Extended Analysis for Self-Consumption Solar Rooftop in a Manufacturing Factory

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Abstract

This study presents a financial analysis of a rooftop solar project for industry and considers other benefits including carbon trading possibilities. It suggests exchanging renewable energy certificates that could both bring additional values to the project and be supporting the energy transition process of Vietnam. This research utilizes a financial calculation tool named Rooftop Solar Toolkit for Industrial Energy Users by CEIA in cooperation with Apparel Impact Institute (AII) and Sustainable Trade Initiative (IDH). CEIA Toolkit is used to evaluate solar power installation projects, helping users compare different investment options and which option is the most profitable to the investors. As a finding, installing rooftop solar power, regardless of investment option, brings more financial benefit to the company than buying electricity from the national grid. Using 70% of loan is the best option in terms of NPV. Emission reduction can be up to 155 tCO2/year during the system's lifetime. In addition, applying for the Renewable Energy Certificates or joining the carbon trading market further increase the profits for the project investors, not to mention other values such as increasing company's social responsibility and branding.

Keywords: net zero, solar rooftop, CEIA, REC, carbon market

1. INTRODUCTION

Vietnam is a developing country which is in the process of industrialization and modernization. Vietnam has experienced significant economic growth and development over the past few decades, with a focus on industry, trade, and foreign investment. Demand for electricity keep increasing year by year. However, according to the Resolution No. 55 of the Politburo [2020], the energy sector has faced several challenges and limitations that hinder the goal of assuring national energy security. Domestic supply does not meet the energy demand, leading to increasing energy import. Limited management and extraction of energy resources capacity, low energy efficiency, incomplete energy infrastructure, slowly improved technology qualification, human resource quality, incomprehensive competitive energy market or energy price policies are among other key concerns.

Regarding energy source management, hydropower potential has been utilized to its potential. Large hydropower projects with favourable locations and low investment costs are almost fully exploited, with the capacity of over 100MW [EVN, Overview of hydropower in Vietnam 2019]. Some are only able to expand their scales or to include pumped storage hydropower plants to match the power structure in the national power system. Regarding coal-fired thermal power, the amount of coal exploited domestically is not enough to meet coal-fired power plants, resulting in using imported coal for most of coal-fired power plants put into operation in the period from 2020 onwards. Viet Nam was the second-largest coal-consuming economy in the Asia-Pacific region in 2021, after Indonesia. The coal consumption, with approximately 70% of which is for power, increased three-fold to meet the high coal demand for coal power and industry sectors over the 2011-2021 period. According to the eight edition of the national Power Development Plan, coal-fired power plant capacity increases gradually to 37,4 GW by 2030, which is much lower than in the seventh-revised Power Development Plan due to net zero commitments. Vietnam also expects no longer coal project financing from Korea, Japan, and China [APERC 2023]. For oil and gas thermal power, the gas supply has not met the demand for electricity production, while the oil output in mobilized electricity production is quite low. Therefore, renewable energy with decreasing cost overtime, is one suitable option for developing power system to meet the requirements of the sustainable economic development.

Vietnam has potential strengths to develop wind and solar power. Solar power is an easy-to-install renewable energy source that can be flexibly used on different scales from households to medium-scale production and business, and also

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utility scale such as multi-megawatt solar power plants. Government issued Decision No. 11/2017/QD-TTg on the mechanism to encourage the development of solar power projects in Vietnam created a strong development of solar power in Vietnam. Decision 500/QD-TTg dated May 15, 2023 of the Prime Minister approving the national electricity development plan for the period of 2021 - 2030, with a vision to 2050 (usually referred to as PDP8) targets to reach the share of about 30.9 - 39.2% by 2030 for renewable energy, up to 67.5 - 71.5% in 2050. Therefore, the government has chosen to switch to this cleaner source of energy.

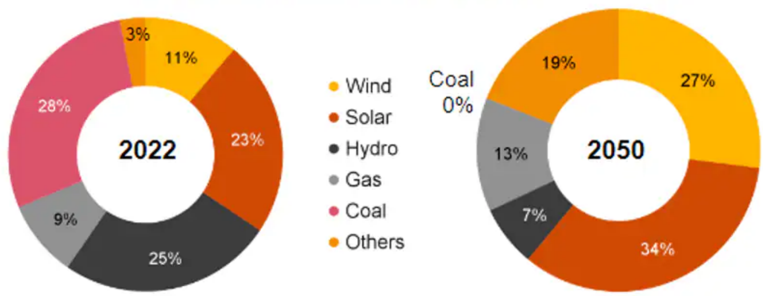

Figure 1 Share of installed capacity in Vietnam power system 2050 vs. 2022 in PDP 8. Source: PWC [2023]

Decision No. 11/2017/QD-TTg, followed by No. 13/2020/QD-TTg, had a significant impact on the development of solar power projects in Vietnam. They introduced a set of guidelines and policies to promote solar power development that helped boosting from almost nothing in 2017-2018 to roughly 21,000 MW in 2021 [EVN 2022]. For the next decade, in order to balance with the pace of power grid development, rooftop solar is going to lead the development of renewable energy as it was clearly stated in PDP 8 as to "have 50% of office buildings and 50% of residential houses by 2030 using rooftop solar power". The target is specifically for self-consumption, not selling electricity into the national electricity system. Rooftop solar can contribute to reducing the burden on the transmission grid and land-use planning, playing a key role in achieving Vietnam's COP26 commitments of net zero.

The potential for solar PV in the industrial, commercial, and residential sectors in Vietnam has been widely studied. While large and dense cities in countries like Vietnam have limited vacant ground for the development of solar power plants, they do have thousands of large buildings with rooftops (of more than 500 square meters) that are suitable for the installation of industrial-scale solar PV systems in addition to hundreds of thousands of residential buildings that, put together, can receive a huge quantity of solar panels [WB 2018].

Table 1 Estimated Solar rooftop PV capacity of Vietnam. Source: The World Bank [2018]

Large rooftops – high built-up density	14 887 MW
Large rooftops – medium built-up density	1 059 MW
Small rooftops – high built-up density	97 496 MW
Small rooftops – medium built-up density	151 517 MW
Small rooftops – low built-up density	105 871 MW
Total	**370 829 MW**

According to the World Bank's monitoring, built-up areas in Vietnam offer a huge potential for producing PV electric energy from its rooftops. After PDP8 issued in May 2023, the ministry of Industry and Trade (MOIT) has submitted a mechanism to the Prime Minister for consideration and approval the incentives for rooftop solar power applied to rooftop solar power installed in residential, commercial, and corporate buildings for self-consumption without selling electricity to other organisations or individuals. This proposal on one hand, fails promote the region with higher irradiation potential; and on the other hand, exclude rooves of manufacturing sectors for the reason of not putting too much impact on the operation of the power system. It is also commented that incentives were not attractive enough to encourage massive investment in the field, reported by a news agency [2023].

The attractiveness of a solar project, not any more underlies the Fit-in-Tariff commitment, is that the owners of renewable energy sources can buy and sell carbon credits or renewable energy certificates for profit. The market for buying and selling carbon credits, or renewable energy certificates is of national interest and should be promoted. Although this mechanism has not yet been implemented in practice, it is under the market planning. This study intends to take a financial analysis of a rooftop project for industry and considering other benefits including carbon trading possibilities. It provides information about exchanging renewable energy certificates in this potential market that could be supporting the energy transition process of Vietnam. Besides, the results hopefully could encourage the self-production and self-use of solar power by providing a full incentive for businesses to shift their energy using habits.

2. LITERATURE REVIEW

Rooftop solar PV system means a solar PV system with photovoltaic panels mounted on the rooftop of construction works with an output not exceeding 1 MWp, directly or indirectly connected to the Electricity Buyer’s grid with a voltage of 35kV or less [GOVVN 2020]. Rooftop solar systems must have solar cell efficiency of more than 16% or module efficiency of more than 15%. The rooftop system must be installed on a building. The relevant regulations require that the rooftop system must be installed on the rooftop of “construction works”. This suggests that an installation on the ground is not possible. Ground-mounted solar projects underlie an entirely different legal and administrative framework. [GIZ 2021].

Solar power has grown at fast speed, with installed capacity many times higher than before. By the end of 2019, solar power (including rooftop) has only reached about 4.7GW, but by the end of 2020, it is estimated that solar power nationwide is about 16.7 GW [EHCMC 2022]. Rooftop solar power has increased dramatically with a total installed capacity of 9,730 MWp at the end of December 2020, increased more than 25-fold from 378 MWp at the end of 2019. It is estimated at 105,000 solar systems throughout the nation by 2020 [UNICEF 2022].

Similar studies on solar power feasibility are available. J. Peng and L. Lu [2013] investigated on the development potential of rooftop PV system in Hong Kong and its environmental benefits and found out that 5.97 GWp potential installation capacity of rooftop PV systems may account for 14.2% of the total electricity used in Hong Kong in 2011 and avoid about 3,7 Mt of greenhouse gas emissions yearly. Carbon credits benefits are considered, and installation cost can be further reduced. Setyawati [2020] analysed of perceptions towards the rooftop photovoltaic solar system policy in Indonesia using an online survey of almost a thousand customers of the State Electricity Company (PLN). The paper revealed that, at a country with roughly similar conditions as Vietnam, the installation of PV systems is constrained by both consumer (high capital cost, long term return on investment and lack of information) and institutional barriers (the limited role of PLN and the absence of government financing mechanisms). The export rate for electricity injected into the grid as the main barrier to attracting prospective users.

Zander et al [2019] studied the preferences for and potential impacts of financial incentives to install residential rooftop solar photovoltaic systems in Australia. They have proved that financial incentives for people are important factors to motivate them to switch to rooftop solar. Factors likely to influence included their level of electricity consumption, rising electricity prices and decreasing costs for storage systems. PV systems pay off even without government subsidies in Australia. Income, education, knowledge about Australia's renewable energy polices and believing in environmental benefits of solar energy all positively influenced the willingness to install a photovoltaic system.

The research on reviewing of potential and actual penetration of solar power in Vietnam [2020] has pointed out barriers and challenges of Vietnam in solar power development including institutional issues such as unsustainable FIT prices. Besides, the retail electricity price in Vietnam is quite low in comparison with the international price, which could be a disincentive for investments in energy sector. In comparing the investment in rooftop solar power systems connected to the grid verses compound interest bank deposits, Nguyen Duc Tuyen et al [2020] has provided a way to select the specifications of solar cells suitable for households as well as a formula for calculating the profit gained from saving on electricity bills. This was obtained from self-consumption and selling excess solar power to the national grid so that households can flexibly decide whether to invest in solar power or not. Based on PVsyst, with the same amount of roughly USD 12,000, depositing in a bank in 25 years can receive six times, while investing in a rooftop solar power system can return 10 times more than the investment.

The German Development Cooperation Organization [GIZ 2021] published a thorough guidelines for investment in rooftop solar power systems in Vietnam. It provides accurate and comprehensive information on technical and administrative issues related to the development and investment of rooftop solar power systems in commercial buildings or industrial facilities. The development process includes eight stages: feasibility, overview of contracting, financing, permits and licenses, procurement – construction and installation, commissioning and grid connection, operation and maintenance, and finally decommissioning. This paper will take a lot of advice from GIZ’s publication on basic technical issues of setting up the rooftop project.

3. METHODOLOGY AND BASIC ASSUMPTIONS

This research utilizes a financial calculation tool named Rooftop Solar Toolkit for Industrial Energy Users by CEIA program in cooperation with Apparel Impact Institute (AII) and Sustainable Trade Initiative (IDH). CEIA is jointly led by Allotrope Partners, World Resources Institute (WRI), and the National Renewable Energy Laboratory (NREL). Rooftop Solar Toolkit for Industrial Energy Users from now on is referred to as CIEA Toolkit. According to CIEA, these tools, guides, and templates were developed to support industrial energy users throughout the clean energy procurement process and have a specific focus on Vietnam but can be replicated and customized to support energy users across a range of geographies. The tool provides users with a project's preliminary, high-level financial analysis, to help a facility owner determine whether to explore procuring installation of onsite PV generation.

In this research, CEIA Toolkit is used to evaluate solar power installation projects, helping users compare different investment options and which option is the most profitable to the investors. Besides, the study also approaches other beneficial aspects, especially environmental and social aspects, when installing solar rooftop power at a manufacturing facility to encourage industry to switch to using renewable energy sources. A greenhouse gas (GHG) inventory is to be calculated.

We take an example of a cigarette production factory in northern Vietnam for initial assumptions. Most of input energy currently is electricity from the national grid. The total roof area is 30,000 m^2, with areas are not shadowed by any high rise and the roof structural frame system is robust. Therefore, efficient irradiation receiver can be up to 60-70% of the existing roof area of as large as 21,000 m^2. In the North, the irradiation is not as abundant as in the South Vietnam, but it is within the profitable level for solar yield in the world (Figure 2).

However, as a pilot, the factory chooses to install on the rooves of the office and garage first to see whether installing rooftop solar power will bring more benefits than buying electricity from the grid. We propose a 20-year project of rooftop solar for such area (approximately 2,000 m^2), mostly self-consumption, without storage batteries.

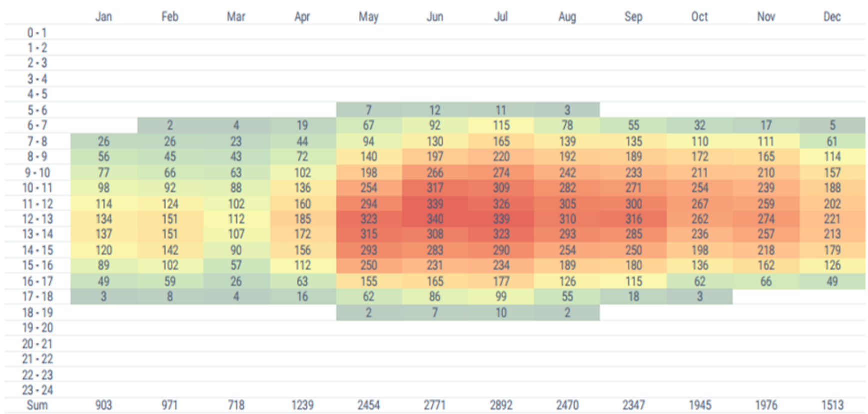

Figure 2 Direct normal irradiation (wh/m2) of the site area, under Global Solar Atlas

Current power voltage that the factory use is 0.38kV, then the cost of purchasing electricity from EVN of the factory is regulated as in the below table. Assume that tariff might increase 3.6% per year [Brown , Vu 2020]. Income tax for solar investor is set at 10% per year.

Table 2 Retail electricity tariff for manufacturing industries. Source: EVN

Voltage of below 6kV	Tariff in VND
a) Standard hour	1,738
b) Off-peak hour	1,133
c) Peak hour	3,171

Electricity consumption of the factory can be summarised as in Table 3.

Table 3 Electricity Consumption of the site in kwh/year

Standard hour	(Mon-Sat) 4am - 9:30am, 11:30am - 5pm, 8pm - 10pm (Sunday) 4am - 10pm	2,068,673
Off-Peak hour	(Mon-Sun) 10pm - 4am	275,757
Peak hour	(Mon-Sat) 9:30am -11:30am, 5pm - 8pm	714,625
Total Electricity Consumption		3,059,055

4. RESULTS AND DISCUSSION

4.1 Financial analysis

Site assessments were made under the guidelines of GIZ. Regarding roof conditions, the roof's inclination angle is lower than 30° and the roof does face south with good orientation. The roof is three years old, have enough space to accommodate a rooftop system. The building's architecture and material can bear an additional weight of about 20 kg/m^2. The roof is not exposed to shade from significant neighbouring buildings, trees, or other structures. Electricity consumption is about 9,000 kwh/day, taking place mainly during daytime from 8am to 16pm. Working time is during sunshine hours, therefore using solar panel can sufficiently help saving the electricity bills.

With certain technical assumptions, the CEIA suggests the optimized system for the site as follows.

Table 4 Rooftop and PV system specifics

Major City Nearest to Location of the roof (° latitude)	Hanoi (20° N)
PV capacity to be installed on the roof	200 kWp
PV electricity exported to grid (in Net Billing)	100.00% % of consumable PV
PV output degradation (from panel aging)	0.50%/year
PV system total output in year 1	214,540 kWh/year

Table 5 CAPEX and OPEX in VND

Unit PV cost	14,100,000 VND/kWp
Total PV cost	2,820,000,000
Insurance cost	0.25% of total CAPEX/year
O&M	117,500 VND/kWp/year
Debt	70.00%
Equity	30.00%
Term	10 years
Amount of debt	1,974,000,000
Amount of equity	846,000,000
Price discount from EVN tariff	7.00%
PPA net billing revenue retained	0.00%

With the assumption of constant consumption (Table 3) and the retail price of electricity from 2021-2040 would increase at the rate of 3.6% per year, we got the results of electricity costs during the time frames, before installing a rooftop solar system. The factory must pay as much as 8.8 billion VND for average annual electricity expense to EVN. This amount may accumulate to 176 billion VND by 2040.

With 200 kWp rooftop system installed on the roof, the power output for the first year will be 214,540 kWh. Taking 0.5% degradation due to panel aging into account, the power output of the following year is calculated as:

PV system total output in year i+1 = PV system total output in year i x (1 – degradation rate)

CEIA Toolkit defaults 25% for peak hour and the rest is for normal hour. Then the project financial indicators are shown in the table below.

Table 6 Two scenarios of solar rooftop installation: with and without a loan

		VND	USD
Self-purchase	**Total Upfront Cost**	-2,820,000,000	-120,000

	Project IRR	15.4%	15.4%
	Average annual PV savings (expense)	422,799,125	17,991
	Total PV savings (expense)	8,455,982,509	359,829
	NPV	1,298,428,692	55,252
	Project payback period (years)	6.61	6.61
	LCOE - Levelized Cost of Energy (per kWh)	1,659	0.071
Self-purchase with loan	**Total Upfront Cost**	-846,000,000	-36,000
	Equity IRR	21.8%	21.8%
	Average annual PV savings (expense)	332,344,227	14,142
	Total PV savings (expense)	6,646,884,541	282,846
	NPV	1,447,756,421	61,607
	Project payback period (years)	6.42	6.42

In either case (with or without loan), NPV is more than 1.2 billion VND, and the pay-back period is less than 7 years. Another scenario is also suggested by the toolkit, although supporting policy (Direct Power Purchase Agreement) is not yet fully institutionalized in Vietnam. If paying no initial cost and buying electricity from a third party who could possibly offer a 7% discount from EVN tariff, annual savings for operational expenditure are about 42.6 million VND (1,815 USD equivalent), which can add up to 334 million VND as a net present value.

4.1 Other benefit analysis

According to EPA (the United States Environmental Protection Agency) a renewable energy certificate (REC), is a market-based instrument that represents the property rights to the environmental, social, and other non-power attributes of renewable electricity generation. RECs are issued when one megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable energy resource. How they work can be found here[1,2]. RECs can be used for both voluntary (stakeholders choose to consume clean power) and compliance (government requirement) purposes, similar to carbon credit mechanism. While carbon credits account upon the reduction, avoidance, or sequestration of one metric ton of CO_2, REC is measured by the production of 1MWh of renewable electricity. The REC issuer in Vietnam has been the Green Certificate Company (GCC) as a central issuer. In recent days, big renewable energy players like Greenyellow offer supporting the owning of international REC. GCC does not require registration application fee. Initial facility registration fee (5-year validity) for capacity less than 250kW is EUR 100, but with approved method of digital meter reading access it would become zero. Registration or renewals of device groups submitted after 1 September 2023 are no longer supported and may be submitted as individual registrations based on capacity. Renewal fee for additional five-year validity is 40% of the registration fee, equivalent to EUR 40, or none regarding the latter case. Issuance fee for self-consumption (this case) is EUR 0.035 per MWh. Assuming that the project is eligible to get a free registration fee, then the only cost for REC is issuance fee multiplied by 214.54 (Table 4) for the first year, which is very minor, while for each REC it costs about one US dollar, considering discount rate of 4% till 2040.

Regarding emission, as the factory uses mainly electricity, its greenhouse gases emission comes from indirect emission sources, depending on the national grid. The country's power grid is made up of many types of sources such as thermal (coal, oil, gas), hydropower, nuclear power and other types of renewable energy such as wind and solar and this changes through time during energy transition process. These types of electricity emit different amounts of GHG, therefore we base our calculation upon the rough emission factor of the power system as a whole. The lower emission coefficient is, the cleaner it is assumed to be. According to the Department of Climate Change, Ministry of Natural Resources and Environment (1278/BĐKH-TTBVTOD), 2021 emission factor of the power system is 0.7221 kgCO2/kWh. As a result, GHG emissions of the factory is roughly two to three MtCO_2/year. After installing the rooftop system, emission reduction can be up to 155 tCO_2/year during its lifetime.

Once the carbon market is well developed, GHG emissions reduction will soon be exchanged to monetary value to bring more profit for the company. This encourages them to expand the installation of rooftop solar power since the available space is currently 19,000 m^2. After filling with rooftop solar panels, the amount of GHGs reduction can be ten-fold as tentatively estimated above.

1 https://www.epa.gov/green-power-markets/renewable-energy-certificates-recs
2 https://www.irecstandard.org/fee-structure-for-market-players/

5. CONCLUSION

Although northern Vietnam is not the area with the highest solar radiation intensity in the country, it is the area with the highest growth rate in electricity consumption. Self-consuming rooftop solar power is not only cleaner, but also can help avoiding the risk of power shortage.

It can be clearly seen that installing rooftop solar power, regardless of investment option, brings more financial benefit to the company than buying electricity from the national grid as they are doing now. They can choose among three investment plans, of which would return the highest benefits. In addition, applying for the Renewable Energy Certificates or joining the carbon trading market further increase the profits for the project investors, not to mention other values such as increasing company's social responsibility and branding.

Climate change and GHG reduction is of concern in the whole world. At the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26), Vietnam committed to net zero emissions by 2050. The government issued Decree No. 06/2022/ND-CP on reducing GHG emissions and protecting the ozone layer afterwards, which enables the carbon market in Vietnam officially from year 2028. Supporting policies should be clear and detailed for motivate the self-consumption of solar power as described in the research.

6. ACKNOWLEDGMENTS

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