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The potential for solar energy in Vietnam. A study conducted to determine whether solar energy is still relevant for meeting growing power demand in Vietnam in 2023.

Vy Dan Le*, Tan Tai Le, Surender Rangaraju, Phu Le Vo, Khuong Vinh Nguyen

*Corresponding author: vydan.hf@gmail.com

Abstract—**The significant growth of industrialization in developing countries demand the high amount of energy. In terms of overtaking the negative affect on the environment, the economic sectors aim to find environmentally friendly alternatives. One of the most appropriate alternatives is solar energy which is a renewable source of energy. In order to lower their reliance on fossil fuels and increase their domestic solar energy output, different countries have developed solar energy programs. In Vietnam, solar energy is regarded as possessing a significant potential for producing. Therefore, Vietnam is one of top solar energy producing nations worldwide. However, the barriers and challenges of policies, technology, economic and financial expressly evaluated and taken into consideration for the future growth and sustainability of solar energy in Vietnam. This study is to discuss the need of solar energy, whether it is still remains feasible for the Vietnam's expanding energy demands.**

***Index Terms*—solar energy, renewable energy, potential, demand, Vietnam**

Vy Dan Le, Department of Business Administration, Van Lang University, Ho Chi Minh City, Vietnam, (+84) 913889820, (e-mail: vydan.hf@gmail.com).

Tan Tai Le, Department of Business Administration, Van Lang University, Ho Chi Minh City, Vietnam, (e-mail: tailee1302@gmail.com).

Surender Rangaraju, Faculty of Business Administration, Van Lang University, Ho Chi Minh City, Vietnam, (e-mail: surendher23@outlook.cm).

Phu Le Vo, Faculty of Environment and Natural Resources Ho Chi Minh City University of Technology, Ho Chi Minh City, Vietnam/ Vietnam National University Ho Chi Minh City, Thu Duc District, Ho Chi Minh City, Vietnam, (e-mail: volephu@hcmut.edu.vn).

Khuong Vinh Nguyen, School of Science, Engineering and Technology, RMIT University, Ho Chi Minh City, Vietnam/ Faculty of Electrical Engineering and Computer Science, VSB - Technical University of Ostrava, Czech Republic (e-mail: khuong.nguyenvinh@rmit.edu.vn).

I. INTRODUCTION

Global energy needs are dramatically rising because of significant growth of population and industrialization. For a long time, fossil fuel energy became the most consumption source of energy. However, due to the limit of reserves and unfriendly environmental affects, there is a need for figuring out new kinds of energy which are more sustainable and everlasting. There are many studies on the global reserves of various fossil fuel resources and for various purposes. Overall, it is an unchangeable fact that fossil fuel reserves are unrenewable. Moreover, it is reported that *'The use of lignite and hard coal releases proportionately more CO2 emissions than other fossil energy carriers''*. (Thielemann et al., 2007). Developing nations are currently under pressure to look for energy sources because of their rapid population increase and need for economic development to become economically feasible (Asafu-Adjaye, 2000). In addition to other renewable energy sources, solar energy is a potential and freely available energy source that can be used to address long-term energy crisis difficulties (Kannan & Vakeesan, 2016).

Vietnam is known as an emerging market and a growth developing economy with the average growth was estimated to be around 7.1 percent before Covid-19 pandemic breakdown (World Bank Group, 2023). The energy industry is carried out and remains to play a significant part in this progress. The key fuels covering this rise are coal and oil, whereas the contribution of renewables was minimal. The demand for primary and final energy climbed by almost 5% annually (Riva Sanseverino et al., 2020). In order to ensure national and energy security and green and sustainable growth, Vietnam must navigate a number of opportunities and overcome several obstacles (Dana, 1994; Dana and Dana, 2003). In accordance with Decision 1855/QD-TTg, the Communist of Vietnam Party (CVP) developed the country's national energy development policy with a focus on 2050. Renewable energy sources, in particular, should develop concurrently with other primary energy sources like coal and crude oil. Their respective 2020 and 2050 coverage targets are 5% and 11% of total primary energy consumption (Riva Sanseverino et al., 2020). For this reason, solar energy become one of the most appropriate sources of renewable energy for Vietnam. It is shown that the potential of solar energy in Vietnam is very high thanks to large suitable land areas for solar power and high amount of solar irradiance (Zissler, 2019). However, due to barriers of policies, technology, economic and financial expressly, the efficiency and economical of solar energy production is still considered carefully.

II. LITERATURE REVIEW

A. Solar energy

Solar energy is made by atomic combination that takes put within the sun. It is vital for life and can be gathered for human employment. Photothermal, photovoltaic, and photocatalytic methods all make use of solar energy. Solar energy could be used in a variety of industries by being converted via photo electrochemistry into chemical energy and fuels using artificial photosynthesis and photocatalytic chemical synthesis (Gong et al., 2019). In the 1970s, a finding made an early development in solar energy conversion, which suggests *"water can be decomposed by visible light into oxygen and hydrogen, without the application of any external voltage* (Fujishima & Honda, 1972)". Recently, photocatalytic system (PC) and photo electrocatalytic (PEC) system are the two main methods for performing water splitting reactions directly using solar energy (Gong et al., 2019).

B. Solar panels

Solar panels are also known as solar or photovoltaic modules (PV), work by directly converting solar radiation into electrical energy utilizing the photovoltaic effect of the semiconductor material in the panel (Xu et al., 2018). Solar energy has been widely applied in recent times and solar panels are still on the rise, namely by the end of 2020, the source. Grid-connected solar power has been put into operation up to 9 GW (of which, Ninh Thuan and Binh Thuan provinces are nearly 3.5 GW). The capacity scale of the additional planned solar power projects is over 13 GW.

Sun oriented vitality is any sort of vitality created by the sun. Sun oriented vitality can be saddled specifically or in a roundabout way for human utilize. These sun oriented boards, mounted on a housetop in Germany, gather sun powered vitality and change over it to power.

Figure 2.1. Solar panels in Germany

III. THE POTENTIAL FOR SOLAR ENERGY IN VIETNAM

Vietnam is considered as a country with great potential for solar energy. The map of Vietnam's solar radiation is prepared by three leading Spanish research institutes, CIEMAT, CENER, and IDEA, based on data from 171 hydrometeorological stations in Vietnam that measure the number of hours of sunshine in 30 years, satellite image database for 5 years and data of 12 automatic hydrometeorological measurement stations for 2 years.

Electricity consumption in Vietnam increases by about 10% per year on average, significantly faster than the country's GDP. However, domestic fossil fuel production is not enough to meet demand as well as climate change and Vietnam's dependence on imported energy to operate the electricity system is the driving force behind the government, redirect the development of renewable energy, especially solar energy. Vietnam is one of the countries with the most sunlight on the world solar radiation map. The number of sunshine hours per year in Vietnam is quite large.

Region	***Sunshine hour of the year***	***Solar radiation (kw2/m^2 per day)***	***Applicability***
Northeast	1600 – 1750	3,3 – 4,1	Medium
Northwest	1750 – 1800	4,1 – 4,9	Medium
North Central	1700 – 2000	4,6 – 5,2	Good
South Central and Central Highlands	2000 – 2600	4,9 – 5,7	Very good
Southern Vietnam	2200 – 2500	4,3 – 4,9	Very good
National Average	1700 – 2500	4,6	Good

Figure 3.1. Amount of solar radiation in regions of Vietnam (Năng lượng Việt Nam Online, 2020).

According to the radiation map developed by the World Bank (WB), the potential of solar energy in Vietnam is theoretically huge. Solar radiation intensity ranges from 897 to 2108 kWh/m2/year, equivalent to 2.46 and 5.77 kWh/m2/day (MOIT & AECID, 2015). The highest radiation intensity is concentrated in the Central Highlands and Southern provinces such as Dak Lak, Gia Lai, Nha Trang, Ninh Thuan, Binh Thuan, Tay Ninh and Binh Phuoc.

By the end of 2020, 16,700 MW of solar power capacity (including rooftop solar power) has been connected to the national power system (accounting for 24% of the whole system's capacity). It is expected that by 2023, it will continue to increase.

According to the Draft Power Plan VIII (SE Solar, 2022), it is expected that the installed capacity of solar power will increase from 17 GW (in the period 2020-2025) to about 20 GW (in 2030). The proportion of solar power is expected to account for 17% (in 2025), 14% (in 2030) in the structure of power sources. Ember et al. (2022) believed that encountering problems is inevitable and the problems that solar panel manufacturers in particular and the electricity industry in general are:

+ ***Policy issue***

The biggest barrier in the policy is the lack of a national plan on solar power. Currently, Vietnam only has a solar power development plan at the provincial level. Especially concentrated in some potential provinces and cities. This limitation has reduced investor confidence and negatively impacted the orientation of connecting solar power projects to the national power system in the short term as well as the ability to develop sustainably and synchronously across the country. country in the long run.

+ ***Technology problem***

The current electricity infrastructure has not been developed commensurate with the potential of solar power. The explosion of solar power in 2019 has put great pressure on existing infrastructure, requiring the need to consolidate and establish new connections to the grid in a short time. This is also the reason why EVN's electricity purchase and sale policy has stopped since the end of 2020. Changes in policies on taxes, fees, prices, planning, and development plans for investors are confused when investing. solar installation.

+ ***Economic and financial problems***

Because the electricity purchase and sale policy has stopped, in this section we will only discuss the economic and financial issues for rooftop solar power projects. The biggest problem is the responsibility to share risks between the parties. A solar power system has a very long life, up to 30 years or more if maintained regularly and used properly. Therefore, during the period of use, if an incident occurs but the installation unit is no longer operating, the investor will face many difficulties in warranty. This is also the cause that seriously affects the experience of using solar power.

IV. SKY-HIGH DEMAND FOR SOLAR ENERGY FROM CITIZENS AND BUSINESSES IN VIETNAM

Solar has quickly emerged as a cheap, reliable and clean source of electricity for Vietnamese citizens. With incomes rising and the Vietnamese economy growing, many businesses and households can now afford to install rooftop solar. Public support was also buoyed by concerns over air pollution – an issue that is expected to kill 650,000 ASEAN citizens every year by 2040 if the region pursues fossil fuel dependency. The localised health benefits associated with clean electricity generation, combined with the generous FITs and tax breaks, have led businesses and residents to install solar modules anywhere they can.

By the end of 2020, when the second round of the FIT closed, there were over 101,000 rooftop solar systems installed across resident, commercial, and industrial buildings throughout Viet Nam. This is a massive 25-fold increase on installed capacity the year before. While the roll out of solar – both utility and rooftop – has defied expectations, there are still issues to overcome. Financing options for lower income groups have not materialised, creating a gulf in access to clean and reliable energy. However, a variety of Fairtrade accredited businesses across Vietnam have formed clean energy cooperatives to help build capacity and increase deployment. Solar cooperatives have also popped up to increase electrification in rural Vietnamese communities. What's more, with the demand for rooftop solar systems growing, there are concerns that the current supply chain may falter, driving delays and pushing targets further out of reach.

Instead of silicon crystalline panels that are routinely used, thin film solar panels are used as their energy yield is higher than silicon Making a marked departure from the conventional system, a Chennai-based company provides a comprehensive system that ensures that a 2 kW solar panel can power a 1.5 tonne air conditioner, one 300 litre refrigerator, five fans, five LED tube lights (4 feet in length and 16 watts each) and eight LED bulbs (6 watts each) during the day.

The current collected by solar panels then feeds into a charge controller, which controls how much current goes to a battery. Charge controllers prevent batteries from being overcharged. They also have the ability to shut down a system if the energy stored dips below 50%. Batteries store and produce DC power. In order to use AC appliances, such as microwaves, laptops, and phone chargers, an inverter is used to change the power from DC into AC power. In a home, solar panels are connected to a grid inverter, which is then connected to the existing electrical network in your house. In an RV, van, or boat, you can choose from a range of different inverters based on your specific energy needs.

The average refrigerator takes about three or four average solar panels to run. The average refrigerator found in the United States uses approximately 57 kWh per month while the average freezer uses 58 kWh. Adding those together brings a combined total of 115 kWh.

V. VIETNAM'S RAPID RISE TO BECOME A SOLAR POWERED STATE

Over the past ten years, Viet Nam has been able to scale up solar power quickly due to a number of variables, including supporting government action, a favorable policy climate, and international cooperation. An increasing demand from Vietnamese citizens and enterprises for affordable, secure, and clean energy necessitated targeted investment in crucial infrastructure. The groundwork has been laid for Vietnam to maintain its strong solar growth and move up the global rankings.

Solar energy production keeps growing on a global scale. According to Do et al. (2021), after 143 TWh of extra solar capacity were added to the global energy mix in 2021, solar's contribution to global generation for the first time ever exceeded 1,000 TWh, or 3.7 percent, for the first time in history. Given that solar energy is, in the words of the International Energy Agency (IEA), "the cheapest electricity in history," the proliferation of this technology is not surprising. As output increases and technologies advance, costs are falling quickly. According to the Intergovernmental Panel on Climate Change (IPCC), the cost of solar electricity has decreased by 85% over the past ten years.

Solar is likely to be the most widely used new energy generating technology at prices like this. Solar was the most added technology in 53 of the 112 countries that Bloomberg NEF polled for its 2021 annual report, up from just 14 percent in 2012. By 2027, the IEA projects that solar energy will overtake coal as the primary source of electricity generation worldwide. By 2030, BloombergNEF projects a more than 150 percent increase in yearly solar PV demand.

With Russia's invasion of Ukraine 'turbo-charging' investments in clean energy as nations around the world start

to recognise the geopolitical dangers that emerge from a dependent on fossil fuels, solar demand is expected to climb by between 20 and 30 percent in 2023. The golden times for solar energy may, however, temporarily come to an end due to supply chain constraints and inflationary pressures along the value chain, which may prevent further cost reductions. The primary cause of this supply chain crisis is polysilicon, a pure form of silicon required for the production of ingots that are then cut into wafers to produce solar cells and modules. However, in response to this, global production is expected to expand up quickly: 900GW of polysilicon capacity has been announced, for example.

The robustness and sustainability of the supply chain as well as the lifecycle of solar production projects are being focused on appropriately as the deployment of solar technology grows. Large quantities of heavy metals and caustic chemicals are needed to manufacture solar panels, which can have a variety of negative environmental effects on the surrounding area and the workers who use them. Solar panels typically last 30 years and must be recycled in order to be sustainable. If facilities for recycling and reusing solar panels are not expanded, there may be 60 million tonnes of solar panel trash in landfills by 2050, releasing harmful chemicals into the soil and groundwater. Fortunately, several businesses and concerned governments are working to find a solution to this issue, including some achieving a material reuse rate of up to 95 percent.

The rise of Vietnam into the top 10 solar power producers worldwide must be seen in the larger Asian regional context. The Asian continent is currently undergoing a rapid shift to renewable energy, with five Asian governments currently ranking among the top 10 solar-powered nations worldwide. Only two Asian countries made the top ten just ten years ago, and Europe dominated the market. However, the top 10 countries now include China, Japan, South Korea, India, Vietnam, and South Korea. In Asia, there are also no signs of solar activity slowing. Up until 2030, solar capacity is anticipated to increase in China, India, the Philippines, Japan, and Indonesia at a pace of 22% annually.

Asia's quick switch to renewable energy is crucial for the fight against global warming. Even though it has made enormous strides in the production of clean energy, Asia still ranks among the top emitting regions, with about half of the world's energy consumption currently coming from this region. Additionally, Asia is experiencing the fastest growth in global electricity demand. The world's demand for electricity increased by 31.8% between 2010 and 2021. However, Asian countries reported far bigger increases in demand for energy during the same time period: China's demand increased by 102%, India's by 82%), and Indonesia's by 75%.

The country with the largest rise in electricity demand, though, was Viet Nam, which saw a 125 percent increase.

As net energy importers, Viet Nam and many other Asian countries have paid a high price for the recent instability in the markets for energy commodities and the ensuing price increases. The risk that comes with being open to international markets has sparked efforts to switch to domestic renewable energy sources. But it will take global cooperation to make sure that this energy demand is satiated through renewable generation. This could take the kind of the recently finalized Just Energy Transition Partnership (JET-P) agreement between Viet Nam and the "International Partners Group" (IPG), which consists of the EU, UK, US, Japan, Germany, France, Italy, Canada, Denmark, and Norway.

Over the next three to five years, $15.5 billion will be raised for the collaboration, with funds from both the public and private sectors in the form of grants, low-interest loans, and investments. However, there are worries that this arrangement lacks transparency and civil society engagement, two crucial components for a just and quick transition, as mentioned by Global Witness. This is crucial in Vietnam, where advocates for land rights and climate justice continue to face arrests, including lawyers and climate campaigners.

VI. Conclusion

It can be seen that solar power in Vietnam has initially developed but lacks sustainability to ensure the sustainable development of solar power and harmony with other energy sources. In addition to calculating and approving the total installed and generating capacity in line with the goals of each period, more comprehensive policies need to be developed, especially the price mechanism for solar power. Continuously updating the solar power policy will remove difficulties that slow down the development of solar power and respond to unexpected situations in the future.

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