponding to the latitude of each city. Additionally, the orientation and tiltangle of the PV cell also affects the amount of solar energy produced. The maximum energy can be obtained when the PV cell is perpendicular to the direct beam radiation and the tiltangle is equal to the latitude of the location. The flow research was conducted in the steps which is illustrated in Fig. 1. Sunlight hours represent the average number of hours per day in which the sun is shining without interference from clouds.

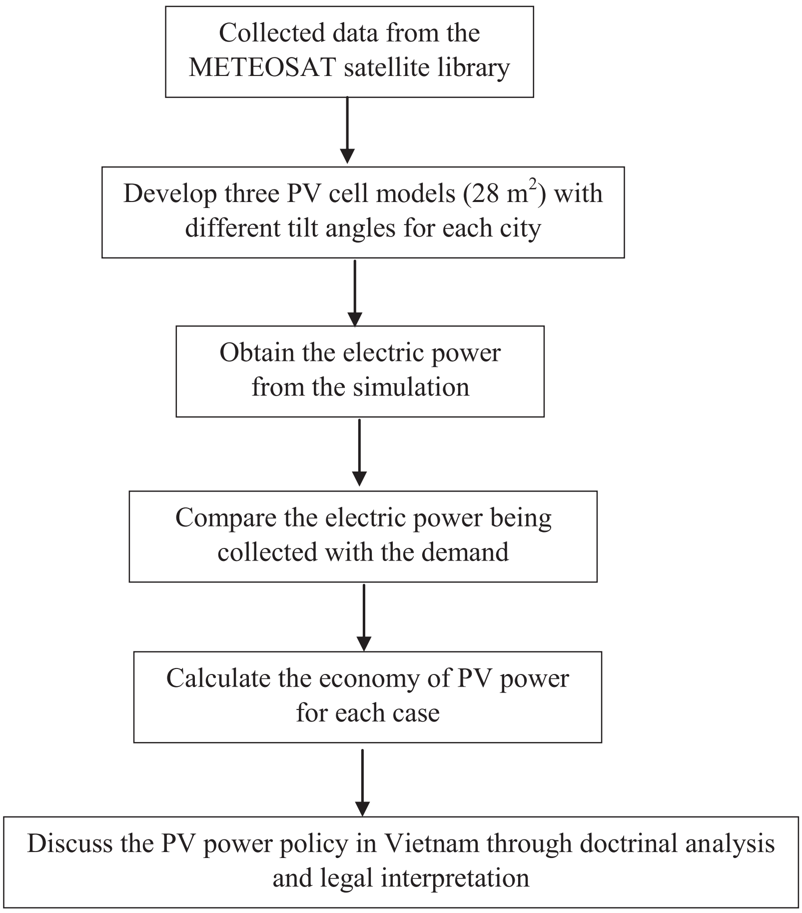

Fig. 1. Methodology flow chart.

Results and Discussion

Solar Power Energy Profiles

The power capacity of PV cells is significantly impacted by the sunshine hours and the average daily sunshine hours of the three cities, which were obtained using Autodesk Ecotect, and are presented in Fig. 2.

The data provided compares the average daily sunshine hours in three cities in Vietnam: Ho Chi Minh City, Da Nang City, and Ha Noi City. The results show that Ho Chi Minh City has the largest number of average daily sunshine hours, with a high of 11.4 hours in April and a low of 4.6 hours in July. Meanwhile, Da Nang City experienced the most significant number of daily sunshine hours in November, at 9.8 hours, with a low of 4.3 hours in January and December. On the other hand, Ha Noi city has the lowest number of average daily sunshine hours in February, at 2.3 hours, with the highest being 9.2 hours in October. When considering the total average sunshine hours per year, Ho Chi Minh City has the largest electric consumption at 2954.3 hours, and its average sunshine daily hours are more stable compared to the two other cities. The second largest electric consumption is in Da Nang City, at 2594.6 hours per year, and the remaining city has a total of 2544.3 hours per year. The yearly electric power generated by PV cells in the three cities was calculated using Autodesk Ecotect and is displayed in Fig. 3.

The electric power generated by PV cells in the three cities over the course of a year was determined using Autodesk Ecotect, with the results shown in Fig. 3. The highest power generation was recorded in Ho Chi Minh City in April, reaching 506542 Wh. For Da Nang City and Ha Noi City, maximum power was generated in September, at 539108 Wh and 524617 Wh, respectively. The power of PV cells is heavily influenced by solar radiation and sunshine hours. The lowest power was recorded in Ha Noi City in February, with only 183745 Wh due to the lowest sunshine hours of 2.3 hours. Overall, PV cell power in Da Nang City is the highest and most consistent, totaling 5584669 Wh, followed by Ho Chi Minh City, with 5069882 Wh, and Ha Noi City, with 4843111 Wh. The determination of annual electricity consumption necessitates the multiplication of the daily household energy demand, which has been established at 11590 Wh, by the number of days in a year. As a result, the calculated yearly electricity consumption is 4242.2 kWh. Furthermore, Fig. 4 illustrates the results of the simulation conducted to estimate the monthly surplus and shortfall in household electricity supply for each city.

The chart reveals that positive electric consumption represents the excess electric power generated, exceeding the household demand. Conversely, negative electric consumption denotes the energy demand that must be supplied by the power grid. Specifically, Ho Chi Minh City experiences the lowest electrical shortage due to the high amount of sunshine hours, with deficiency occurring only in July, at 24580 Wh. In contrast, Da Nang city faces deficiency in January and December, at 48610 Wh and 52441 Wh, respectively, while Ha Noi city encounters a shortage in the first three months

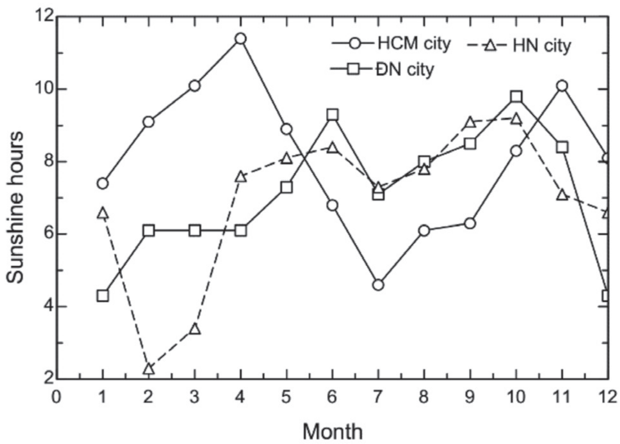

Fig. 2. The average daily sunshine hours of Ho Chi Minh, Da Nang City, Ha Noi City from the simulation.

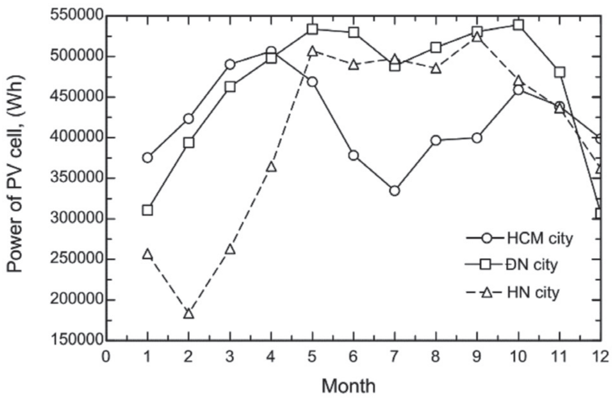

Fig. 3. Simulation results for the yearly generation of electricity from photovoltaic (PV) cells.

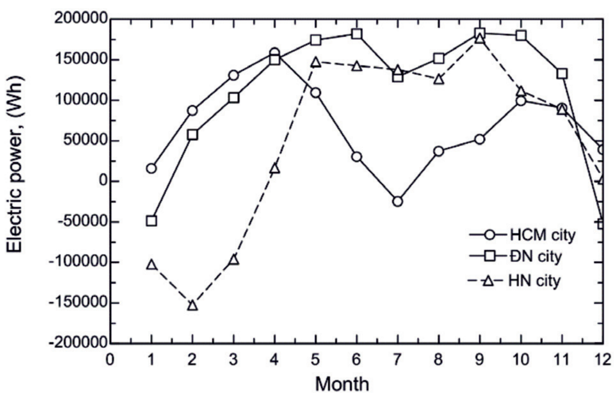

Fig. 4. The excess and deficient power of PV cells a year.

of the year, at 102126 Wh, 152365 Wh, and 96012 Wh, respectively. In general, PV cell energy satisfies household demand, generating an excess of demand, except during the aforementioned periods.

The household power demand of 4242.2 kWh can be fulfilled by energy generated from the PV cells. Any shortfall can be met by supplementing it with grid energy. Hence, annual energy savings can be calculated as the difference between the total power demand and the energy shortfall shown in Fig. 4. According to Viet Nam Electricity (EVN) [19], the cost of electricity is 2834 VND, equivalent to 0.128 USD per kWh. The electric power and corresponding savings per year from avoiding grid power can be determined. The results indicate that Ho Chi Minh City has the highest amount of power and money saved, at 4217 kWh and 539.8 USD, respectively, accounting for approximately 99.4% of household power consumption. Da Nang city ranks second with power savings of 4141 kWh and money savings of 530 USD, corresponding to a 97.6% power satisfaction rate. Ha Noi city comes in third, with power savings of 3892 kWh and money savings of 498.1 USD, accounting for a 91.7% power satisfaction rate. These findings suggest that residents of Ho Chi Minh City can save the most money by using PV power. In other words, for the same area of PV cells, the highest amount of power generated to meet household demand occurs in Ho Chi Minh City. Furthermore, any surplus power can be sold when the electricity generated exceeds demand, yielding a benefit with a selling price of 1943 VND, equivalent to 0.088 USD per kWh, as indicated in Table 1. The surplus power is calculated as the difference between the electricity generated from PV cells and the household electricity demand.

Table 1. The benefits of electric selling in 2021.

Months	HCM City (USD)	Da Nang city (USD)	Ha Noi city (USD)
Jan	1.41	0	0
Feb	7.68	5.08	0
Mar	11.52	9.08	0
Apr	13.97	13.2	1.48
May	9.64	15.3	13
Jun	2.68	15.9	12.53
Jul	0	11.37	12.12
Aug	3.28	13.35	11.12
Sep	4.58	16.09	15.56
Oct	8.77	15.82	9.82
Nov	7.97	11.70	7.82
Dec	3.45	0	0.26
Total	75	127.03	83.73

The highest electric sales are recorded in Da Nang while the lowest are in Ho Chi Minh city. Despite having the most hours of sunshine, Ho Chi Minh City has the lowest excess power due to lower solar radiation during certain months. Despite being 10% lower than Hanoi, Ho Chi Minh City has the lowest electric deficit at 24580 Wh in July as a result of weak radiation. When comparing the power and money saved in Ho Chi Minh City and Ha Noi City, PV power is slightly better in Ho Chi Minh City, with savings of 4217 kWh and 539.8 USD compared to Ha Noi City's savings of 3892 kWh and 498.1 USD.

It is widely acknowledged that utilizing PV power can lead to significant financial savings for households, with an estimated yearly reduction of around 500 USD from reduced reliance on grid electricity. Additionally, the economics of PV power can be further improved in certain areas, such as Danang or central Vietnam, through the sale of excess electricity. Riva Sanseverino et al. (2020) [3] stated that the average daily solar radiation ranges from 4 to 5 kWh/m2.day and the average annual number of sunshine hours ranges from 1600 to 2600 hours. The central region received the highest amount of radiation followed the southwest and the Northeast and Red River Delta areas have the lowest levels of radiation, at approximately 4 kWh/m2 which consistent with other finding of Do et al. (2020) [20] the radiation approximately 3.4 kWh/m2. Vu Minh Phap et al. [2] installed a PV system on the building's rooftop with a total capacity of 56.7 kWp, and found that it can generate a total annual electricity production of 68625 kWh. Similarly, Tung Nguyen Thanh et al. [21] investigated the benefits of a PV system installed on a building in Hanoi using VSYST software. Their system had a total electricity power of 3080 Wp and included a 3 kW hybrid inverter. The authors noted that the PV system had a higher power generation from May to September, and identified factors such as dust, weather, and system loss that contributed to a small difference between the simulation and experimental results. The results of these studies highlight the potential of PV systems for sustainable electricity generation in Vietnam and the need for continued research and development to optimize their performance. Despite these advantages, the development of PV power has been impeded by government policies aimed at maximizing economic value. The following section focuses on addressing these obstacles and proposes possible recommendations.

Policy of Solar Energy Development in Vietnam

The Development of a Legal Framework for Facilitating Solar Energy Projects

Vietnam initially identified solar energy as one of the essential renewable resources under clause 3, Article 2 of the Law on Economic and Efficient Use of Energy 2010. Even this resource is currently categorized as one of the emerging industry groups in Vietnam and joined in the global development of renewable energy sources. Specifically, Solar and wind energy are currently encouraged to develop further under the Decision 2068/QD-TTg of the Prime Minister dated November 25, 2015, approving Strategies for Renewable Energy Development in Vietnam to 2030. With a vision to 2050, the decision aims to ensure the development of power sources via nuclear power projects and reduce fossil-fired thermal power plants. Moreover, to promote the efficient use of solar energy, the government also issues Decision No. 428/QD-TTg dated March 18, 2016, approving the adjustments of the national electricity development plan from 2011 to 2020 with a vision to 2030, one of which is an increase of about 850 MW by 2020; 4000 MW by 2025 and 12000 MW by 2030 in the capacity of solar energy [22].

The government of Vietnam encourages individuals and organizations to utilize all energy sources for the country's development effectively. Therefore, the general regulations on the use and saving of all types of energy, in general and solar energy in particular, are stipulated under the Law on Economic and Efficient Use of Energy 2010. The scope of the law includes policies and measures to promote energy saving, rights and obligations of organizations, households, and individuals in the economical and efficient use of energy. At the central level, Article 45 of the Law, the government will uniformly manage all activities of energy use and efficient saving. Specialized authority is granted to the Ministry of Industry and Trade, formulating strategies, plans, and programs, coordinating with other governmental agencies at the same level, and resolving complaints. At the local level, this authority will belong to the provincial people's committee [23].

In Vietnam, solar energy is mainly used for electricity production, which is said to have great potential for efficient energy exploitation. The government of Vietnam encourages people to install rooftop PV cells to utilize solar energy and maximize economic and environmental benefits. Specifically, regarding the economic side, the use of solar heat is a clean energy source with relatively high output, which helps the state minimize the budget capital in the investment of power generation projects and transmission grids [20]. Simultaneously, this promising industry creates job opportunities and income for local people. From the perspective of environmental advantages, CO_2 emissions into the atmosphere may be reduced by 0.6612 kg for every 1 kWh of solar power saved, according to the Ministry of Natural Resources and Environment. Moreover, it is estimated that just about 2 million rooftops in Vietnam install rooftop PV cells with a capacity of 10 kW/roof, which will lessen about 16 million tons of coal/year used for coal-fired power [24]. Therefore, governmental policies aim to develop investment in solar energy projects and increase public approachability. Initially, on April 11, 2017, the Prime Minister issued Decision 11/2017.QD-TTg on the mechanism is encouraging the development of solar power projects in Vietnam; Circular 16/2017/TT-BCT dated September 12, 2017, on project development and a sample purchase agreement. Subsequently, the government continued to issue Decision No. 02/2019/QD-TTg dated January 8, 2019 on amending and supplementing several articles of Decision No. 11/2017/QD-TTg; and Circular No. 05/2019/TT-BCT dated March 11, 2019 amending and supplementing a number of reports of the Minister of Industry and Trade's Circular No. 16/2017/TT-BCT. The principal issues specified in these aforementioned legal documents include the planning and development of solar power projects; electricity selling price of grid-connected and rooftop solar power projects; payment methods, tax issues, and responsibilities of relevant organizations and individuals. The Annexes issued together with the Circular provide contents of the provincial solar power development planning scheme: Sample Purchase Agreement for solar power projects (grid connection and rooftop) [24, 25].

Under these bylaw documents, solar power projects are entitled to the electricity selling price at the electricity delivery point of VND 2086/kWh (equivalent to 9.35 Uscents/kWh, adjusted for fluctuations in the VND/USD exchange rate) [25]. This is a common price (Feed Tariff) for solar power projects and has no distinction among technology types. By comparison with other ASEAN member states, this price in Vietnam was relatively low. For example, in 2015, the government of Thailand applied 12 US cents/kWh for all projects with a term of 25 years. In 2016, the electricity selling price in the Philippines was 17 cents/kWh with a 20-year term and a 0.6% tax reduction rate [20]. Furthermore, the electricity buyer is responsible for purchasing all electricity output from solar power projects with a commercial operation date before June 30, 2019, according to a sample power purchase agreement applied for 20 years. In addition, the promulgation of the Circulars along with the Decisions will transparentize the investment procedures on solar power in Vietnam, add capacity to the electricity system, gradually increase the proportion of renewable energy in the national power system, and reduce dependence on fossil energy sources and greenhouse gas emissions for sustainable development [24, 25].

After Decision 11/2017/QD-TTg expired, the Government of Vietnam continued to issue Decision No. 2023/QD-BCT dated July 5, 2019 approving the promotion program on the development of rooftop solar electricity in Vietnam for the period 2019-2025. Subsequently, Decision No. 13/2020/QD-TTg dated April 6, 2020 on the mechanism encouraging the development of solar power projects in Vietnam officially took effect from May 22, 2020 in order to replace decision No. 11/2017/QD-TTg expired on June 30, 2019. Compared with the previous regulations, Decision 13/2020/QD-TTg made positive changes in economic development. First, Decision No. 13/2020/QD-TTg promotes the opening of the solar energy market more competitively, which no longer limits electricity purchasers to only the Electricity of Vietnam Group (EVN) and its member units [29, 30]. The decision extends to other organizations and individuals who can directly purchase solar electricity from the electricity seller. Second, Decision No. 13/2020/QD-TTg classifies electricity purchase prices from different projects more reasonably with current economic development. Previously, suppose a project has a commercial operation date before June 30, 2019. In that case, the purchase price of solar electricity is 9.35 UScents/kWh (FIT1), equivalent to 2086 VND/ kWh, excluding value-added tax and applied within 20 years, regardless of the type of technology, according to Decision No. 11/2017/QD-TTg. [33, 35]. However, according to Decision 13/2020/QD-TTg, if a project has a commercial operation date in the period from July 1, 2019 to December 31, 2020, there are different purchase prices (FIT2) of electricity on the basis of solar electricity technology, including floating solar electricity (7.69 Uscent/kWh), ground solar electricity (7.09 Uscent/ kWh) and rooftop solar electricity (8.38 Uscent/kWh).

Third, Decision 13/2020/QD-TTg facilitates rooftop solar electricity projects with more detailed regulations. Specifically, the Decision adds a more precise definition of "roof solar power system" with the following characteristics: PV cells installed on the roof of a building with a capacity of not more than 01 MW, which are connected directly or indirectly to the Buyer's electricity grid with a voltage level of 35 kV or less. Furthermore, the Decision provides a separate chapter for the rooftop solar electricity system, including conditions and requirements for the sale of electricity [26].

To date, the expiration of Decision 13/2020/QD-TTg has left investors eagerly anticipating new government policies. Nevertheless, the decision's merits have greatly stimulated investment from individuals and organizations in the solar electricity industry, thereby bolstering Vietnam's economic development. According to a 2020 report by the Vietnam Electricity Group (EVN), over 100000 rooftop solar power systems, totaling almost 9300 MWp, had been connected to the national electricity grid [19]. The significant surge in solar power, particularly in the southern region, has helped alleviate the immense pressure on the electricity sector in recent years. Additionally, the ground solar electricity market has shown positive growth in various provinces, such as Ninh Thuan, where seven projects were completed from January to August 2020. By the end of 2020, it was expected that an additional 12 projects would be completed and operational, bringing the total number of projects in this province to 37 [27].

Current Challenges in the Development of Solar Energy in Vietnam

The rooftop solar system in Vietnam is relatively new, and policies were established during a period of high electricity demand. As a result, the system of legal documents, detailed regulations, and implementation guidelines from related state agencies is difficult to update, especially regarding procedures, technology, safety, environmental protection, and business. There are currently three shortcomings that both investors and the government of Vietnam are concerned about. Firstly, Vietnam has a short time to update and prepare for the urgent development of solar energy. Although research on solar energy in Vietnam is not inferior to other countries in the world in terms of theories and ideas, the country lacks advanced technology and practical experiments. Consequently, many studies on solar energy have been conducted for years but have not been implemented. For instance, module manufacturing technology, operation and maintenance technology, power industry waste treatment technology, and technology to connect solar power to the national grid electricity have not yet been developed and instructed in practice [24]. Secondly, Vietnamese businesses' investment in solar energy is not commensurate with the current potential. Despite Vietnam ranking 7th worldwide in solar power output, only behind the US and China in the number of installed PV cells, the number of businesses in Vietnam selfproducing PV cells is modest. In fact, as of August 2019, only 9 factories are manufacturing PV cells in Vietnam, and only two of which are owned by Vietnamese enterprises. The limited manufacturing products are mainly in the lowpriced segment [26]. Thirdly, the current legal framework of Vietnam on solar energy lacks stability and feasibility for the process of applicability. The latest policy, Decision No. 13/2020/QD-TTg, issued on April 6, 2020, by the Prime Minister, expired at the end of 2020, and until now, the government of Vietnam has not issued any new regulations on the facilitation of solar electricity projects. Policy instability is one of the severe risks that causes investors not to estimate the project's efficiency, payback time, price policy, and expenses for the operation of manufacturing and trading units. Moreover, when Decision No. 13 of the Prime Minister stipulates a fixed purchase price for rooftop solar electricity at 1943 VND/kWh for 20 years, a myriad of solar electricity projects were implemented for pricing advantages. This led to an overloading supply of electricity and difficulties in controlling the quality of imported equipment. When the decision expired, the solar electricity projects slowed down, relevant businesses lost 50-90% of their revenue, and even their employees became jobless. Enterprises failed to build a long-term orientation regarding personnel, technology, finance, pricing, and imported materials.

Policy Recommendations for Effective Governance of Solar Energy in Vietnam

To overcome the above barriers, the government of Vietnam should further introduce long-term regulatory mechanisms to promote the development of solar electricity about technology, investors, and local people [20, 24]. In terms of technology, the solar electricity industry comprises manufacturers of modules, production lines, and key inputs in close cooperation with researchers and technicians. Hence, the government needs to support these subjects by following policies. First, Vietnam should strengthen international cooperation to further improve the efficiency, performance ratio, and durability of solar modules and systems, especially PV cells. Second, research and technology development on the value chain of the solar electricity industry should be facilitated. Third, the government should develop training programs and educate sufficient personnel in the operation of solar electricity systems. Finally, governmental agencies need to guide and issue urgently specific technical standards for solar power installations. With respect to investors, governments should give policies to facilitate the investment of projects and guarantee stability and practicability in the implementation. This includes: i) setting or updating long-term targets for the utilization of solar electricity with key short-term milestones in line with the national energy strategies; ii) developing a stable financial support mechanism in the long term and a plan to organize the implementation of support packages for investors in specific ways; iii) identifying and providing an appropriate level of public funding for each locality in accordance with the cost savings and potential of the technology and the CO_2 reduction objective; and iv) gradually amending policies on the capacity of investors in projects and the reasonable electricity price for users which recovers fixed costs. Eventually, regarding local people, the government should diversify the means of communication to the community about the investment possibilities and the benefits of solar electricity when not many fully understand the role of renewable energy in society. Additionally, the government is necessary to provide supporting mechanisms for the initial installation of solar electricity preferential subsidy programs for households by region. Currently, many countries provide effective policies to support citizens in their approach to the use of solar electricity. For example, the Japanese government supports loans to buy houses using renewable energy with a maximum repayment period of 10 years. For families switching to using solar electricity via PV cells, the government can lend households a maximum amount of up to 5 million yen for installation (nearly 5000 USD).

Conclusions

The study calculated the electric demand of the household, and then conducted the PV cell simulation to find the electrical production in three locations: Ho Chi Minh city, Ha Noi city, and Da Nang city using Ecotect software. Moreover, the study addressed concerns regarding the economy and policy of using solar electricity. The study assumed that the electric demand for the household was 11590 Wh/day, and a 28 m^2 PV cell was utilized. From the simulation, the highest electricity output from the PV cell was observed in Da Nang city, with 5584.7 kWh per year, followed by Ho Chi Minh City, with 5069.8 kWh per year, and Ha Noi city, with 4843.111 kWh per year. On average, this household was estimated to save about 550 USD annually. Through this study, the economic value of using solar energy in electricity production is undeniable. Therefore, the government of Vietnam has realized the potential and importance of renewable energy in recent years. This is proved by the fact that new policies are regularly amended and updated to facilitate the development of solar power plants. Nonetheless, investors and developers are confronted with shortcomings arising from instability and ambiguous governmental strategies regarding electricity prices and potential projects. The government then should be further concerned about these problematic issues and find quick solutions as soon as possible.

Acknowledgments

We appreciate the effort of an anonymous reviewer and the useful comments and suggestions for improving the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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