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Solar PV Rooftop Investment Opportunities in Vietnam

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List of Abbreviations

AHK-GIC	Auslandshandelskammer/Delegate of German Industry and Commerce in Vietnam
BAU	Business-as-Usual
DCF	Discounted Cash Flow (Model)
DSCR	Debt Service Coverage Ratio
ECC	Energy Conservation Center
ERAV	Electricity Regulatory Authority of Vietnam
EuroCham	European Chamber of Commerce in Vietnam
EDS	Electrical Distribution System
EVN	Electricity of Vietnam
EVN-CPC	EVN Central Power Corporation
FIT	Feed-in Tariff
GBA	German Business Association in Vietnam
GDE	General Directorate of Energy (of the MoIT)
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWp	Gigawatt Peak
HCMC	Ho Chi Minh City
INDC	Intended Nationally Determined Contribution
IoE	Institute of Energy
kWp	Kilowatt Peak
LCOE	Levelised Costs of Electricity
MoIT	Ministry of Industry and Trade
MWp	Megawatt Peak
PDP	Power Development Plan
SPPA	Standard Power Purchase Agreement
PV	Photovoltaic
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VCCI	Vietnam Chamber of Commerce and Industry
WB	World Bank Group

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Executive Summary

Previous analysis of the Vietnamese solar energy sector has revealed that **commercial and industrial solar PV rooftop applications have great development potentials** and **promise interesting investment opportunities for the private sector.**

Deploying this substantial potential of solar energy at production sites would **help manufacturing industries in Vietnam improve the reliability of power supply** and **reduce the burden on national power demand**. This would also help the commercial and industrial sector **reduce their significant expenses on electricity consumption** due to high tariffs during peak hours and cross-subsidization policy from large consumers to smaller ones. On the other hand, developing solar PV in the Vietnamese commercial and industrial sector would **significantly contribute to the countries' Green Growth strategy** and related efforts to reduce GHG-emissions in particular.

The **main objective** of the present assessment is to **identify and demonstrate the potential for solar PV rooftop applications in the commercial and industrial sector of Vietnam** and hence to **reveal business opportunities for German solar companies** in Vietnam. The **focus geography** of the project is industrial zones and private factories/commercial operations located in **Central and Southern Vietnam** with the highest solar energy potential.

The core of the analysis is defined by **six case studies with the character of pre-feasibility studies**. In general, two different business models were applied in the calculations of costs & benefits: **1. Self-consumption and 2. Net metering.**

Potentials for Solar PV in Vietnam

- Vietnam has **expansive solar resources**. Current scientific estimates state an **average of 4-5 kWh/m^2/day** in most regions of Southern, Central and partially even Northern Vietnam (totalling 1,460-1,825 kWh/m^2/year) and average peak irradiation levels of up to 5.5 kWh/m^2/day in some Southern regions (totalling up to 2,000 kWh/m^2/year). These solar irradiation levels are **comparable to most countries in the region**, including developed solar markets such as China, Thailand or the Philippines, as well as **to mature international solar markets, such as Spain and Italy**.

- The **long-term potentials for residential and commercial PV applications** are estimated to reach to **at least 2-5 GWp** within the next decade. Estimates for **suitable areas for ground-mounted PV capacities** reach an overall potential of **22 GW** for the southern regions of Vietnam. However, these estimates are only preliminary and more detailed research has to be done.

- **Market potentials for PV investments in the commercial and industrial sector are vast**. All economic indicators show that the Vietnamese economy will most likely continue to grow at a rate of 5-6% per year and foreign direct investments (FDI) increase likewise. Vietnam's high level of regional and international economic integration is widely seen as a guarantor for further economic growth and the development of the Vietnamese commercial and industrial sector in particular.

Legal Framework Conditions for PV Investments

- Vietnam's reform agenda already includes energy market reform, fossil fuel fiscal policy reform and a transition to green growth. The **newly revised Power Development Plan (PDP7)** includes **ambitious development targets for renewable energies** in general and for solar energy in particular. In the next 15 years until 2030 the share of installed renewable energy capacity in Vietnam is supposed to increase from 5.4% to 21% (2020: 9.9%). At implementation level, progress is slower, however.

- The **solar PV capacity shall increase** from currently around 6-7 MW by the end of 2015 **to 850 MW by 2020**, **4,000 MW by 2025** and **12,000 GW by 2030**. Regarding the potentials of the country these targets may seem to be conservative. But **regarding the current state of the solar market** and the pace of development in the past years, these numbers **appear to be very ambitious**.

- In **May 2015** the General Directorate of Energy (GDE) of the MoIT **drafted the first version of a PV support law (**"Legislation on the support mechanism for the development of solar power projects in Vietnam"). The draft **included a net metering scheme** with a remuneration (net metering credit) of 3,150VND/kWh or **15USDct/kWh** that would be paid in VND and be adjusted to currency exchange rate development.

- The net metering scheme, as far as outlined in this first draft, would thus have the **character of a 'net billing' system** with a predetermined credit (not developing in line with the individual power tariff of the system operator) for excess solar power to be sold to the grid/to EVN (or to EVN's local power utility companies). It can thus be assumed that only excess power after self-consumption would be remunerated with the net metering credit.

- However, the **draft was amended two times since its first publication and finally rejected by the Prime Minister in June 2016 as being not sufficiently studied and designed.** A new process of reviewing this draft among the relevant government institutions is supposed to start in the second half of 2016. A resubmission of a revised draft can be expected for end of 2016 or early 2017. In addition to the PV support law, some accompanying **implementation guidelines** and more **detailed technical regulation** is expected to be issued at the time or even after the final PV support law will be issued. In the course of this assessment for those cases with substantial excess solar power generation a net metering business model will be calculated based on the first draft legislation.

Current Market Structures and PV Business Models

- The **current solar PV market** in Vietnam is in an **early stage of development**. Markets in this stage are usually found in countries highly dominated by fossil fuels, often with a substantial level of subsidies for fossil power generation and a lack of an effective policy framework for renewables. This applies to the situation of solar PV in Vietnam, at least for the past years.
- At the **end of 2014**, approximately **4.5 MWp of solar PV capacity was installed** throughout the country. Approximately **80%** of that capacity **was deployed off-grid** (mainly through small-scale applications) and **only 20% is connected to the grid**, with a few medium and large size systems of more than 50 kWp.

- Since there has not been a suitable political framework for solar PV investments in Vietnam so far, **the main business model that prevails up to now is self-consumption**. Most private sector investors of rooftop systems that have been installed in the past years have intentionally "avoided" direct grid connection due to a lack of connection standards and power sales procedures with EVN and therefore designed the systems for 100% self-consumption.

Results of the Investment Calculations – Opportunities for Solar PV Rooftop Investments

- The pre-feasibility studies for the six commercial and industrial cases that have been developed in the course of this study show that there are a**ttractive investment opportunities for solar PV rooftop** in the Vietnamese industry sector. However, they **also show** that the current **low level of electricity tariffs** in Vietnam is a **big challenge** and the assumption on the future increase of retail power tariffs is a critical factor for investment calculations.

- For the whole examined company sample, **equity IRRs** (before tax) **range from 5% to almost 18%** in the conservative **base scenarios** and **from 8% to 21%** in the **more optimistic scenarios** with lower investment costs assumed. **Equity payback times range from 9 to almost 18 years** in the **base scenarios** and **from roughly 7.5 to 14 years** in the **more optimistic scenarios** or even below 7 years when low investment costs and a higher increase of power tariffs are assumed (the 'net metering' case 3 reaches 6.8 years of payback time in a scenario with 1,500 USD/kWp investment costs and a 7% annual increase of power tariffs over the project period).

- The results show that there is a **divide in results between business sectors** that pay the **'business'** and the **'manufacturing' electricity tariffs of EVN**. **Equity IRRs** (before tax) **reach double-digit values** even in base case scenarios in those cases that are either paying the **EVN-Business tariff or** the EVN-Manufacturing tariff but **are able to benefit from the net metering support mechanism**. In those cases **equity payback times** are **below or close to 10yrs** in the base cases.

- The case with a **manufacturing company in Central Vietnam** shows **less attractive results due to the substantially lower solar irradiation** in this part of the country.

- The results also show that the a **net metering support scheme as foreseen in the first draft legislation from 2015/2016 would have the potential to improve investment cases substantially** for those PV system designs that allow for excess energy generation. This, however, will apply only to a very small number of cases, and hence shows that the legal framework for rooftop applications as was proposed would have had only limited impact on a rapid development of this market segment. In the short- and medium-term the key driver for PV investments will thus remain self-consumption and the benefits of power purchase savings.

- The analysis also revealed that despite the general expectation of investors to reach short equity payback times, there also is the **perception of "added values" of a solar PV investment** that make longer payback times feasible for many investors. These "added values" range from benefits for green building certification to contributions to corporate programs, greening products or services in the eyes of customer target groups or the increase of security of energy supply.

Key Challenges of Market Access and PV Project Development

- The analysis of the framework conditions for solar PV investments as well as previous experience with solar PV rooftop investments in the Vietnamese commercial and industrial sector show that, despite the very promising opportunities, **there are a number of challenges to be tackled**. Among these are the following:

- **Uncertainty of the legal-administrative framework:** Since the first draft of the PV legislation has been rejected by the Prime Minister to be discussed and revised again within the government there still remains uncertainty regarding the main parameters of the support scheme as well as details of the investment framework such as technical standards for grid connection (grid code) or administrational procedures.

- **Low level of electricity tariffs and uncertainty about energy market development:** The case calculations have shown that despite outstanding solar resources the low retail tariffs for electricity are a real challenge for investments and assumptions on tariff development are a crucial variable of the calculations. However, there is no political roadmap or official development scenario that could give guidance for investors or project developers. Thus, many commercial/industrial power consumers have only **low motivation to invest in an own power generation** facility or regard the **equity payback times of 7-10 years** that result from these low tariffs as being still **too long**.

- **Access to external financing sources:** The survey suggests that many companies, larger foreign owned corporations in particular, are willing to finance small and medium sized PV rooftop systems solely with own equity or have access to low interest rate loans at international capital markets. However, for other companies access to financing or even additional funding sources is of high relevance. Since there has not been any experience with financing solar PV projects in Vietnam yet, local financing institutions lack knowledge about the technology in general and risk assessment for PV projects in particular.

- **Finding reliable local partners:** Finding and motivating potential companies to invest in solar PV needs a lot of marketing and sales efforts. Furthermore, once investors are found, it might be necessary to involve local partners for construction work etc. to reach an efficient price structure for the project. Be it for project acquisition or for construction, finding a reliable local partner is a challenge in Vietnam. Firstly, there is not much experience with renewable energy in general and solar PV in particular among potential partners or respective industries. And secondly, the language barrier and cultural differences can make this process even more difficult.

- **Unawareness about solar PV technology:** Solar PV is a new technology in Vietnam and many potential customers lack knowledge about the technology and its possible contribution to the energy supply of a commercial or industrial operation. The public debate on the governmental support mechanism that started in 2015 has raised awareness among private sector stakeholders to some extent. However, approaching potential customers and investors requires extensive knowledge building and explaining the very basics of solar PV contributions regarding energy supply and investment economics. Interestingly, this study has sparked the idea of investing into a PV system even for some of the international companies with their factories and warehouses in Viet Nam for the first time.

Key Recommendations for Market Entry

- **Use available information and support from GIZ and business associations:** The GIZ Energy Support Programme provides support to inquiries regarding contacts, experience and reference points in the solar sector and has been supporting the government in the past seven years with the development and improvement of framework conditions. Furthermore, local and international business associations such as GIC-AHK, the GBA or EuroCham are first contact points to get information on business operations and potential investors in the sector.

- **Analyse cost-structure of potential investors/customers:** The specifics of the commercial/industrial electricity tariffs are a big challenge for solar PV investments. On the other hand, due to their limited variety and simple categorisation, they allow for good forecast and predictability of customer energy cost structures. Commercial operations that are subject to the EVN “Business” tariff will have the highest tariffs and opportunities for cost savings by solar self-consumption.

- **First, focus on international corporations:** German and international companies might be the first starting point when looking for potential investors in PV rooftop systems. These companies are more likely to have the financial background and necessary long-term investment perspective for a PV investment. They often implement ambitious sustainability programmes and apply higher energy efficiency standards when building manufacturing sites which both makes renewable energy investments more likely. Furthermore, fewer barriers regarding language and culture can be expected. Finally, financing issues might be less relevant in this investor group, and (longer) expected payback times for a PV system are more acceptable than for Vietnamese companies.

- **Find good local partners:** Good and reliable local partners can be of great importance in different phases of the investment project. They can support (or take over) customer/investor acquisition, help lowering costs in the construction phase or take over operation and maintenance tasks as well as after sales service. In some cases, a reliable local partner can be an important “intermediate” or even “mediator” who helps trouble shooting or building up trust to local investors or potential customers.

- **Be present and operate on site:** Since Vietnam is a new and immature market, finding investors and customers demands a lot of communication and direct contact on site. Furthermore, making business in Vietnam is much about building trust and a good relationship. A reliable local partner can take over much of this work but certainly not all of it.

- **Identify the “added value” of customers/investors:** Since the mere economics of a solar PV rooftop investment, regarding IRR and equity payback time might not be convincing enough for many investors, it is crucial to identify the individual “added value” of solar PV for the respective investor. Arguments might range from contributions to a green building certification, over PR purposes to the enhanced security of energy supply (see previous section of this chapter).

- **Emphasise on quality:** Vietnamese investors value quality and technology from reference markets, in particular technology and engineering “made in Germany”. International investors may do so even more. Furthermore, the emerging Vietnamese solar market needs good quality PV systems as reference points and best practice for further growth and development. However, the promises of cheap investment costs that allow higher returns are tempting and a few low-quality flaw systems causing trouble could lead to a loss of reputation and trust in the whole technology before solar PV even takes off in the market.

- **Help developing the market and capacity building:** Not only related to the previous point, every new commercial solar PV investment should be used to raise awareness for the technology and develop local capacities. Partners such as the GIZ Energy Program not only help with finding local partners or building up networks, they can also use commercially successful projects for capacity building reference in the whole sector, including the promotion of political support and knowledge in central and local governments as well as the development of capacities of local industry partners or financing institutions.

- **Use support for financing:** National and multilateral financing institutions as well as GIZ can offer support for partly financing solar PV projects. The German funded DeveloPPP.de programme for example, provides funding partly to innovative projects in developing countries and emerging markets while generating long-term benefits for the local population or business sector.

1. Introduction

1.1 Vietnam: An Emerging Solar Market

In early 2015 the Vietnamese government announced that it was going to include solar photovoltaic (PV) into its renewable energy portfolio. Wind and bioenergy had already been part of it for a number of years. Solar PV development targets found their way into the latest version of the strategic Power Development Plan (the PDP VII revised)[1] as well as the newly released Renewable Energy Development Strategy 2030 with an Outlook to 2050[2] of the central government.

Alongside this strategic decision came the release of a draft solar PV support law that included a feed-in tariff (FIT) for large-scale grid connected PV power plants as well as a net metering support scheme for PV rooftop systems. This long awaited political move – though widely unexpected at this point in time – created quite a momentum in the premature Vietnamese solar market. Until then, the Vietnamese PV “market” had developed to a size of merely 6-7 Megawatt (MW) with only a dozen rooftop projects exceeding 50kW in size and not a single large-scale ground-mounted power plant.

Since the beginning of 2015 Vietnamese media sources have reported more than 650 MW of planned PV investments in total. Most of them have been multi-megawatt ground-mounted solar power plants. For the majority of these projects it remains unclear if and when the investments will be realized. However, first projects have already seen ground-breaking progress despite the fact that the financial support mechanism has not even been officially implemented.[3]

The Vietnamese commercial and industrial sector has grown a lot of interest in solar PV rooftop as well. First business models for commercial PV rooftop investments emerged in 2015 such as the Solar PV Utility Company (SPUC) initiative of the Singapore based Dragon Capital investment fund. However, with the financial support mechanism still only at the horizon only a few commercial PV rooftop investments have been realized to date.

Going further up the value chain the Vietnamese solar market is developing more rapidly. 2015 and 2016 have seen a number of investments and investment announcements for new or expanded PV module and cell manufacturing capacities. These investments are partly made by local Vietnamese investors such as the expansion of the existing Red Sun module manufacturing or the Solar BK/IREX module and cell manufacturing but mostly by foreign (mainly Chinese) investors such as the Canadian Solar, CSUN, Boviet, Viet Nam Sunergy or Vina Solar projects. All these current manufacturing investments add up to more than 3 GW annual capacities.

Looking at the political and economic framework conditions in mid-2016 a mix of pull-and-push forces can be observed that give way for optimism regarding the prospects of the solar PV market Vietnam. The continuously strong growth of the Vietnamese economy is fuelling a steady increase of power demand of more than 10% per year. This poses a big challenge to the country's energy supply security, the generation of long-term cost efficient power and the provision of energy services. At the same time, Vietnam has to secure its energy sector's sustainable and green development and contribute to its international commitments to tackle climate change. Accompanying this, international partners and multilateral institutions such as the UN or the World Bank continuously propose to the Vietnamese government the necessities to reduce the country’s dependency on unsustainable and increasingly costly fossil energy production.[4]

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[1] Prime Minister Decision No. 428/QĐ-TTg: Approval of the Revised National Power Development Master Plan for the 2011-2020 Period with the Vision to 2030. March 18, 2016.

[2] Prime Minister Decision No. 2068/QĐ-TTg: Approving the Viet Nam’s Renewable Energy Development Strategy up to 2030 with an outlook to 2050. November 25, 2015.

[3] See e.g. http://nangluongvietnam.vn/news/en/nuclear-renewable/groundbreaking-a-192mw-solar-power-project-in-quang-ngai-province.html

[4] See e.g. UNDP (2014). *Green Growth and Fossil Fuel Fiscal Policies in Viet Nam.* Ha Noi: United Nations Development Programme. For an overview of current support measures of international development partners in the Vietnamese energy sector see Nam Hoai Nguyen (2015). *Review of the current policies, plans and strategies within the energy sector in Vietnam.* Final Report for the EU-Vietnam Strategic Dialogue Facility/The Delegation of the European Commission in Vietnam.

1.2 Investment Opportunities for Solar PV Rooftop in Vietnam: Approach and Objectives

Previous analysis of the Vietnamese solar energy sector has revealed that commercial and industrial PV rooftop applications not only have great development potentials in Vietnam but also promise interesting investment opportunities for the private sector, due to the specific Vietnamese electricity tariff structure that exposes commercial and industrial operations with the highest power tariffs per kilowatt hour (kWh).[5]

Vietnam has high solar potentials (see chapter 2.1). Deploying this substantial potential of solar energy at production sites would help manufacturing industries in Vietnam improve the reliability of power supply and reduce the burden on national power demand. This would also help the commercial and industrial sector reduce their significant expenses on electricity consumption due to high tariffs during peak hours and cross-subsidization policy from large consumers to smaller ones.

The main objective of this assessment was to identify and demonstrate the potential for solar PV rooftop applications in companies and factories within industrial zones in Central and Southern Vietnam with highest solar energy potential and hence to reveal business opportunities for German solar companies. The core of the analysis is defined by 6 case studies of different interviewed and analyzed companies that showed interest in solar PV investment and have been selected against a set of technical (roof availability, building structure and grid quality) and economic criteria (power demand and power cost structure). In general, two different business models were applied in the calculations of costs & benefits: 1. Self-consumption and 2. Net metering (if the load profile of the company allowed for excess solar energy to be fed into the grid).

Beyond the assessment of solar PV rooftop potentials for the selected company cases, the analysis will in addition provide a brief overview of energy management and efficiency at each of those factories. This is due to the country's rapidly-increasing electricity demand over the past years and the fact that the government is planning to issue new rules on energy consumption criteria for different industries to stop imports of outdated energy-guzzling machines and equipment as well as machinery using old technology in industries like steel, paper, plastics, food and beverages. The inclusion of energy efficiency measures could also be an additional opportunity for solar companies approaching potential commercial and industrial investors in Vietnam.

To provide the necessary background information the second chapter of this analysis gives an initial overview of solar potentials and framework conditions for solar PV. Chapter three develops the six case studies in detail. Chapter four will then, based on the interviews with potential investors and other sector stakeholders in Vietnam as well as derived from the results of the case studies, provide some recommendations for entering the Vietnamese solar PV market.

[5] See GIZ (2015). A Market Survey and Stakeholder Mapping of the Vietnamese Solar Energy Sector. GIZ Project Study (Rainer Brohm)

2. Potentials and Framework Conditions for Solar PV in Vietnam

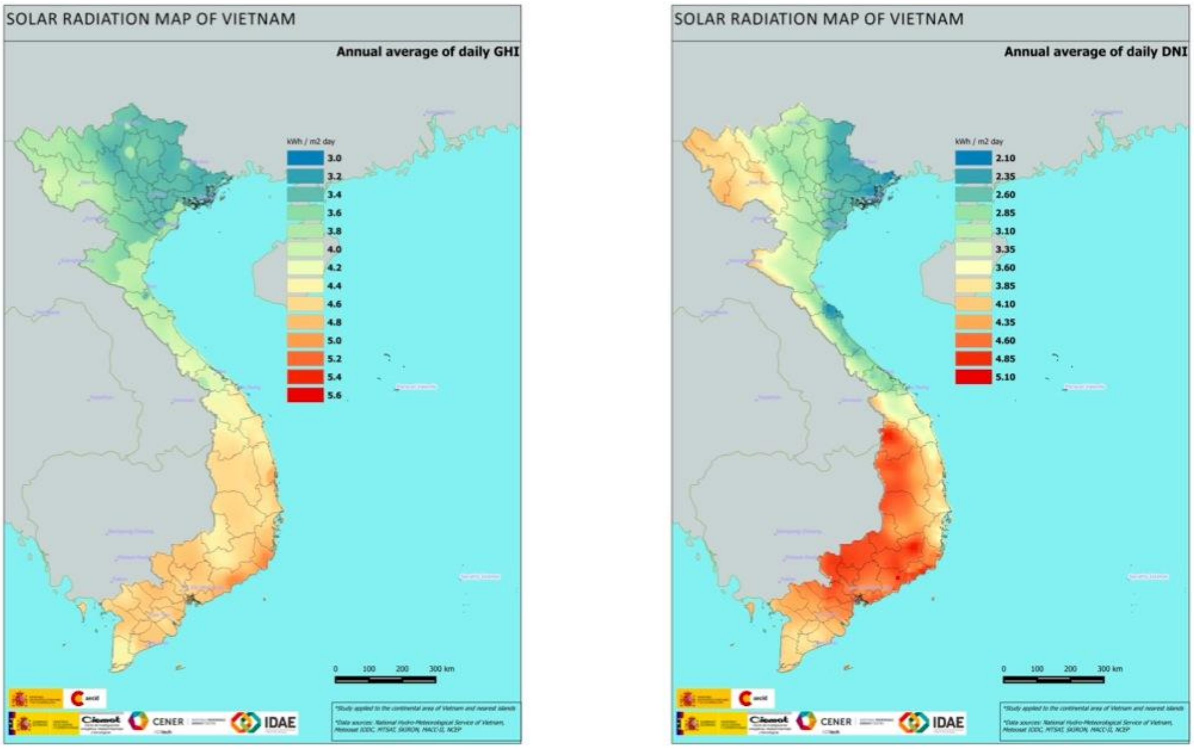
2.1 Solar Resources and Potentials for Solar PV in Vietnam

Vietnam has expansive solar resources that could be used to successfully develop the solar energy sector. Current scientific estimates of the overall solar resources in Vietnam state an average of 4-5 kWh/m^2/day in most regions of Southern, Central and partially even Northern Vietnam (totalling 1,460-1,825 kWh/m^2/year) and average peak irradiation levels of up to 5.5 kWh/m^2/day in some Southern regions (totalling up to 2,000 kWh/m^2/year). These solar irradiation levels are comparable to most countries in the region, including developed solar markets such as China, Thailand or the Philippines, as well as to international solar markets, such as Spain and Italy.

Solar Resources in Vietnam

The most up-to-date and scientifically comprehensive assessment of solar resources in Vietnam was recently undertaken by a Spanish research consortium, led by the Spanish Research Centre for Energy, Environment and Technology (CIEMAT) with support from the Spanish government in collaboration with the Vietnamese Ministry of Industry and Trade. As a result of these efforts, detailed maps of Vietnam's solar resources are now available for policy makers, investors and researchers (CIEMAT et al., 2015).[6]
These mappings include measurements of global horizontal irradiation (GHI) and normal direct irradiation (DNI, see Figure 1.), as well as theoretical and technical potentials.[7]

Figure 1: Solar irradiation maps of Vietnam – Annual average of daily GHI and DNI



Source: CIEMAT et al. (2015)

6 CIEMAT et al. (2015). *Maps of Solar Resource and Potential in Vietnam*. Ha Noi: CIEMAT, CENER & IDAE with support from AECER in collaboration with GDE/MoIT. Download: http://bit.ly/1Q0FEhb

7 The maps were generated based on ground measurements, satellite imagery and the analysis of numerical weather prediction models. The estimated technical potentials however need to be treated with caution since the availability of data to derive the technical potential from the overall GHI was limited.

Development Potentials for Solar PV

So far, no thorough analysis of the overall expansion of Vietnam's solar capacity has been conducted. Only a few rough estimations of MWp potentials in Vietnam have been undertaken, either looking at the different parameters, such as utilizable roof or ground areas, or demand-oriented approaches that analyse the typical load curves of selected power consumers.[8]

These research projects on the technically utilizable rooftop areas in cities, towns and provincial municipalities in Vietnam from the early 2000's had rather conservative assumptions. They estimated a capacity potential for solar PV of roughly 1 GWp. It can safely be assumed that the available rooftop areas and corresponding PV potentials are 30-40% higher today (and expected to increase further) due to rapid urbanization over the past decade - a trend that is predicted to continue.[9] As a result, the long-term potentials for technically utilizable roof-area for residential and commercial PV applications should reach at least 2-5 GWp within the next decade.

In the context of another GIS-assisted research project[10], estimates for suitable areas for ground-mounted PV capacities reach an overall potential of 22 GW for Vietnam, with a focus on southern regions with high irradiation levels of 5 kWh/m^2/day or more.[11]

All economic indicators show that Vietnams economy will most likely continue to grow by 5-6% per year and foreign direct investments (FDI) increase likewise. Vietnam's high level of regional (ASEAN/AFTA) and international (Trans Pacific Partnership, EU-Vietnam Free Trade Agreement, etc.) economic integration is widely seen as a guarantor for further economic growth and the development of the Vietnamese commercial and industrial sector in particular.[12] Vietnam therefore undoubtedly has the resource potential to become a major solar PV market with a strong commercial and industrial rooftop segment.

2.2 The Vietnamese Power Sector and the Legal Framework for PV Investments

The rapid growth in demand for electricity is posing a huge challenge to Vietnam's energy sector and green growth strategy. The growth rate for power consumption has far exceeded the GDP growth rate over the last decade. From 1995 to 2005, power consumption increased by more than 14.9% a year, while the annual GDP growth rate totaled 7.2%. Between 2005 and 2015 the growth rate of power consumption still remained above 10% a year.[13]

Power Sector Reform and Vietnam's Commitments for Green Growth

In response to this challenge, Vietnam's reform agenda already includes energy market reform, fossil fuel fiscal policy reform and a transition to green growth. The Party Resolution on Climate Change, Natural Resource Management & Environment and the national Green Growth Strategy with its Green Growth Action Plan both include commitments to green growth and the removal of fossil fuel subsidies. In addition, the government has committed to gradually re-orientate price setting in line with a market-based approach. Legislation is now in place for market-based pricing for coal, petroleum, gas and electricity prices, including gradually liberalizing energy markets, and increasing the share of clean and renewable energy in Vietnam's total energy use. These policies are recent and implementation has only just begun.

Vietnam's International Climate Change Commitments

In December 2015 the Vietnamese government has signed the Paris agreement and committed itself to greenhouse gas (GHG) emissions reduction targets. Following the "Intended Nationally Determined Contribution" (INDC) that Vietnam has submitted to the UN Climate Change Secretariat (UNFCCC) the country will reduce its GHG emissions by 2030 by 8% compared to a business-

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[8] For an estimation of available rooftop space see Nguyen, Quoc Khanh (2005). *Long-term optimization of energy supply and demand in Vietnam with special reference to the potential of renewable energy.* PhD thesis submitted at Carl von Ossietzky University Oldenburg, Germany.

[9] According to World Bank and UNHABITAT data the rate of urbanization in Vietnam varied between 2.5 and 3.4% per year between 2005 and 2010.

[10] See Nguyen, Quoc Khanh (2005).

[11] In general, these estimates should be interpreted with great caution. Some of the assumptions are questionable and the lack of data on the types and numbers of buildings or available rooftop areas makes a valid estimation of potential capacities, especially solar rooftop applications, a difficult task.

[12] See e.g. Nguyen, The Dung (2016). *Market Structure and Business Opportunities: AHK Target Market Analysis and AHK Business Trip.* Presentation of the German Delegation of Industry and Commerce in Vietnam at the GIZ/PDP Information Workshop *Photovoltaics in Vietnam: Freefield and net-metering before breakthrough?* Berlin: June 2, 2016. Download: www.export-erneuerbare.de

[13] For an overview of the Vietnamese power sector and current developments see http://www.renewableenergy.org.vn or ADB (2015). *Assessment of Power Sector Reforms in Viet Nam.* Manila: ADB. Download: http://www.adb.org/sites/default/files/institutional-document/173769/vie-power-sector-reforms.pdf

as-usual (BAU) scenario using domestic resources. Furthermore, emission intensity per unit of GDP shall be reduced by 20% compared to the 2010 levels. The above-mentioned 8% contribution could be increased to 25% if international support is received through bilateral and multilateral cooperation, as well as through the implementation of new mechanisms under the Global Climate Agreement, in which emission intensity per unit of GDP will be reduced by 30% compared to 2010 levels.[14]

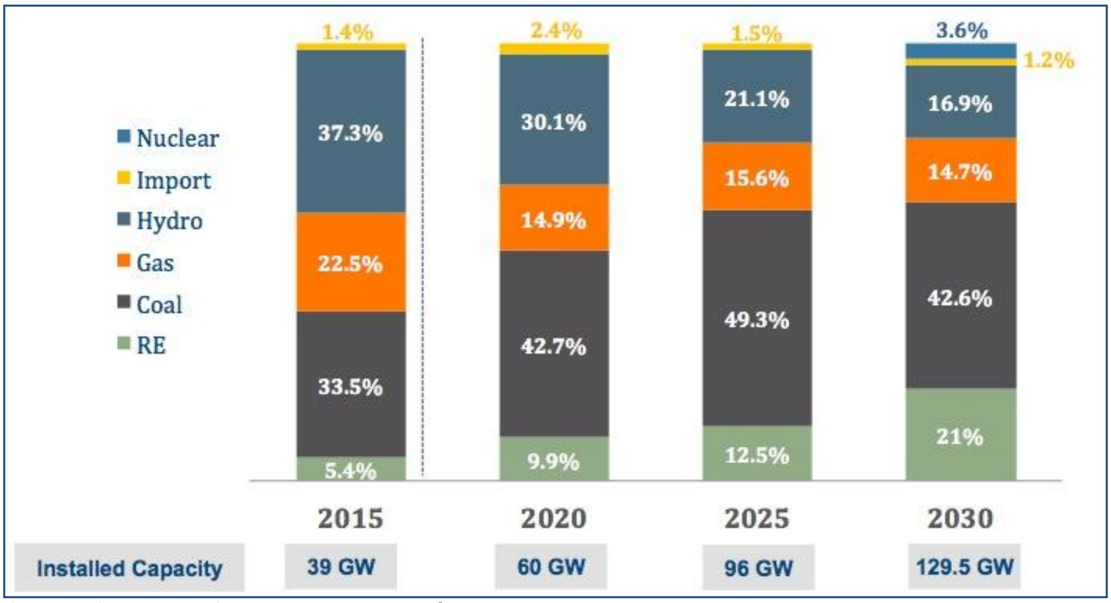
To reach these targets Vietnam has committed to a set of measures including to "change the energy structure towards a reduced share of fossil fuel, encouraging the exploitation and use of renewable and low GHG emission energy sources" and to "develop and implement financial and technical mechanisms and policies to support research and the application of appropriate advanced technologies; exploit and optimize the use of renewable energy sources, both on-grid as well as off grid" as well as to " develop a renewable energy technology market, domestic industries and local service providers."[15]

Most experts believe, that the majority of GHG reductions will have to be realised in the power sector and through the shift from fossil to renewable power generation.

The National Power Development Planning and New Targets for Solar PV

The central political planning instrument of the Vietnamese government for the power sector is the Power Development Plan (PDP). In 2015 the current PDP7 has been under revision. The newly revised PDP7 now includes more ambitious development targets for renewable energies in general and for solar energy in particular. In the next 15 years until 2030 the share of installed renewable energy capacity in Vietnam is supposed to increase from 5.4% to 21% (2020: 9.9%). However, due to an immense increase of the anticipated overall power demand – according to the plan the installed power capacities will more than triple in the same timeframe – the share of fossil power plants will remain high with almost 60% in 2030 (see figure 2).

Figure 2: Development of installed power capacity until 2030 according to PDP7 revised



Source: GIZ Energy Support Programme Vietnam

The necessary investments for this capacity development will be enormous (more than 100 billion USD until 2035) and apart from national and international funding, private sector investments have to be mobilised to a much larger extend than in the past. However, renewable energies in general and solar PV in particular have the potential not only to reach these targets in Vietnam but also to mobilise the necessary private sector investments if the legal and administrational framework for investments is beneficial.

[14] See INDC of Vietnam. Download: http://www4.unfccc.int/submissions/INDC/Published%20Documents/Viet%20Nam/1/VIETNAM'S%20INDC.pdf
[15] ibid.

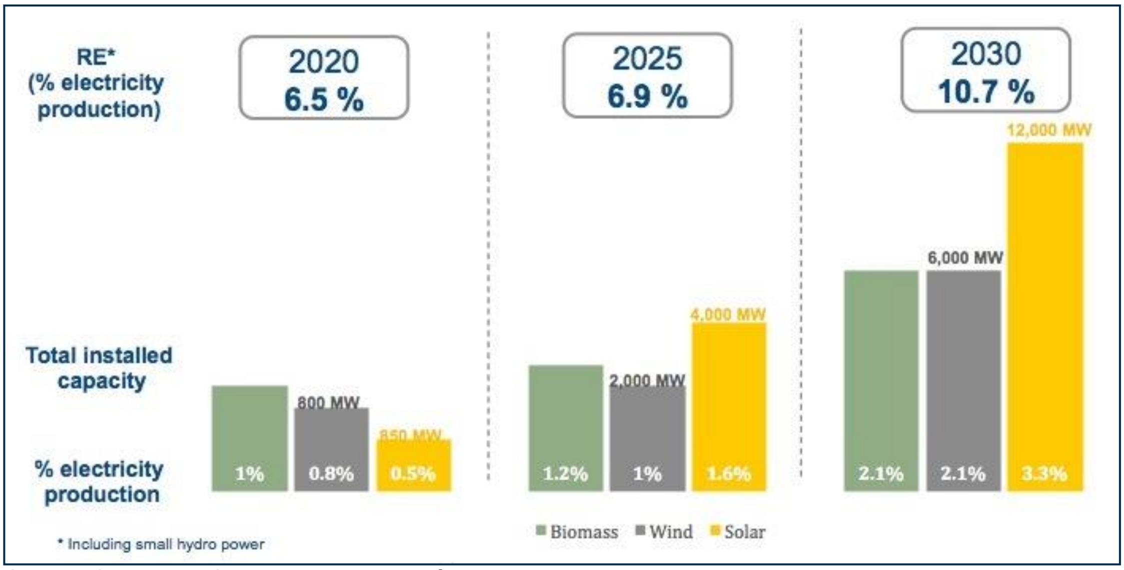
The Government Targets for Solar PV Development

The newly revised PDP7 as well as the Renewable Energy Development Strategy include specific development targets for solar energy.[16]

Following the revised PDP7 the solar PV capacity shall be increased from currently around 6-7 MW by the end of 2015 to 850 MW by 2020, 4,000 MW by 2025 and 12,000 GW by 2030 (see figure 3). Regarding the potentials of the country these targets may seem to be conservative (see previous chapter 2.1). But regarding the current state of the solar market and the pace of development in the past years, these numbers appear to be very ambitious.

However, for the first time the government of Vietnam has set official targets for solar PV development and is about to implement a support framework to mobilise investments and to foster market growth.

Figure 3: Solar energy targets for 2020, 2025 and 2030 according to the PDP7 revised



Source: GIZ Energy Support Programme Vietnam

The Current State of the Solar Market in Vietnam

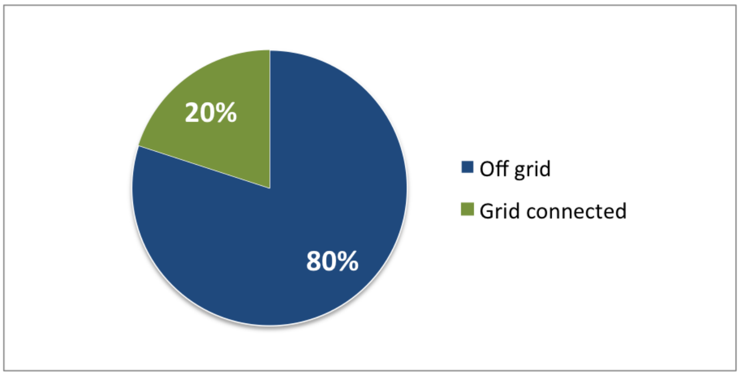
The current solar PV market in Vietnam is in an early stage of development. Markets in this stage are usually found in countries highly dominated by fossil fuels, often with a substantial level of subsidies for fossil power generation and a lack of an effective policy framework for renewables. This applies to the situation of solar PV in Vietnam, at least for the past years.

At the end of 2014, approximately 4.5 MWp of solar PV capacity was installed throughout the country.[17] Approximately 80% of the currently installed solar PV capacity was deployed off-grid through around 10,000 to 15,000 small-scale applications, such as Solar Home Systems (SHS) or smaller systems for public use, and a number of larger-scale off-grid systems, either in stand-alone PV applications or in hybrid systems that include PV arrays and additional energy sources, such as diesel generators or wind turbines. Only 20% of the total PV capacity is connected to the grid, through a few medium and large size systems of more than 50 kWp.

Figure 4: Share of on-grid and off-grid PV capacities in Vietnam

[16] The revised PDP7 was published in March 2016 and therefore roughly four months after the Renewable Energy Strategy. Both planning instruments are mostly in line regarding the development of renewable energies and solar PV in particular with minor differences. Since the PDP is the more relevant and binding political document it is primarily referred to within the cause of this report.

[17] Unfortunately, there is no official or publicly available commercial database on installed PV systems in Vietnam. This is due to the absence of registration procedures or similar regulations that could document solar installations. Most publicly available figures on installed capacity or systems are based on private or scientific data collection and related publications. For 2014 data see e.g. IoE (2015).



Source: IoE (2015)

The installed capacity connected to the grid is dominated by a rather small number of medium sized rooftop systems, such as the installations of Intel Corporation in HCMC (220 kWp), Big C Green Market in Binh Duong province (212 kWp), PUMA/Avery Dennison in Long An (100kWp), Deutsche Bekleidungswerke (DBW) in Long An (165 kWp) the National Conference Hall in Hanoi (154 kWp), the UN building in Hanoi (119 kWp), the new National Assembly in Hanoi (50 kWp) or the building of the Ministry of Industry and Trade (MoIT) in Hanoi (22 kWp).

Most of these existing larger PV rooftop systems were financed by donor funds or corporate public relations (PR) and corporate social responsibility (CSR) budgets. This is mainly due to the fact that there have been no standardized regulations for the sale or feed-in of solar power so far, i.e. until now there was no viable business model that fostered PV investments. With the coming political support framework this is about to change. The latest commercial rooftop projects show this shift in investment motive already now. The DBW investment in Long An for example has a clear commercial investment motivation that includes economic benefits beyond the mere IRR or equity pay-back (also see the following chapter 2.3 for an overview of this project).

A very recent development is the emergence of pilot support programmes on the provincial or city level. In 2015 the People's Committee of HCMC together with the HCMC Department of Science and Technology initiated a pilot support programme to fund around 800 kWp of PV rooftop systems on private, commercial and public buildings. With a total budget of 10 billion VND (app. USD 500,000) the implementing Energy Conservation Centre of HCMC (ECC-HCMC) is funding a FIT of 2,000 VND per kWh (app. USD 0.09) in form of a generation tariff (the whole solar power production is remunerated with the tariff). The programme is limited to 18 months but shall be extended for 3 more years after the planned review end of 2016.[18]

As already outlined, the PV power plant segment has not yet developed but sees a lot of investment announcements and first ground-breakings of multi-megawatt projects.[19] More than 650 MW of project announcements have been reported in media publications and international investors and EPC show a lot of interest in the Vietnamese market.[20]

A mapping of the stakeholders in the solar energy sector reveals a small but growing solar industry with domestic enterprises already covering most parts of the value chain, from the manufacturing of key system components, such as PV modules, EPC and installer capacities, to energy service companies that have implemented modern business and financing models such as the leasing of systems and energy sales in general. However, industry capacities and experience with solar PV applications are still very limited. This applies in particular for the planning and EPC part of the value chain.

The PV industry in Vietnam further up the value chain is developing as well. New or expanded PV module and cell manufacturing capacities have been realised or have been announced in the first months of 2016. These investments, partly made by local Vietnamese but mostly by foreign (mainly Chinese) investors, currently add up to more than 3 GW annual production capacities.[21]

With regard to project development, construction and distribution of solar PV systems, a small number of domestic and international companies are active on the market. Solar BK[22] and Red Sun[23], both manufacturers of PV modules, have also developed EPC

[18] Interview with Mr. Diep The Cuong, head of the Renewable Energy Department of ECC-HCMC on April 1st, 2016.

[19] See Introduction and footnote 3.

[20] See e.g. the feedback from the participants of the Solarplaza Trade Mission Vietnam & Southeast Asia in April 2016 (see Post-Show Report on www.pvtrademissionvietnam.com)

[21] See introduction.

[22] http://en.solarbk.vn

capacities. The two companies have implemented a number of off-grid and on-grid projects so far, with Solar BK specializing in island off-grid systems. Regarding international solar companies Aschoff Solar[24] and Schneider Electric[25] have both implemented PV rooftop systems, such as the system on top of the new National Assembly in Hanoi and the DBW Garment Factory system (Aschoff Solar) or the commercial system of XP Power (Schneider Electric). Apart from the small supplier and EPC segment there are a few consulting experts with experience in solar PV project development and planning such as ILF Consulting[26] (for ground-mounted power plants) or Artelia Vietnam[27] (e.g. planning for the Big C system in Binh Duong).

However, the EPC sector as well as the supporting industry for PV installations (construction, engineering) is still small and developing and it will be a challenge for companies seeking market entry to find suitable partners for projects.

The Legal Framework for Grid-Connected Solar PV and the Draft Support Mechanism

Up to now the political framework conditions for solar PV in Vietnam have not been beneficial but rather restricted investments in on-grid and rooftop applications in particular since solar energy had not been integrated into the regulatory energy policy framework. There was no feed-in tariff or other financial support mechanism in place and no standardized interconnection code (grid code) or connection procedures such as a net metering scheme either. There have been first donor funded attempts to develop a grid code and a net metering scheme for Vietnam that partly built the ground for the current political implementation of a support framework for solar PV.[28]

Furthermore, there has been no standard for solar power sales to the grid or EVN respectively, such as a standardized power purchase agreement (SPPA), or any other specific regulations developed and implemented yet.

In May 2015 the General Directorate of Energy (GDE) of the MoIT drafted the first version of a PV support law.[29] In September 2015 GDE/MoIT organised a stakeholder consultation workshop and issued a draft version of the PV support law to selected organisations and experts that were invited to participate in the consultation process. Since this first draft at least two more versions have been drafted by GDE/MoIT but have not been issued publicly. Despite many rumours about the content and changes that have been made compared to the first draft, there is no reliable information on possible adjustments on the first draft that could be referred to. In June 2016 the Prime Minister rejected the draft to further study and revision within the government and its relevant ministries and institutions. At this point of time it is not clear when the revision and publication of the final legislation can be expected.

According to this, the present analysis refers to the first draft, issued in September 2015 and develops the framework and all assumptions for the case and investment calculations for the “net metering” cases on that base (see chapter 3.1). This allows developing a view on a second business model apart from self-consumption that uses potential benefits from a net metering support mechanism as foreseen in the first draft of 2015/2016.

Following this, the PV regulatory framework that is assumed following the first draft legislation provides a net metering scheme with a remuneration (net metering credit) of 3,150 VND/kWh or 15 USDct/kWh that would be paid in VND and adjusted to currency exchange rate development. The net metering scheme, as far as outlined in the first draft, would thus have the character of a ‘net billing’ system with a fixed credit (not developing in line with the individual power tariff of the system operator) for excess solar power to be sold to the grid/to EVN (or to EVN’s local power utility companies). In this framework it could thus be assumed that only excess power after self-consumption would be remunerated with the net metering credit.

However, the first draft was not very detailed and even unclear in some parts. Furthermore, some implementing guidelines and more detailed technical regulation would be expected to be finalised at the time or even after the PV support law will be issued. This applies in particular to the implementation details of a potential net metering scheme as well as the interconnection code (grid code) for solar PV rooftop systems.

The following table 1 shows the details of the first draft regulation in an overview. Regarding the ongoing revision of this first draft all information displayed underlies a high level of uncertainty and therefore has to be treated with great caution.

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[23] http://redsun-solar.com

[24] http://www.aschoff-solar.com

[25] http://www.schneider-electric.com.vn/sites/vietnam/en/company/company.page

[26] http://www.ilf.de

[27] http://www.arteliagroup.com/en/vietnam&r=true

[28] A partly on-going effort is the joint project of the International Copper Association Southeast Asia (ICA-SEA), EVN Central (EVN-CPC) and the Danang Energy Conservation and Technology Consultant Center (DECC). See e.g. the Report of the Consultation Workshop “National Interconnection Standards and Net Metering for Rooftop Solar PV in Vietnam”, January 7, 2015. Info: http://www.cpc.vn/english/Detnew.aspx?ChannelID=11&ID=60

[29] Draft Decision 654/2015/QĐ-TTg.

Table 1: Solar PV Regulatory Framework According to Draft Decision 654/2015/QĐ-TTg

	Grid-connected PV systems (ground-mounted solar power plants)	Rooftop PV systems (residential, commercial/industrial)
Political targets	**2,000 MW** by 2030 (?) • Investments/grid-connections must be consistent with the national/provincial power development planning and electricity master plans (licensing requirements).	**4,000 MW** by 2030 (?)
Max. system size	**100 MW**	**No limit** >500 kW: electricity production license required (?)
FIT/ net metering credit	**11.2 USCents/kWh** (2,352 VND/kWh) • 20 years PPA with possible extension • Paid in VND, not indexed (?)	**15 USCents/kWh** (3,150 VND/kWh) • For excess of net-balance • 10 years with possible extension • Paid in VND, indexed to USD-VND exchange rate (?) • Details of billing yet undefined (usage of a bi-directional meter required)
Tax incentives	• Exemption from import tax for imported systems or components. • Exemption from or reduction of business income tax (not clearly defined).	
Land use incentives	• Areas for PV power plants, transmission lines and substations are subject to exemption or reduction of land use fees (not clearly defined). • Provincial People's Committees and public authorities shall allocate sufficient land area for solar investors.	N/A
Grid connection	• Investor responsible for grid connection (transmission lines/substations) to agreed connection point with the purchaser. • Grid-connection standards (grid code) yet undefined	• Grid-connection standards (grid code) yet undefined.
Project implementation	• Projects have to be implemented 24 months after issuing of investment licence. Construction work has to be started within 12 months.	• No investment licence required. • Potentially electricity licence required above a defined system size (500kWp?).
Further requirements and regulations	• Solar cell efficiency >16%.	N/A

Source: Draft Decision 654/2015/QĐ-TTg (September 2015)

2.3 Solar PV Rooftop Business Models and Selected PV Rooftop Projects

Previous assessments of the solar energy sector in Vietnam have identified the commercial/industrial PV rooftop segment as one of the most promising with the highest development potentials.[30] In particular, this segment shows the highest "readiness for business case" due the specific structure of the Vietnamese retail electricity tariffs.

Table 2: EVN Electricity Tariff Structure (Decision 2256/QĐ-BCT as of March 15, 2015)

EVN Electricity Tariff Structure 2016	VND/kWh	USDct/kWh
Retail Tariffs for Households		
Band 1: 0 - 50 kWh	1,484	6.65
Band 2: 51 - 100 kWh	1,533	6.87
Band 3: 101 - 200 kWh	1,786	8.01
Band 4: 201 - 300 kWh	2,242	10.05
Band 5: 301 - 400 kWh	2,503	11.22
Band 6: 401 kWh above	2,503	11.22
Retail Tariffs for the Business Sector		
Above 22 kV		
a) Normal hours	2,125	9.53
b) Low hours (off-peak)	1,185	5.31
c) Peak hours	3,699	16.59
From 6 kV to 22 kV		
a) Normal hours	2,287	10.26
b) Low hours (off-peak)	1,347	6.04
c) Peak hours	3,829	17.17
Below 6 kV		
a) Normal hours	2,320	10.04
b) Low hours (off-peak)	1,412	6.33
c) Peak hours	3,991	17.90
Retail Tariff for the Manufacturing Sector		
Above 110 kV		
a) Normal hours	1,388	6.22
b) Low hours (off-peak)	869	3.90
c) Peak hours	2,459	11.03
From 22 kV to 110 kV		
a) Normal hours	1,405	6.30
b) Low hours (off-peak)	902	4.04
c) Peak hours	2,556	11.46
From 6 kV to 22 kV		
a) Normal hours	1,453	6.52
b) Low hours (off-peak)	934	4.19
c) Peak hours	2,637	11.83
Below 6 kV		
a) Normal hours	1,518	6.81
b) Low hours (off-peak)	983	4.41
c) Peak hours	2,735	12.26

[30] See e.g. GIZ (2015). This assessment was based on the criteria 1. Development potential – the potential to increase the share of renewable energies in power capacities and power generation; 2. Readiness for business case – the level of competitiveness that a solar application has reached in Vietnam so far (a high readiness for business case implies only limited or no need for financial support to trigger market development); 3. Existing framework conditions – the political framework conditions and the prevailing market environment and 4. Co-benefits for Vietnam – possible industry and job effects as well as co-benefits for the energy system, such as peak demand reduction etc.

The Electricity Tariff Level and Structure in Vietnam

For the cost competitiveness of PV on-grid applications, Vietnam's low electricity tariffs have been a major barrier for investments. In the past years, Vietnam has been substantially subsidising the retail price of electricity for all consumer groups.[31] According to IEA figures, subsidies for fossil fuels in Vietnam, imposed to keep power price levels low, varied from USD 1.2 - 4.49 billion annually in the period 2007-2012.[32]

Table 2 gives an overview of retail tariffs (extract) for residential, commercial ("business") and manufacturing power consumers.[33] With an average electricity retail tariff of 1,622 VND/kWh (without VAT) or 7.3 USDct/kWh the Vietnamese electricity prices are among the lowest in Asia.[34]

Electricity tariffs in Vietnam are still regulated by the government. Although EVN as the quasi-monopolist utility has the general right to change tariffs independently, this is limited to tariff increases of less than 5% per year. To increase tariffs beyond that a government approval is needed. For the last tariff adjustment in March 2015 EVN and the Ministry of Planning and Investment (MPI) proposed an increase of tariffs by 9.5%[35] but, mainly for socio-political reasons, the government finally allowed an increase of the average retail tariff by only 7.5%.

One consequence of this political power price regulation is a high level of uncertainty regarding the future power price development for the private sector. Therefore, business associations such as the European Chamber of Commerce in Vietnam (EuroCham) or the German Business Association (GBA) repeatedly call for more transparency and predictability in power tariff developments.[36]

Apparently, this low level of electricity tariffs is a challenge for solar PV investments. However, day-time peak tariffs for manufacturing and commercial operations are already at comparatively high levels of 11 to 18 USDct/kWh. The following case studies will show that EVN day-time tariffs calculated in an avoided cost approach for solar PV rooftop systems reach levels that allow attractive returns on capital and – for certain investor groups – acceptable equity payback times (see the following chapter).

Main Solar PV Rooftop Business Models

Since there has not been a suitable political framework for solar PV investments in Vietnam so far, the main business model that prevails up to now is self-consumption. Most private sector investors of rooftop systems that have been installed in the past years have intentionally "avoided" direct grid connection due to a lack of connection standards and power sales procedures with EVN and therefore designed the systems for 100% self-consumption.

Looking at the first draft solar PV support mechanism there could be more business models available and applicable for potential investors in the future. Table 3 gives an overview of internationally prevailing business and financing models for solar PV investments (except off grid, hybrid and micro PV models).[37]

[31] For a detailed and comprehensive analysis of fossil fuel subsidies in the Vietnamese power sector see the publications of the UNDP Green Growth and Fossil Fuel Fiscal Policies Project: http://www.vn.undp.org/content/vietnam/en/home/presscenter/pressreleases/2014/06/18/fossil-fuel-subsidies-need-to-be-phased-out.html

[32] UNDP (2014).

[33] The tariff structure was introduced in March 2015 and has not been changed since then (as of mid-June 2016). A VND-USD currency conversion factor of 22,300VND=1USD was applied.

[34] See ADB (2015)

[35] See http://vietnamnews.vn/economy/265858/power-tariffs-to-rise-95-per-cent.html

[36] See e.g. EuroCham Vietnam (2014). Whitebook 2015 - Trade/Investment Issues & Recommendations. Ho Chi Minh City: European Chamber of Commerce in Vietnam.

[37] For an overview and more detailed typology of international solar PV business models see BSW-Solar (2014). *PV Investor Guide. New business models for photovoltaics in international markets.* Berlin: The German Solar Industry Association (BSW-Solar). Available under: https://www.solarwirtschaft.de/en/international-activities/new-business-models.html

Table 3: Overview of Solar PV Business and Financing Models and their Role in Vietnam

Business Model	Self-Consumption	FIT	Net Metering	PPA* (direct line)	PPA* (utility PPA)	Leasing
Main Features	100% of solar energy directly consumed on site by system owner. No access energy, no feed-in to grid.	Whole solar energy production is fed into the grid and remunerated with a fixed tariff (sale to utility/ grid operator). Sales price, terms and risks regulated via legislation and/or standard PPA.	Excess energy that is not consumed on site is balanced against consumption by: 1. Credits (=net balancing) or 2. Reversed metering (=net metering).	PV system owner sells solar power to third party off taker within building or nearby via direct line. A PPA regulates sales price, terms and risks. No use of public grid.	Sale of solar power to a utility or grid operator. A utility PPA regulates negotiated sales price, terms and risks (often tendered). Often related to RPS* and/or green certificate schemes.	Financing model in which the solar PV system is not purchased but leased by the system operator. System ownership remains with leasing company. Helps to avoid high upfront investments.
Main Driver of Profitability	Cost of grid electricity.	Level of FIT (vs. costs of grid electricity).	Cost of grid electricity (net metering) or level of credit (net billing).	Cost of grid electricity (=alternative costs of electricity).	Wholesale electricity costs or avoided costs of electricity production.	(Choice of financing model influenced by individual financing situation of investor.)
Applicable Market Segment	**PV rooftop** (residential, commercial/ industrial)	**PV rooftop** (residential, commercial/ industrial) **PV ground-mounted**	**PV rooftop** (usually residential and medium sized commercial/ industrial)	**PV rooftop** (multi-family residential, commercial/ industrial). **PV ground-mounted** (small)	**PV utility-scale**	**PV rooftop** (residential, commercial/ industrial)
Role/ Applicability in Vietnam	<u>Draft PV law:</u> Applicable for rooftop PV systems. Most attractive for commercial/ industrial and high demand residential power users (due to high electricity tariffs). Prevailing model of the past.	<u>Draft PV law:</u> Applicable only for grid connected ground-mounted PV systems.	<u>Draft PV law:</u> Applicable only for rooftop PV systems.	Currently <u>not applicable</u> (EVN is singly buyer of electricity).	<u>Currently possible</u> (individual PPA with EVN). With draft FIT law potentially still possible (individual contract with EVN) RPS scheme for EVN and power producers in planning (RE Strategy 2020).	<u>No supporting legal framework</u> for PV leasing implemented. One business model on the market (with complex legal structure).

* PPA=Power Purchase Agreement
** RPS= Renewable Portfolio Standards (minimum share of renewable energy that a utility must reach in its portfolio)

Self-consumption: The consumption of the whole solar energy production of a (rooftop) system will remain a main business model in Vietnam for the future. The planned net metering scheme will make self-consumption models even more attractive in particular for those investors that reach a very high self-consumption ratio but, due to certain features of their demand structure, will still have a certain amount of electricity from their system that can not be consumed on site (e.g. manufacturers that do not operate on Sundays and only have a minimum load on these days. To reach 100% self-consumption these investors would have to downsize the PV system capacity to a level that would not justify an investment).

Sale to EVN for a fixed feed-in tariff (FIT): The first draft solar PV support law included a feed-in tariff for grid connected ground-mounted PV systems. If the intended level of the FIT (see previous chapter 2.2) and the additional legal framework would be suitable to attract investments, this would most likely become a main business model for large-scale PV investments.
Sale to EVN for a fixed net metering credit: The first draft solar PV support law included a net metering credit for excess solar energy exported to the grid (see previous chapter 2.2). This would improve the economic feasibility of PV rooftop self-consumption systems that still generate excess solar production on site. Since the credit for excess energy was supposed to be higher than the average day-time electricity tariffs of commercial and industrial operations, the net metering would be the more attractive the higher the share of excess solar energy is (see in particular case study 3, chapter 3.4 and 6, chapter 3.7).

Sale to EVN on the base of an individual utility PPA: Potentially possible as well could be the negotiation of an individual sales price with EVN apart from the fixed FIT. This could be attractive for EVN in case the planned scheme of Renewable Portfolio Standards (RPS) would come in to force in the coming years and the FIT scheme does not attract enough investments to meet the RPS requirements for minimum shares of renewable energy.[38] Furthermore, there have been first reports of EVN plans to introduce a specific renewable electricity retail tariff for customers that want to cover their electricity demand completely with renewable power but do not want to invest in own generation capacities.

Direct sales to third party off takers: On the base of the current legal framework and the draft solar PV support act it will **not be possible** to sell solar power to a neighbouring third party off taker (such as another company or manufacturer in the same industrial park) via a direct line. So far the legal framework leaves EVN and its directly owned power companies to be the single-buyer of electricity in Vietnam. This might change in the future in the course of the further liberalisation of the Vietnamese power sector but up to then it is not an option.

Leasing: As a financing model for solar PV investments, system leasing has developed as an attractive alternative to purchasing a system in many solar markets (in particular in the USA but also in an increasing number of further developed solar markets). However, leasing requires a beneficial legal framework and trustworthy partners to establish a viable business model. In Vietnam so far only one leasing business model has evolved and started to operate on the market.[39] So far, there is no supporting legal framework for solar PV leasing in place in Vietnam and the legal structure to make such a financing model operable is complex. For that reason, leasing is not further considered in the course of this analysis and the development of the investment cases.

The following two project examples may give a first insight into recent solar PV rooftop investments in the commercial sector of Vietnam. The first one, a 212 kWp system on a supermarket's carport canopy, has been installed in 2013. The second one is the most recent installation in the sector with 165 kWp on a German garment factory that started operation end of May 2016. Both systems are located in surrounding provinces of HCMC in Southern Vietnam.

Project Example 1: Big C Supermarket in Binh Duong (212 kWp)

BigC Green Square in Di An, Binh Duong province belongs to a series of Big C shopping malls scattered in different provinces of Vietnam. The building was constructed in 2012-2013 with the aim to reach advanced energy efficiency standards and the requirements of international and national green building standards. With a mix of energy efficiency measures such as LED lighting, a highly insulated building envelope and low energy glazing on the one side and the installation of a solar PV system on the carport canopy in front of the market on the other side, the building obtained LEED[40] (Gold Standard) and LOTUS[41] (Silver Standard) certification.[42]

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[38] The Renewable Energy Strategy 2020 (Decision No. 2068/QĐ-TTg) provides the plan to introduce RPS for power generation and distribution entities requiring them to reach a share of renewable energy of 3% by 2020, 10% by 2030 and 30% by 2050. However, this strategy has not yet been implemented.

[39] The Solar PV Utility Company (SPUC) initiative of the Singapore based Dragon Capital investment fund (Mekong Brahmaputra Clean Development Fund L.P.). More info: http://www.dragoncapital.com/dragon-capital-funds/mekong-brahmaputra-clean-development-fund-lp

[40] LEED is a US-based building certification programme, which is applicable to global projects as well. It is currently the most widely used green building rating system in the world. Ratings are LEED Certified, Silver, Gold and Platinum. For more information see: http://www.usgbc.org.

[41] LOTUS is one of the growing number of locally-based certifications, which are structured and benchmarked similarly to international certifications, but are published in a dual-language format and are attuned to local climate and construction practices. For more information see: http://www.vgbc.org.vn.

[42] More information: http://en.e4g.org/gb_case_study/big-c-green-square/

The PV system on the carport canopy went into operation in March 2013.

Source: Artelia VN

The following tables give an overview of the project and the investment that was financed with 100% equity by the investor group owning Big C Vietnam, Viet Nhat RE JSC.[43]

Table 4: Case Example Big C – Project and Investment Report

Project Information	
Location	Di An, Binh Duong Province
Type of system	Carport canopy
Investor	Viet Nhat RE JSC/Big C
Design/supervision	Artelia VN
Start of operation	March 2013
Installed capacity	212 kWp
Annual yield (est.)	290,000 kWh
Specific yield (est.)	1,368 kWh/kWp
Energy demand coverage	5.6%
Total energy savings*	23%
Avoided CO_2-emissions	152,000 kg/yr

*Including energy efficiency measures (LED, additional insulation)

Investment Report	
Specific investment*	2,150 USD
Total invest. *	455,000 USD
Equity	100%
Av. avoided electricity costs*	2.058VND / 0,10USD
Assumed power tariff increase	10%/yr
Discount rate	4%
Equity IRR	20%
Equity payback time	14ys

* Exchange rate in March 2013: 1 USD = 20580 VND

[43] All data based on information provided by Artelia VN and Viet Nhat RE JSC.

Project Example 2: DBW Garment Factory in Long An (165 kWp)

Royal Spirit Group, headquartered in Hong Kong, is a group of companies that are market leaders in the design, production and export of fashion apparel and accessories to major brands worldwide. The Group combines wholly owned manufacturing facilities as well as partnerships across Asia.

In Vietnam the Deutsche Bekleidungswerke (DBW) is operating as one of the Group's companies. DBW, to keep up with the Group's visions of sustainability and worker's well-being, has planned and constructed a new state-of- the-art factory, which opened in May 2016. The five storey building with 18,000 square meters reached Platinum status in both international LEED and Vietnamese LOTUS certification systems.[44] It is the first double Platinum internationally accredited factory in Vietnam and it features some of the most technologically advanced machinery and industrial system processes from Germany, Italy and Japan.[45]

Part of the renewable energy concept for the building is a 165 kWp solar PV system on the roof of the factory[46] that was planned and installed by the German solar company Aschoff Solar. The system started operation end of May 2016.[47]

Source: Aschoff Solar

[44] See footnote 40 and 41 for more information.

[45] For more information on the factory operational and building concept see: http://deutschebekleidungswerke.com/mainwp/index.php/factory-profile/ and http://www.vgbc.org.vn/index.php/lotus-project/011-NR-20-NC-Nha-may-DBW-Long-An-29

[46] In addition to the PV system, a biomass boiler that is mainly fired with rice husk provides the steam demand of the factory.

[47] Performance data of the system are available under: http://deutschebekleidungswerke.com/mainwp/index.php/carbon-footprint-savings/

The following tables give an overview of the project and the investment that was financed with 100% equity by the investor group:[48]

Table 5: Project Example DBW – Project and Investment Report

Project Information	
Location	Long Hau IZ, Long An Province
Type of system	Rooftop (flat+tilted)
Investor	DBW/Royal Spirit Group
Supplier/installer	Aschoff Solar
Start of operation	31.5.2016
Installed capacity	165 kWp
Annual yield (est.)	248,000 kWh
Specific yield (est.)	1,504 kWh/kWp
Energy demand cover ratio	5-6.5%
Avoided CO_2-emissions	140,000 kg/yr
Special features	Solar data logging/monitoring system, energy management system (DSM), preparation for grid connection and future DSO access

Investment Report	
Specific invest.	App. 1,800-1,900 USD
Total invest.	App. 300,000 USD
Equity	100%
Equity payback time	7-8ys

The next chapter will present the six case studies that were developed in the course of this project in different commercial and industrial sub-sectors of Vietnam.

[48] All data based on information provided by DBW and Aschoff Solar.

3. Investment Opportunities for Solar PV in Vietnam – Case Studies

3.1 Process and Methodology of Case Studies

The general objective and approach of the analysis has already been outlined in chapter 1.1. The following section outlines the process of the case study development and the main methodology of the investment calculations.

Process of Company Selection

The companies for the case studies have been selected in a multi-step process. The initial aim was to find a diverse sample of German, international and Vietnamese companies that represent different business sectors in Vietnam and show a sincere interest in renewable energies as an energy solution for their operations and a motivation to take part in the analysis.

Another leading thought was, with initially assumed capital payback times of more than 7-8 years for good cases going up to 10 or more years for most of the manufacturing cases with low electricity tariffs, selected companies should be financially sound and generally accepting long-term investment horizons for value-added investments such as a sustainable energy supply.

With this in mind the final sample of companies was selected in multiple steps:

First company selection: Using various available business data sources a sample of 25 companies in Southern and Central Vietnam were approached with information on the project and a requested of interest.

First visits and interviews: End of March/beginning of April 2016 the project team visited and interviewed 14 companies in HCMD and Da Nang, selected first data including site information, energy demand and investment/financing horizon of the respective companies.

Data pre-assessment and second visit: After the review of the collected data and general feasibility the project team, supported by the technical consulting and PV experts from Artelia Vietnam, six companies were selected for a further visit to gather more detailed data on power use (load profile based on company data or short-term measurements) and electricity cost structure, the energy efficiency situation and the building and roof structure of the respective site. If otherwise not available, the load profiles were measured for a few days and extrapolated on the base of further information on production or operation patterns. Available data reports e.g. from previous energy audits were taken into account as well.

Final data assessment and company selection: The final sample of six companies was selected assessing 1. technical (quality of roof and building structure, quality of grid connection and local power supply); 2. economic (load profile and cost structure of electricity demand, financial situation of the company) and 3. motivational criteria (interest in renewable energies/solar PV, existence of corporate programmes supporting sustainability and/or clean energy supply, further expectable added value of a PV investment for the company such as contributions to green building certificates etc.).

Final visit and presentation of results: After the development of the case studies and investment calculations the project team visited the companies to present the calculation results and discussed further steps within the project (workshop and German solar company trade mission in September 2016) and general investment and financing options.

Calculation of Investment Cases

After the final selection of companies, the development of the case studies was based on the following steps:[49]

[49] It has to be noted that the case studies in this report are developed as pre-feasibility studies. They are not intended to replace a full feasibility study nor a project offer from a solar company. Hence and in particular for the PV system design and solar output calculation some simplifications and standardised

PV system design: Based on the technical (roof availability etc.) and the load profile assessment a standard PV system design was developed. For some companies with large roofs and/or potential for the application of different business models, two different system designs were developed – a large and a small PV system. Further assumptions regarding system design and solar output:

- Two types of roof were standardised: Flat or tilted, for several reasons: 1. The slope of the roofs considered in this analysis is rather similar and low; 2. These two types need different technologies for the solar structure; 3. This standardisation simplifies the computing and therefore allows the developing of several case studies at the pre-design stage.

- Peak power: One peak power factor for each type of roof was selected (60 Wp/m^2 for the flat roof and 135 Wp/m^2 for the tilted roof), based on the technical consultant's experience in the region and to take into account different products and module efficiency levels available on the market. These power ratios include a site-specific safety factor (to account for potential equipment/structures on the roof, to limit the risk of shading from the barriers and to account for the distance between solar panels or arrays as well as a safety distance from the roof edge).

Calculation of solar output data: Based on the standard system design and two sets of solar irradiation data for HCMC[50] and Danang[51] the solar output data for all cases and system designs was calculated. The solar excel-based calculation tool allowed the assessment of the avoided electricity costs for the individual system as well as the monthly excess energy (balance of solar production and power demand of the company) for the development of the net metering calculation (the assumption was that the new legislation will implement a monthly billing period).

Calculation of the investment cases: For the investment calculation the "PV Power Invest" tool, developed by the German Solar Industry Association (BSW-Solar),[52] was used for the investment calculations. The calculation tool uses the common DCF-model (Discounted Cash Flow Model) for project financing. All return calculations are based on the Internal Rate of Return (IRR) method. The set of assumptions for the calculations was selected based on a survey with local Vietnamese and regional solar companies and further financing experts (see following section).

Key Assumptions for the Investment Calculation

Based on a survey with local/regional solar companies and financing experts and a review of further available data within Vietnam[53] and the region the following assumptions were selected for the case study calculations:

Power Tariff Development in Vietnam

Since both of the applied business models (self-consumption and net metering) highly rely on electricity bill savings, the most crucial and influential parameter for the case study calculations (in addition to the investment costs) is the assumption of future retail electricity tariff development in Vietnam. Current electricity tariffs for commercial and industrial operations are very low compared to most countries of the region and even worldwide. Most experts expect that this level cannot be maintained since it is not economically sustainable (see chapter 2.3). However, due to the governmentally regulated power market price forecasts are difficult and there are no political roadmaps or official scenarios available. Therefore, this study resorts to 1. Historic data and 2. Two available expert sources by the World Bank Group[54] (a recommendation to the Vietnamese government) and Fichtner Consulting[55] (a forecast of retail electricity tariffs).

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model assumptions were necessary. Inter alia, there was no specific software used to design the PV system but simplified excel-based modelling tools. This also intends to leave room for solar companies/suppliers to propose their own products and systems designs subsequent to this analysis.

[50] Weather data for HCMC: ASHRAE International Weather Files for Energy Calculations 2.0 (IWEC2), sampling of data from 1985 to 2006 for the Weather station: WMO #489000 (Lat: 10.817, Long: 106.667, Alt: 5).

[51] Weather data for Danang: ASHRAE International Weather Files for Energy Calculations 2.0 (IWEC2), sampling of data from 1985 to 2006 for the Weather station: WMO #489000 (Lat: 16.067, Long: 108.35, Alt: 7)

[52] The „PV Power Invest" tool was developed by Dr. Dominik Dersch/Matobis AG (http://www.matobis.com/en) for BSW-Solar and covers all relevant business models for solar PV rooftop investments (self-consumption, utility or direct PPA, with/without storage, with/without FIT/market premium/net metering, invest or leasing). For more information see: https://www.pv-power-invest.de (GER)

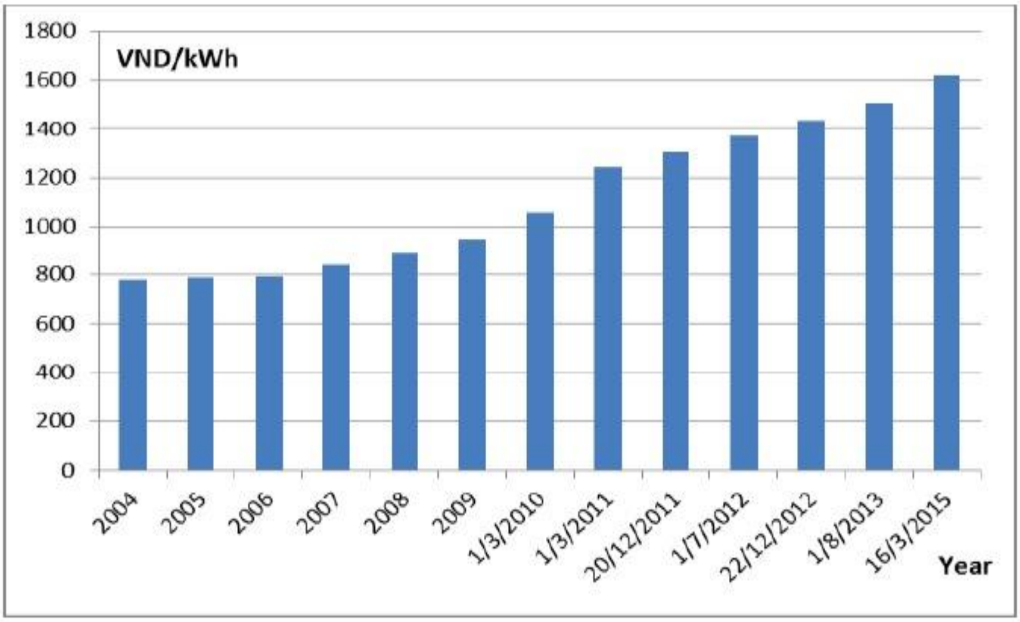
[53] Regarding PV system output and performance data no available data from PV systems in Vietnam could be found or identified. Furthermore, most of the donor funded system are poorly maintained and performance data, if available at all, are not reliable.

[54] See Maweni, Joel and Jyoti Bisbey/ The World Bank Group (2016). A Financial Recovery Plan for Vietnam Electricity (EVN). With Implications for Vietnam's Power Sector. Washington: The World Bank Group.

[55] Fichtner Consult (2014). *Vietnam Electricity Average Retail Tariff Forecast 2014-2023*. Commissioned by Dragon Capital and Holcim Cement.

Historic data for the last 10 years show an average increase of the average commercial and industrial retail electricity tariffs by 5-6%.[56]

Figure 5: Development of the Average Retail Power Price 2004-2015 in Vietnam



Source: Institute of Energy (2015).

In order to get the assumption for power tariff development for a PV system calculation period of 20 years the World Bank and Fichtner Consulting reports may give some guidance.

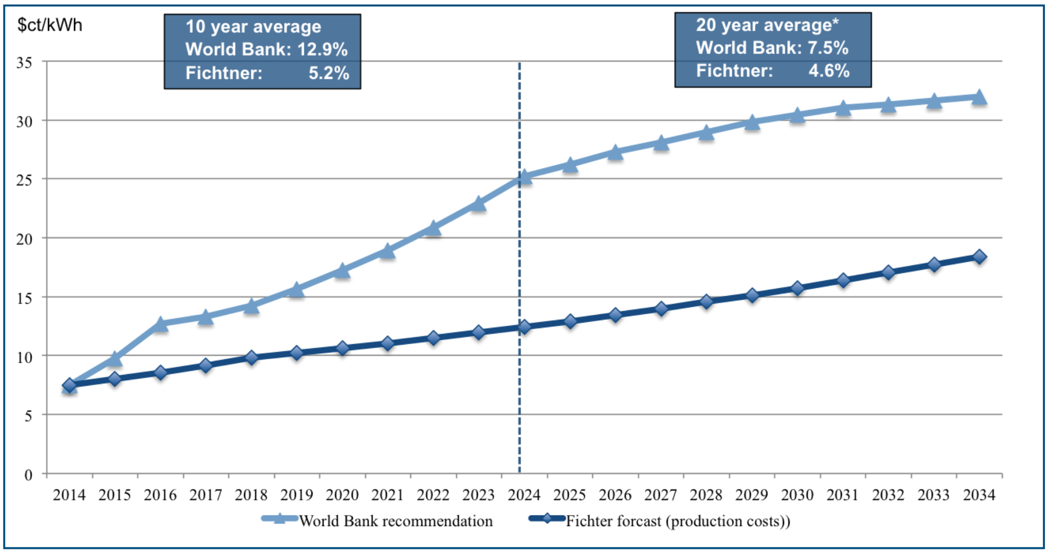
Both perspectives only look at a 10-year period. With additional assumptions a 20-year average was developed for the study:

- The recommendations of the **World Bank Group** result in an average of 12.9% annual increase until 2024. With the own assumption of a substantively flattened increase path for the following 10 years the assumption for 20 years would be roughly 7% p.a. on average.

- The forecast of **Fichtner Consulting** includes an average increase of electricity retail tariffs of roughly 5% until 2024, basically carrying forward the historic development. With the own assumption of a continued, or slightly lower path for the following 10 years the assumption for a 20-year average would be roughly 5%.

[56] If inflation is taken into account prices where largely stable.

Figure 6: Projection of Power Tariff Development in Vietnam until 2035



Source: World Bank Group, Fichtner Consulting and own assumptions.

Derived from these considerations the assumptions and scenarios for power tariff increase for the investment calculations have been set as following:

Table 6: Case Study Assumptions – Annual Power Tariff Increase

Key assumptions / Scenarios	Low Increase	Base	High Increase
Annual power tariff increase	3%	5%	7%

Assumptions on Investment and O&M Costs

Based on the market survey and interviews with solar companies active in Vietnam and the region the following further assumptions and scenarios for investment costs have been set:

Specific investment costs: The ‘base’ case for small and medium sized commercial PV rooftop systems is defined with 1,700 USD/kWp. Only for one case with a system size of almost 4 MWp the ‘base’ case is lowered to 1,500 USD/kWp. Additional scenarios are ‘high’ with 1,900 USD/kWp, ‘low’ with 1,500 USD/kWp and for some of the larger systems ‘very low’ with 1,300 USD/kWp or 1,100 USD/kWp respectively.

Specific costs for operation and maintenance: Since there is only very limited data from commercial PV projects available in Vietnam, the selection of O&M costs has to resort to assumptions derived from other regional markets or refer to the general cost level of comparable businesses or services in Vietnam. For instance, there is no known PV rooftop system yet in Vietnam that has been insured. It is further assumed that the O&M costs increase by 3% per year over the lifetime of the PV system. The following table gives an overview of the chosen assumptions for operation and maintenance (for the 4 GW case study the O&M costs were reduced to 15 USD/kWp):

Table 7: Case Study Assumptions – Operation and Maintenance Costs

Key Assumptions / O&M Costs	
Annual maintenance costs	5 USD/kWp
Annual increase of maintenance costs	3%
Annual insurance costs	5 USD/kWp
Annual provisions for repairs/ component replacement (inverter)	10 USD/kWp
Total maintenance costs	**20 USD/kWp**

Assumptions on Revenues and CO_2-Reduction

Specific system yield: The specific yield of the PV systems was calculated on the base of the solar irradiation data sets for HCMC and Danang, the standard PV system setting individually set correction factors e.g. for shading effects. The specific yield for the HCMC region cases varies from 1,334 to 1,467 kWh/kWp. The Danang case has a lower specific yield of 1,130 kWh/kWp due to the lower irradiation in Central Vietnam.

CO_2-emission factor: To calculate the avoided CO_2-emissions for the PV systems the latest Vietnamese government reports to the UNFCCC secretariat can be consulted. Accordingly, the current power mix of Vietnam has a CO_2-emission factor of 0.5657 tons of CO_2 per kilowatt-hour and year.[57]

Revenues from electricity cost savings: As mentioned already above, revenues from electricity cost savings are calculated in three different cost increase scenarios: 3%, 5% and 7% annual increase of electricity retail tariffs.

Revenues from net metering credits: In the net metering cases, further revenues come from the reimbursement of excess solar power that is sold to the grid (to EVN) and remunerated with a fixed net metering credit. Due to the assumptions regarding the implementation and administering of the net metering scheme (see chapter 2.2), the credit is legally defined and fixed with the implementation of the law. Usually, in net metering and net billing schemes the credit develops with the development of the overall electricity tariffs. In a classic net metering scheme the credit is identical with the individual retail power tariff that the PV system owner pays. If the power tariff rises, the net metering credit rises likewise. In most net billing schemes the credit for excess solar energy exported to the grid is regularly adjusted according to the overall development of electricity tariffs in the country or price zone (thus, and this is different to a classic fixed FIT system, the credit can vary over the lifetime of a PV system).

In the course of this study the latter is assumed. Accordingly, it is assumed that in the different electricity tariff scenarios ('low', 'base', 'high") the net metering credit develops in line with the retail electricity tariff. In addition to that, a zero increase scenario is included where the net metering credit is fixed at the beginning and does not increase over time).

The following table gives an overview on the key assumptions on investment costs, O&M costs, revenues and avoided CO_2-emissions:

Table 8: Case Study Assumptions – Overview Investment Costs and Revenues

Key Assumptions Investment & Revenues	Very Optimistic	Optimistic	Base Case	High Cost/ Low Tariff Increase	
Specific invest cost (USD/kWp)	1,100/1,300	1,500	1,500/1,700	1,900	
Annual O&M costs (USD/kWp)	20 (15) / +3%p.a.				
Specific yield (kWh/kWp)	1,130 – 1,435				
Annual increase power tariff	7%	7%	5%	3%	
Annual increase net metering credit	7%	7%	5%	3%	0%
Avoided CO_2-emissions (t/kWh)	0.5657				

Assumptions on Financing

All cases are based on a 20-year project calculation. Regarding financing two different options are taken into account:

Equity financing: 100% of the investment costs are financed with own equity of the system operator.
Equity/loan financing: The investment costs are financed with 30% equity and 70% loan.
Internal balance sheet funding: For the mixed equity/loan financing two standardised financing models were defined. Since all selected companies are sound German or OECD-country based corporations with in general good creditworthiness it was assumed

[57] Latest available data are for 2013. See MoNRE (2014). Nghiên Cứu, Xây Dựng Hệ Số Phát Thải Của Lưới Diện Việt Nam (Determination of Current Emission Factors for Vietnam). Download: http://noccop.org.vn/Data/vbpq/Airvariable_ldoc_71vnBC%20cuoi%20cung%202013.pdf

that these companies have the option of comparatively low interest rate refinancing on international capital markets. According to that assumption an interest rate of 3% over a 12-year loan tenor and an internal discount rate of 4% was chosen.

Commercial domestic lending: To have the comparison to a local project financing that relies on a commercial domestic (Vietnamese) bank loan a second financing model is calculated in form of a scenario. Here, the interest rate is 9% and a 10% discount rate is applied.

Tax rate: Since it was difficult to assess the individual tax situation of the selected companies with the available time and resources, a standard tax rate of 20% was applied. However, all IRR result figures are displayed 'before tax'.

The following table gives an overview of key assumptions for financing and taxes:

Table 9: Case Study Assumptions – Financing and Taxes

Key Assumptions / Financing & Taxes	
Internal balance sheet funding	3% interest rate / 5% discount rate
Vietnamese commercial lending	9% interest rate / 10% discount rate
Equity / debt	30% / 70%
Loan tenor	12 years
Amortization	Linear / 20 years
Tax rate	20%

Overview of Case Studies

The following table gives an overview of all six case studies with the key features of the respective companies:

Table 10: Overview of Cases

Case Study	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6
Type of business	**Super-market**	**Cold Storage**	**Manufacturing** (EDS)*	**Manufacturing** (consumer products)	**Manufacturing** (automotive)	**Manufacturing** (machine parts)
Operation	24/7	24/7	6 days	24/7	24/7	6 days
Load profile	Medium	Medium	Low	High	High	Medium
Self-consumption	✔	✔	✔	✔	✔	✔
Net metering	□	□	✔	□	□	✔

* Electrical Distribution System

The following chapters will highlight the case studies in detail including the investment calculations for the different business models. Each case study will refer to 1. the general company profile; 2. load profile and cost structure of power demand; 3. the general energy efficiency situation and energy management of the company; 4. the assessment of the building and roof structure; 5. the PV system design and finally 6. the results of the investment calculation.

3.2 Case Study 1: Supermarket

3.2.1 General Company Profile

The supermarket is located in HCMC and was selected for the case study due to suitable roof area on a carport canopy in front of the market, relatively high power costs and high interest in solar PV technology. The market operates 24/7 for 362 days of the year.

The group behind the market is present in Vietnam with a number of markets throughout the country. The group management has implemented an energy efficiency programme that encourages all markets to reduce energy consumption and power bills.

The market management has shown sincere interest in solar PV for some time and had previous contact with solar companies.

3.2.2 Load Profile and Cost Structure of Energy Demand

Power consumption: The total power consumption of the supermarket was 6.05 GWh for 2014 and 5.66 GWh for 2015.

Main energy uses: The main energy uses are:
- The chiller and associated technical systems (AHU, pumps, cooling towers) for the air conditioning of the shopping center.
- The lighting of the sales area.
- The positive and negative cold plants.

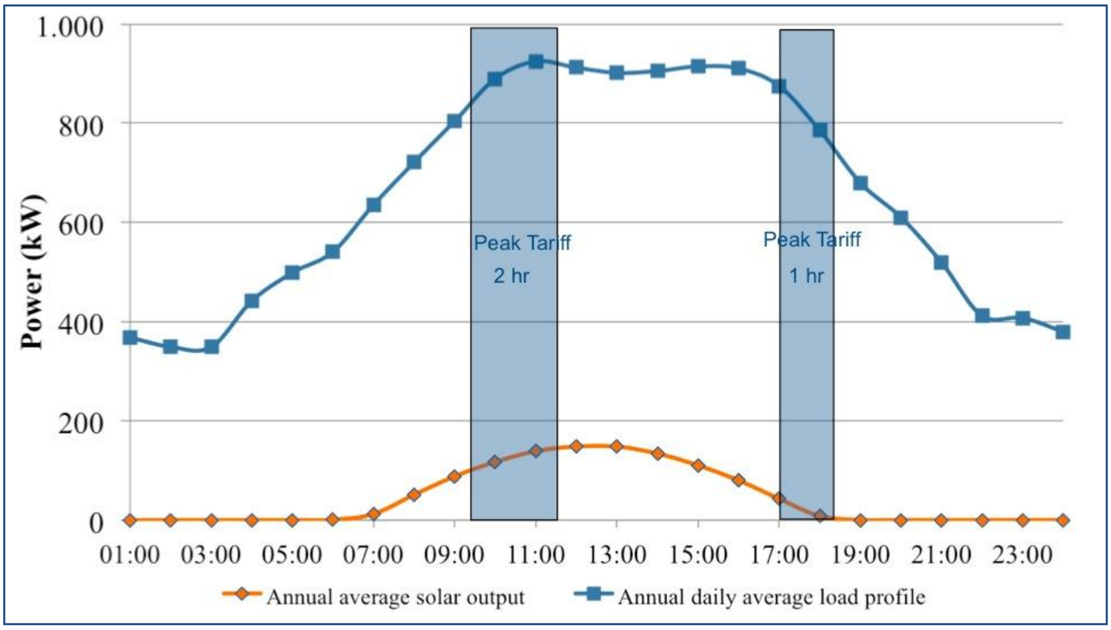
Power tariff: The supermarket has a rather high EVN electricity tariff, as it is a commercial operation with a medium voltage connection (“from 6kV to 22kV”) to the EVN grid. The current electricity tariffs are:

- Normal (4:00-9:30; 11:30-17:00; 20:00-22:00): 2,287VND/kWh (10.3USDct/kWh)
- Low (22:00-4:00): 1,347VND/kWh (6.0USDct/kWh)
- High (9:30-11:30; 17:00-20:00): 3,829VND/kWh (17.2USDct/kWh)

Avoided costs: The average avoided costs for the solar PV system are 2636VND/kWh (11.82USDct/kWh).

Load profile: The market operates 24/7 for 362 days per year. The minimum load during solar production hours is never below 500 kW throughout the year. Maximum load during mid-day hours is between 800kW and 1,000kW depending on the day of week.

Figure 7: Case 1 (Supermarket) – Annual Daily Power and Solar Curve (280 kWp) with Peak Tariff Hours



Data from the supermarket's own monitoring system were provided for a full year, with the total power consumption being recorded every 15 minutes. The above graph shows the annual daily average power curve, calculated based on the data from the monitoring system and the solar curve of the chosen PV system.

The load curve shows that the energy consumption is much higher during daytime, mainly due to the air conditioning system and lighting in the sales areas. It still has rather high energy consumption during the night, showing room for energy efficiency measures.

The same load profiles were calculated for each weekday, Saturday and Sunday for each month of the year, in order to compare it with the solar output. Since the supermarket operates all day throughout the year, there is little variation of load profile between days of the week and months over the year.

The technical staff reported no regular power outages or brownouts. Currently, there is no major renovation of the site planned for the coming years.

3.2.3 Energy Efficiency and Energy Management

Energy efficiency measures: The Supermarket has already implemented some energy efficiency measures, such as:

- Implementation of an energy monitoring system.
- Installation of sky domes for the sales area.
- Installation of LED lighting.

This has resulted in significant savings, between 2014 and 2015:

- -6.50% in terms of kWh (from 6.05 down to 5.66 GWh);
- -6.17% in terms of electricity expenditures.

It is likely that other energy efficiency measures have been implemented, though no energy audit report has been provided.

The sky domes ("solar tubes") on the main roof:

Source: Rainer Brohm (left)/Artelia VN (right)

Energy use: The power monitoring system shows the following energy breakdown (data from 2012):

- Lighting: 16.5%
- Air conditioning: 14.8%
- Cold storage: 18.0%
- Ventilation: 7.1%
- Other: 43.6%

It is likely that the "other" part includes also the main chilled water production.

Energy management: This site does have a total energy use above 500 TOE[58](tons of oil equivalent) per year, therefore has to follow the requirements from the Decree 21/2011/NĐ-CP (detailed regulations and measures for implementing the Law on Use of Energy Saving and Efficiency, issued March 29, 2011):

- Energy audit to be conducted every 3 years, by a specialized firm being trained by MOIT;
- Appoint an energy management officer;
- Develop and implement annual and 5-year plans for energy saving and efficiency;
- Comply with the provisions on energy saving and efficiency during the construction, upgrading or expansion of construction works.

No information was provided regarding ISO certification of the operation.

3.2.4 Assessment of Building and Roof Structure

This main market building has been built in 2003 and has several roofs:

- The main building, with a very small slope and many sky domes and supporting structures on the roof;
- A main carport canopy in front of the market;
- A small motorbike canopy;
- A warehouse on the same compound.

Roof selection: The main roof of the market building carries many sky domes and technical facilities. Therefore a solar PV system could not be installed with an efficient usage of space and adequate sizing without removing or affecting these facilities.

The building and roof structure of the warehouse is of lower quality and condition. Therefore it was not selected for the PV system installation:


Source: Artelia VN

The small motorbike canopy has significant shading issues (low height) and its structure appears to be too weak for an installation of a PV system.

[58] For industry operations the requirement is >1,000 TOE.

Therefore, only the main carport canopy is considered for a PV installation. It has a metal sheet profile and seems to have a stable structure to carry the PV system (to be confirmed with specific calculations). The canopy area is 2,308 m^2, which allows for a PV peak power of 280 kW:

Source: Artelia VN (left), Rainer Brohm (right)

Source: Artelia VN

The potential location for inverters and monitoring display should be determined during further investigations.

3.2.5 PV System Design

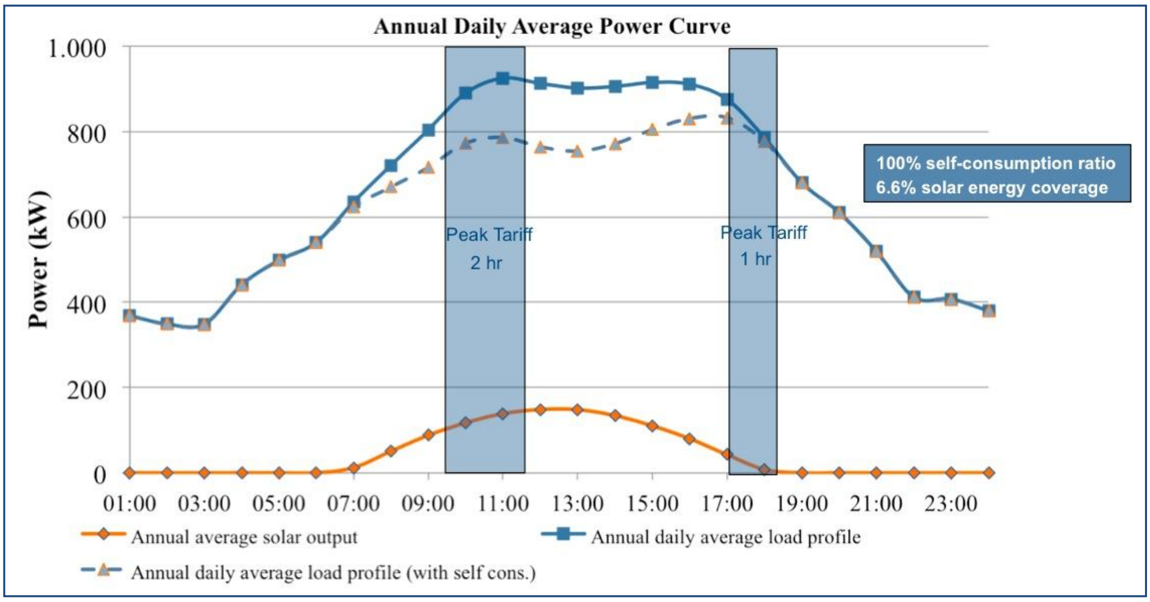
Based on the technical assessment of the roof and building structure as investigated on site, a provisional PV design was developed. Table 11 summarizes the proposed PV system design.

Table 11: Case 1 (Supermarket) – Overview of Proposed System Design

Proposed PV System Design	
Peak power	280 kWp
Estimated number of solar panels (based on typical 150Wp multi-crystalline solar panels)	1867
Type of inverter	50 kVA
Quantity of inverters	6
DC array boxes	To be defined
AC control and monitoring panel	To be located between the inverters and electrical cabinet (to be defined)

The system is designed to maximise on-site energy consumption and reaches a 100% self-consumption ratio and 6.6% solar energy coverage. Figure 8 shows the average annual daily power curve, the solar generation curve and the residual demand curve after self-consumption.

Figure 8: Case 1 (Supermarket) – Daily Power Curve, Solar Curve (280 kWp) and Residual Load



3.2.6 Results of Investment Calculation

The following section summarises the results of the investment calculation. Based on the load profile and the developed PV system design the only possible business model is self-consumption. There will be no excess energy that could be sold to the grid (see load profile in figure 5, chapter 3.2.2).

Project Report and Results of Investment Calculation

Table 12 summarises the project information and main investment and performance parameter of the PV system:

Table 12: Case 1 (Supermarket) – Project Report

System Information	
Location	Ho Chi Minh City, Vietnam
Start of operation	January 2016
Operation lifetime	20 years
Installed capacity	280 kWp
Annual yield (first year)	398,440 kWh
Specific yield	1,423 kWh/kWp
Avoided CO_2-emissions*	213,072 kg/yr

* Average over system lifetime

Power Production and Demand	
Total annual power demand	5,743 MWh
Annual yield*	377 MWh
Self-consumed solar electr.*	377 MWh
Excess solar energy (sale to grid)*	-
Solar energy coverage*	6,6%
Self-consumption ratio*	100%
Avoided cost PV (first year)	2,635VND (11.82USDct)
Annual increase power tariff (Base)	5%

* Average over system lifetime

Costs and Financing	100% Equity	30% Equity
Specific invest.	1,700 USD	1,700 USD
Total invest.	476,000 USD	476,000 USD
Equity	476,000 USD	142,800 USD
Operational costs (first year)*	5,600 USD	5,600 USD
Operational costs per kWp	20USD/kWp	20USD/kWp
Debt	-	333,200 USD
Loan tenor	-	12yrs
Loan interest rate*	-	3%
Discount rate	5%	5%
Tax rate	20%	20%

*Internal balance sheet funding, linear amortization

Table 14 shows the results for two different financing options (as described in chapter 3.1), assuming 1. an internal balance sheet funding with a low interest rate and a low corresponding discount rate and 2. a Vietnamese commercial lending model with high interest rates and a corresponding high internal discount rate.

Table 13: Case 1 (Supermarket) – Financial Report and Scenarios

Main Results*	100% Equity	30% Equity
Equity IRR (before tax)	10.5%	15.9%
Project IRR (before tax)	10.5%	10.5%
Pay-back of equity	10.3yr	10.3yr
Pay-back of total investment	10.3yr	10.3yr
Capital reflux in % of equity	244.6%	545.6%
Capital reflux in % of total invest.	244.6%	244.6%
Solar LCOE	11.62ct/kWh	11.62ct/kWh
Average electricity tariff (over 20yrs)	19.54ct/kWh	19.54ct/kWh
Min. DSCR	-	1,06
Average DSCR	-	1,52

* Internal balance sheet funding (3% interest rate, 12yr loan term, 5% discount rate)

Annual Power Price Increase*	Low Increase 3%	Base Case 5%	High Increase 7%
Project IRR (before tax)	8.4%	10.5%	12.5%
Equity IRR (before tax)	12.6%	15.9%	19.0%
Pay-back of equity (yr)	12.2	10.3	9.0
Capital reflux in % of equity	395.1%	545.6%	738.0%
Solar LCOE (ct/kWh)	11.62	11.62	11.62
Av. electricity tariff (over 20yrs)	15.88	19.54	24.23
Min. DSCR	1.06	1.06	1.06
Average DSCR	1.35	1.52	1.71

* 30% equity financing

System Investment Costs* (USD/kWp)	Low Cost 1,500	Base Case 1,700	High Cost 1,900
Project IRR (before tax)	12.1%	10.5%	9.1%
Equity IRR (before tax)	19.1%	15.9%	13.4%
Pay-back of equity (yr)	8.5	10.3	12.1
Capital reflux in % of equity	645.5%	545.6%	466.8%
Solar LCOE (ct/kWh)	10.44	11.62	12.80
Av. electricity tariff (over 20yrs)	19.54	19.54	19.54
Min. DSCR	1.18	1.06	0.97
Average DSCR	1.69	1.52	1.37

* 30% equity financing

Table 14: Case 1 (Supermarket) – Financing Scenarios

Financing Model (30% Equity)	Internal* 5% Discount Rate 3% Loan Interest	External** 10% Discount Rate 9% Loan Interest
Project IRR (before tax)	10.5%	10.5%
Equity IRR (before tax)	15.9%	11.4%
Pay-back of equity (yr)	10.3	12.9
Capital reflux in % of equity	545.6%	469.6%
NPV of project (USD)	192,353	-36,780
NPV rel. to project value	40.4%	-7.7%
NPV of equity (USD)	235,487	-3,757
NPV rel. to equity	164.9%	-2.6%
Solar LCOE (ct/kWh)	11.62	16.13
Av. electricity tariff (over 20yrs)	19.54	19.54
Min. DSCR	1.06	0.72
Average DSCR	1.52	1.24

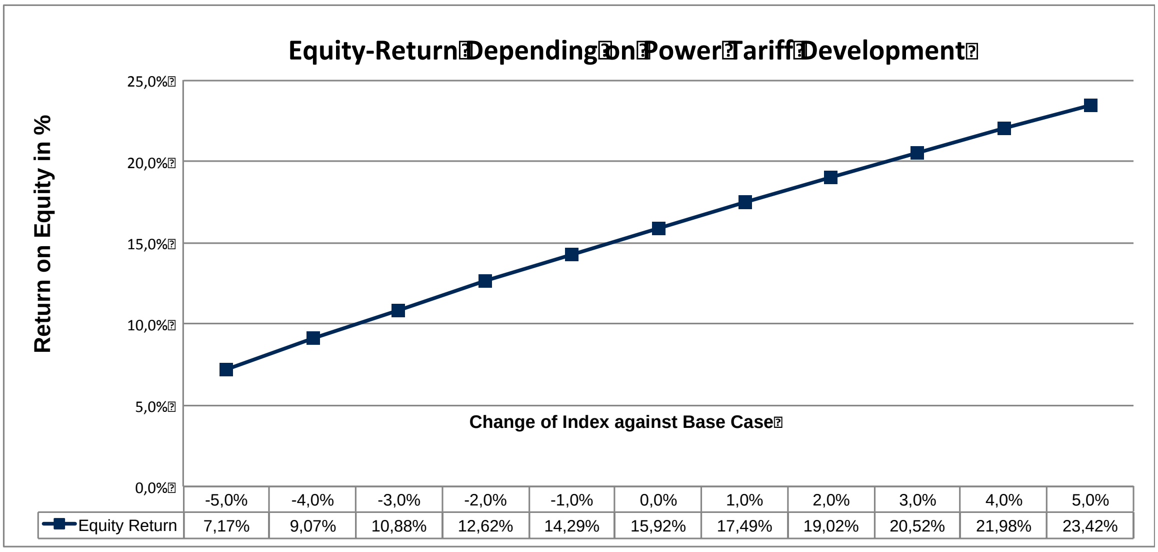
* Internal corporate balance sheet funding, base case
** Vietnamese commercial lending, base case

The overall results of the investment calculation show one of the most attractive investment cases among the selected companies due to the relatively high power tariffs and correspondingly high power cost savings that can be realised with the PV self-consumption business model.

Influence of Key Parameters

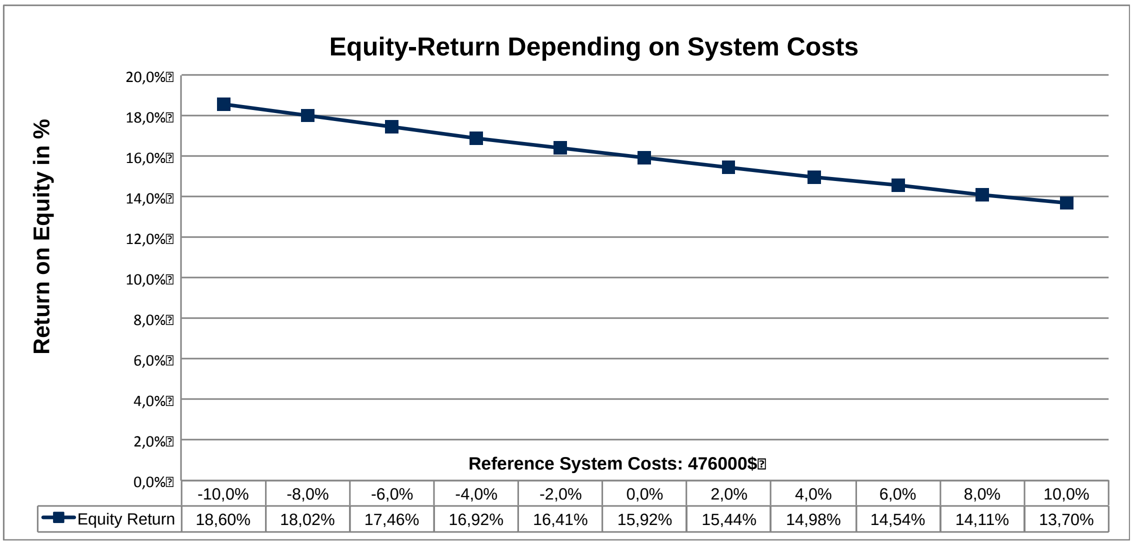
Looking at the key parameters that influence capital return it shows that the assumptions on power tariff development are most influential (see figure 9). This is typical for a 100% self-consumption model and also reflects the influence of the currently low power tariffs that apply for commercial operations in Vietnam.

Figure 9: Case 1 (Supermarket) – Influence of Power Tariff Development on Equity Return



Apart from power tariff development, the assumptions on investment costs have a strong influence on the results of the investment calculations. Figure 10 shows the sensitivity of equity return regarding investment costs.

Figure 10: Case 1 (Supermarket) – Influence of System Investment Costs on Equity Return



Case Study 2: Cold Storage

3.2.7 General Company Profile

The cold storage is situated in Binh Duong province close to HCMC. The facility is cold storing seafood and other products for various wholesalers and retailers in southern Vietnam. The company is currently building another cold storage close to Hanoi in Northern Vietnam.

The company was selected for the case study due to its high interest in solar PV investments and a relatively high power tariff. The company management is considering investing in a PV system at the HCMC operation and the newly planned Hanoi operation.

The company is a family run company with worldwide operations and a high commitment to green tech und sustainability.

3.2.8 Load Profile and Cost Structure of Energy Demand

Power consumption: The total energy consumption of the cold storage is rather high: 14.4 GWh in 2015 and 3.4 GWh in the first three months in 2016.

Main energy uses: The main energy uses are:
- Positive and negative cold rooms (5 screw two-stage compressors): the energy consumption is quite stable, the compressors operate 24/24h;
- Chillers and associated technical systems (AHU, pumps, cooling towers) for the air conditioning;
- Lighting.

Power tariff: The company has a combination of the EVN "business" (65%) and the EVN "manufacturing" (35%) electricity tariff, with a medium voltage connection ("from 22kV to 110kV") to the EVN grid. The current electricity tariffs are:

- Normal (4:00-9:30; 11:30-17:00; 20:00-22:00): 1,873 VND/kWh (8.5USDct/kWh)
- Low (22:00-4:00): 1,086 VND/kWh (4.8USDct/kWh)
- High (9:30-11:30; 17:00-20:00): 3,299 VND/kWh (14.8USDct/kWh)

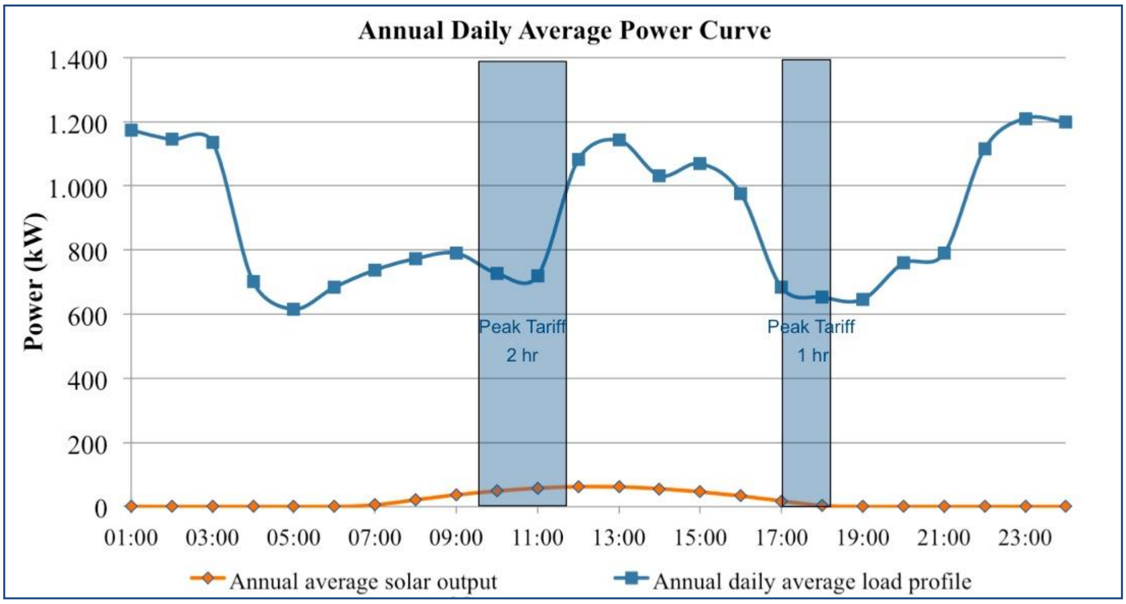
Avoided costs: The average avoided costs for the solar PV system are 2,195VND/kWh (9.84USDct/kWh).

Load profile: The facility operates 7 days per week 24 hours. However, on Sundays there is only minimum maintenance staff at the site and no office staff. The load ranges between 600-1,200 kW during Weekdays and Saturdays. On Sundays the min. load is 500kW.

The management has provided no load profile. Thus, the data was collected by short-term measurements for 5 consecutive days (from 22 to 27 April 2016). For the remaining days of the year, it has been extrapolated based on available monthly consumption data (from January 2015 to March 2016). The power measurements were made at two ATS cabinets:

Source: Artelia VN

Figure 11: Case 2 (Cold Storage) – Annual Daily Power and Solar Curve (123 kWp) with Peak Tariff Hours



The management has implemented a Demand-Side-Management scheme and actively shifts load from peak-tariff hours to normal-tariff hours (compressor operating schedule). Figure 11 shows the effects of this energy management quite clearly.

The same load profiles were calculated for each weekday, Saturday and Sunday for each month of the year, in order to compare it with the solar output. As the cold storage operates 24h throughout the year, there is little variation of load profile between days of the week and months over the year.

According to the technical staff, there is in general one power cut-off by EVN every month for short periods (about 4-5 hours per month). The quality of power supply has improved substantially over the last few years and is not considered as a problem.

The diesel generators (750 and 1,100 kVA) operate every month for testing and to supply electricity during EVN power cut-off hours. The total diesel consumption of the two generators in 2015 was 15,003 litres.

A major renovation or extension of the site is not planned in the coming years. However, the situation of the main roof could be addressed in the context of a planned PV system investment.

3.2.9 Energy Efficiency and Energy Management

Energy efficiency measures: The facility has high power consumption, especially from the compressors for cold rooms, chiller & air conditioning and lighting. According to the energy audit dated on December 2015, some energy efficiency measures have been already implemented, such as:

- Using VSDs and monitoring system for 5 compressors
- Using LED with monitoring system for lighting in the storage
- Installing motion sensors for lighting
- Installing double pane glazing for the offices

Energy use and management: This site has a total energy use above 1000 TOE[59](tons of oil equivalent) per year, therefore it has to follow the requirements from the Decree 21/2011/NĐ-CP (detailed regulations and measures for implementing the Law on Use of Energy Saving and Efficiency, issued March 29, 2011):

[59] For commercial operations the requirement is >500 TOE.

- Energy audit to be conducted every 3 years, by a specialized firm being trained by MOIT;
- Appoint an energy management officer;
- Develop and implement annual and 5-year plans for energy saving and efficiency;
- Comply with the provisions on energy saving and efficiency during the construction, upgrading or expansion of construction works.

The facility got ISO 9001:2008 certified in October 2013.

3.2.10 Assessment of Building and Roof Structure

The cold storage is situated in an industrial park in Binh Duong Province, Vietnam.

This site has been built 10-15 years ago and has several buildings with different roofs:

- The cold rooms (main building);
- The administrative buildings;
- The technical areas;
- The truck yards, parking lots, etc.

According to the site visit and also to the discussion with the management, three roof areas (see below) would be suitable for a solar PV installation. They all have metal sheet profiles, with the following areas:

- Roof 1: 634 m^2
- Roof 2: 242 m^2
- Roof 3: 300 m^2

Totalling 1,176 m^2 of available roof area.

Roof selection: The roof of the main building (cold rooms) seems to be too weak for a PV installation. In order to increase insulation, the company constructed a 2-layer (sandwich) roof. The first layer contains a foam material that has absorbed a lot of moisture and water coming from the cool storage beneath and therefore increased its own weight over time. This inner layer is attached to (hanging at) the top roof layer. Thus, the latter top roof layer cannot carry any more substantial load.

For the three selected roofs, there have been some shading risks identified that come from adjacent buildings. Losses are evaluated at 10% (depending on the distance of the modules from the adjacent wall).

Roof #1 with potential shading issue:


Source: Artelia VN

Metal sheet roof (roof #2):

Source: Artelia VN

Metal sheet roof (roof #3):

Source: Artelia VN

Main building roof with 2-layer hanging structure:

Source: Artelia VN

Other roofs not taken into consideration (motorbike canopy and fish sorting area)


Source: Artelia VN

The total peak power has been estimated based on the total available area of the three selected roofs (1,176m^2) with **123 kWp**.

The potential location for inverters could be next to the two transformers of the site. They should be installed preferably inside a technical room.

3.2.11 PV System Design

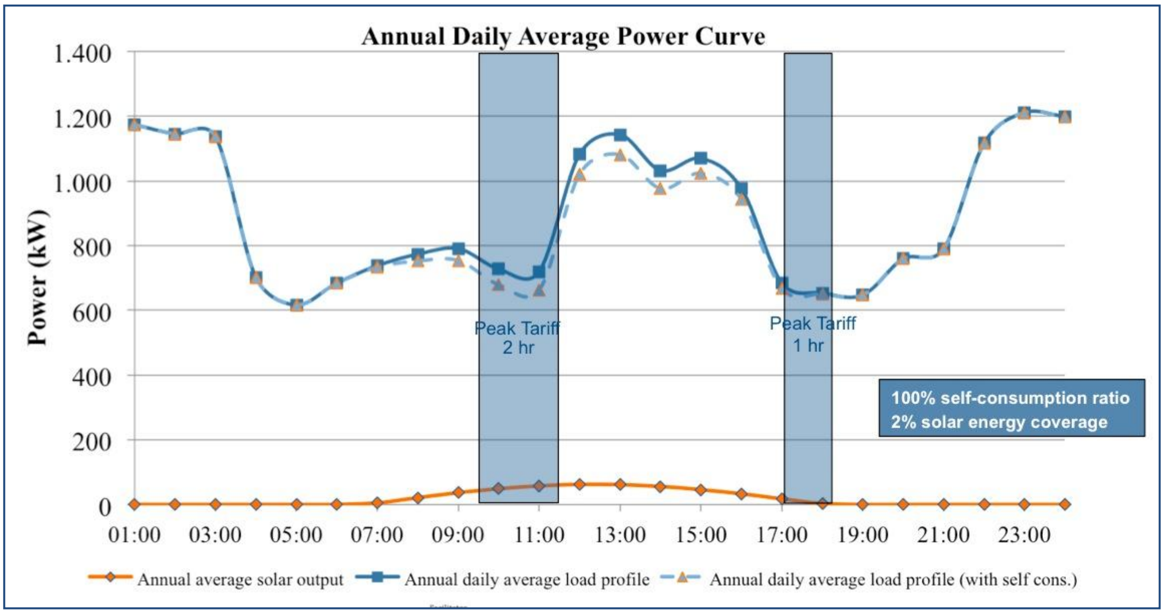
Based on the technical assessment of the roof and building structure as investigated on site, a provisional PV design was developed. Table 15 summarizes the proposed PV system design.

Table 15: Case 2 (Cold Storage) – Overview of Proposed System Design

Proposed PV System Design	
Peak power	123 kWp
Estimated number of solar panels (based on typical 150Wp multi-crystalline solar panels)	820
Type of inverter	20 and 50 kVA
Quantity of inverters	5 (1x20 kVA for Roof #3; 2x20 kVA for Roof #2; 1x50 kVA+1x20 kVA for Roof #1)
DC array boxes	To be defined
AC control and monitoring panel	To be located between the inverters and electrical cabinet (to be defined)

The system is designed to maximise on-site energy consumption and reaches a 100% self-consumption ratio and 2% solar energy coverage. Figure 12 shows the average annual daily power curve, the solar generation curve and the residual demand curve after self-consumption.

Figure 12: Case 2 (Cold Storage) – Daily Power Curve, Solar Curve (123 kWp) and Residual Demand



3.2.12 Results of Investment Calculation

The following section summarises the results of the investment calculation. Based on the load profile and the developed PV system design the only possible business model is self-consumption. There will be no excess energy that could be sold to the grid (see load profile in figure 8, chapter 3.3.2).

Project Report and Results of Investment Calculation

Table 16 summarises the project information and main investment and performance parameter of the PV system:

Table 16: Case 2 (Cold Storage) – Project Report

System Information	
Location	Binh Duong, Vietnam
Start of operation	January 2016
Operation lifetime	20 years
Installed capacity	123 kWp
Annual yield (first year)	164,082 kWh
Specific yield	1,334 kWh/kWp
Avoided CO_2-emissions*	87,745 kg/yr

* Average over system lifetime

Power Production and Demand	
Total annual power demand	7,870,000 MWh
Annual yield*	155 MWh
Self-consumed solar electr.*	155 MWh
Excess solar energy (sale to grid)*	-
Solar energy coverage*	2.0%
Self-consumption ratio*	100%
Avoided cost PV (first year)	2,195VND (9.84USDct)
Annual increase power tariff (Base)	5%

* Average over system lifetime

Costs and Financing	100% Equity	30% Equity
Specific invest.	1,700 USD	1,700 USD
Total invest.	209,100 USD	209,100 USD
Equity	1,608,200 USD	62,730 USD
Operational costs (first year)*	2,460 USD	2,460 USD
Operational costs per kWp	20USD/kWp	20USD/kWp
Debt	-	146,370 USD
Loan tenor	-	12 yrs
Loan interest rate*	-	3%
Discount rate	5%	5%
Tax rate	20%	20%

*Internal balance sheet funding, linear amortization

Table 17: Case 2 (Cold Storage) – Financial Report and Scenarios

Main Results – Base Case*	100% Equity	30% Equity
Equity IRR (before tax)	7.2%	10.0%
Project IRR (before tax)	7.2%	7.2%
Pay-back of equity	12.5yr	13.5yr
Pay-back of total investment	12.5yr	12.5yr
Capital reflux in % of equity	190.8%	365.9%
Capital reflux in % of total invest.	190.8%	190.8%
Solar LCOE	12.40ct/kWh	12.40ct/kWh
Average electricity tariff (over 20yrs)	16.27ct/kWh	16.27ct/kWh
Min. DSCR	-	0.83
Average DSCR	-	1.19

* Internal balance sheet funding (3% interest rate, 12yr loan term, 5% discount rate)

Annual Power Price Increase*	Low Increase 3%	Base Case 5%	High Increase 7%
Project IRR (before tax)	5.1%	7.2%	9.2%
Equity IRR (before tax)	6.6%	10.0%	13.1%
Pay-back of equity (yr)	15.1	13.5	12.3
Capital reflux in % of equity	248.3%	365.9%	516.0%
Solar LCOE (ct/kWh)	12.40	12.40	12.40
Av. electricity tariff (over 20yrs)	13.22	16.27	20.17
Min. DSCR	0.83	0.83	0.83
Average DSCR	1.06	1.19	1.34

* 30% equity financing

System Investment Costs* (USD/kWp)	Low Cost 1,500	Base Case 1,700	High Cost 1,900
Project IRR (before tax)	8.6%	7.2%	6.0%
Equity IRR (before tax)	12.5%	10.0%	7.9%
Pay-back of equity (yr)	12.4	13.5	14.6
Capital reflux in % of equity	442.2%	356.9%	304.8%
Solar LCOE (ct/kWh)	11.14	12.40	13.66
Av. electricity tariff (over 20yrs)	16.27	16.27	16.27
Min. DSCR	0.93	0.83	0.74
Average DSCR	1.33	1.19	1.08

* 30% equity financing

Table 18: Case 2 (Cold Storage) – Financing Scenarios

Financing Mode (30% Equity)	Internal* 5% Discount Rate 3% Loan Interest	External** 10% Discount Rate 9% Loan Interest
Project IRR (before tax)	7.2%	7.2%
Equity IRR (before tax)	10.0%	6.2%
Pay-back of equity (yr)	13.5	15.7
Capital reflux in % of equity	365.9%	283.2%
NPV of project (USD)	22,176	-54,330
NPV rel. to project value	10.6%	-26.0%
NPV of equity (USD)	40,896	-42,888
NPV rel. to equity	65.2%	-68.4%
Solar LCOE (ct/kWh)	12.40	17.20
Av. electricity tariff (over 20yrs)	16.27	16.27
Min. DSCR	0.83	0.54
Average DSCR	1.19	0.96

* Internal corporate balance sheet funding, base case
** Vietnamese commercial lending, base case

Table 18 shows the results for two different financing options (as described in chapter 3.1), assuming 1. an internal balance sheet funding with a low interest rate and a low corresponding discount rate and 2. a Vietnamese commercial lending model with high interest rates and a corresponding high internal discount rate.

The overall results of the investment calculation show one of the most attractive investment cases among the selected companies due to the relatively high power tariff and correspondingly high power cost savings that can be realised with the PV self-consumption business model. However, the results are lower than could be expected at this site due to the calculated shading losses. The PV system sizing according to the shading issues should be addressed by solar companies approaching the company again. A different assessment of the shading risks would result in a different specific yield. To illustrate the influence of this factor table 19 shows a sensitivity regarding variations of specific yield.

Table 19: Case 2 (Cold Storage) – Scenario Specific Yield

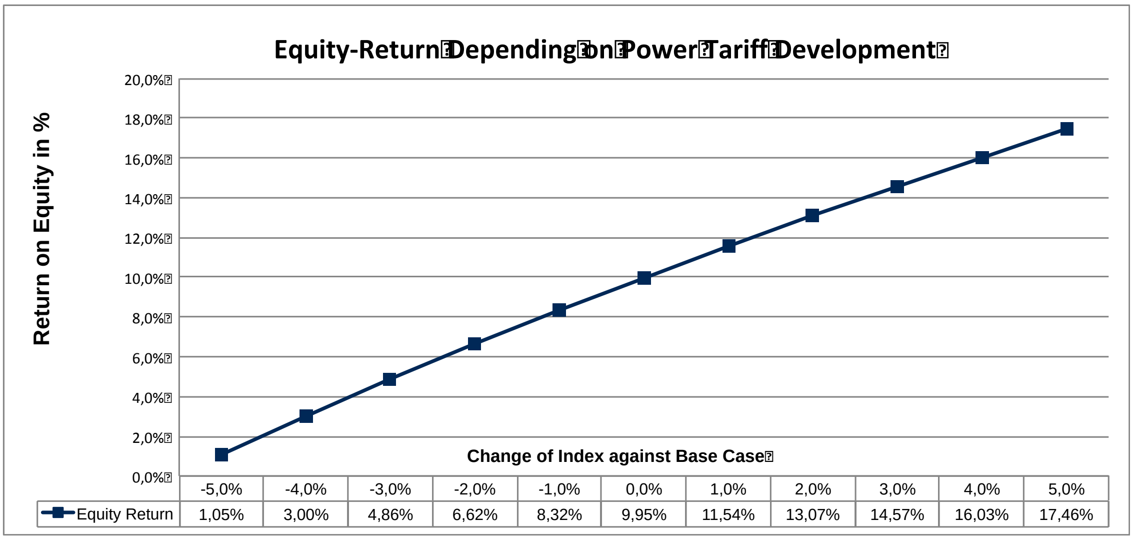
Specific Yield* (kWh/kWp)	Low Yield 1,200	Base Case 1,334	High Yield** 1,435
Project IRR (before tax)	5.9%	7.2%	8.1%
Equity IRR (before tax)	7.7%	10.0%	11.6%
Pay-back of equity (yr)	14.7	13.5	12.8
Capital reflux in % of equity	300.5%	365.9%	415.5%
Solar LCOE (ct/kWh)	13.78	12.40	11.52
Av. electricity tariff (over 20yrs)	16.27	16.27	16.27
Min. DSCR	0.73	0.83	0.90
Average DSCR	1.07	1.19	1.28

* 30% equity financing
** Optimum calculated for other HCMC sites

Influence of Key Parameters

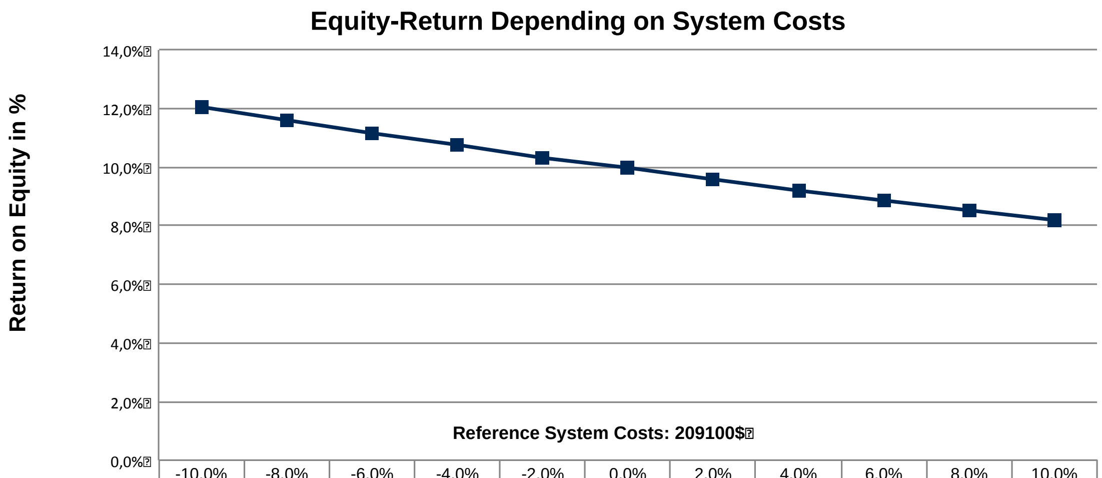
Looking at the key parameters that influence capital return shows that the assumptions on power tariff development are most influential (see figure 13). This is typical for a 100% self-consumption model and also reflects the influence of the currently low power tariffs that apply for commercial operations in Vietnam.

Figure 13: Case 2 (Cold Storage) – Influence of Power Tariff Development on Equity Return



Apart from power tariff development, the assumptions on investment costs have a strong influence on the results of the investment calculations. Figure 14 shows the sensitivity of equity return regarding investment costs.

Figure 14: Case 2 (Cold Storage) – Influence of System Investment Costs on Equity Return



	-10,0%	-8,0%	-6,0%	-4,0%	-2,0%	0,0%	2,0%	4,0%	6,0%	8,0%	10,0%
Equity Return	12,05%	11,60%	11,16%	10,74%	10,34%	9,95%	9,58%	9,22%	8,87%	8,53%	8,20%

3.3 Case Study 3: Manufacturing (Electrical Distribution System)

3.3.1 General Company Profile

The Company is situated in an industrial park in Binh Duong province, close to HCMC and produces electrical distribution systems (EDS) for export markets. The company was selected for the case study due to suitable roof area and infrastructure for solar PV and high interest in energy efficiency and solar PV technology.

The management of the company has already considered a solar PV investment and is highly committed to energy efficiency. Some energy efficiency measures have already been implemented such as high efficiency lighting and efficient air compression.

The company has implemented a corporate strategy for CO_2-reduction.

3.3.2 Load Profile and Cost Structure of Energy Demand

Power consumption: The company has a rather small factory at this site. Its total energy consumption in the period October 2014 - September 2015 was 283.2 MWh.

Main energy uses: The main energy uses are:

- Compressed air system (compressor of 75 kW);
- Chillers and associated technical systems (AHU, pumps, cooling towers) for the air conditioning;
- Lighting system;
- Manufacturing processes.

Power tariff: The company has a direct power purchase contract with the industrial park where it is situated. The factory has a medium voltage (22kV) grid connection. The current electricity tariff from the industrial park is:

- Normal (4:00-22:00): 1,968 VND/kWh (8.83 USDct/kWh)
- Low (22:00-4:00): 1,853 VND/kWh (8.31 USDct/kWh)

Avoided costs: The average avoided costs for the solar PV system are 1,968 VND/kWh (8.83 USDct/kWh).

Load profile: The company operates 6 days per week in currently two shifts. It is noted that in 2015 it partly operated with only one shift. For the future, it is planned to extend production to three shifts (which would therefore increase the power consumption of the site). However, the case study was developed on the base of the current production pattern.

The company management provided load profile data measured on two consecutive days (from 26 to 28 April 2016). For the remaining days of the year, it has been calculated based on the monthly consumption (from October 2015 to September 2016).

The minimum load during solar production hours is on Sundays with around 10 kW. The maximum load on weekday mornings is around 100 kW.

Figure 15 shows the average daily power curve on weekdays and the solar generation curve for the 478 kWp system. Figure 16 shows the average daily power curve on Sundays and the solar generation curve for the 478 kWp system.

Figure 15: Case 3 (EDS) – Daily Average Power Curve (Weekdays) and Solar Curve (478 kWp)

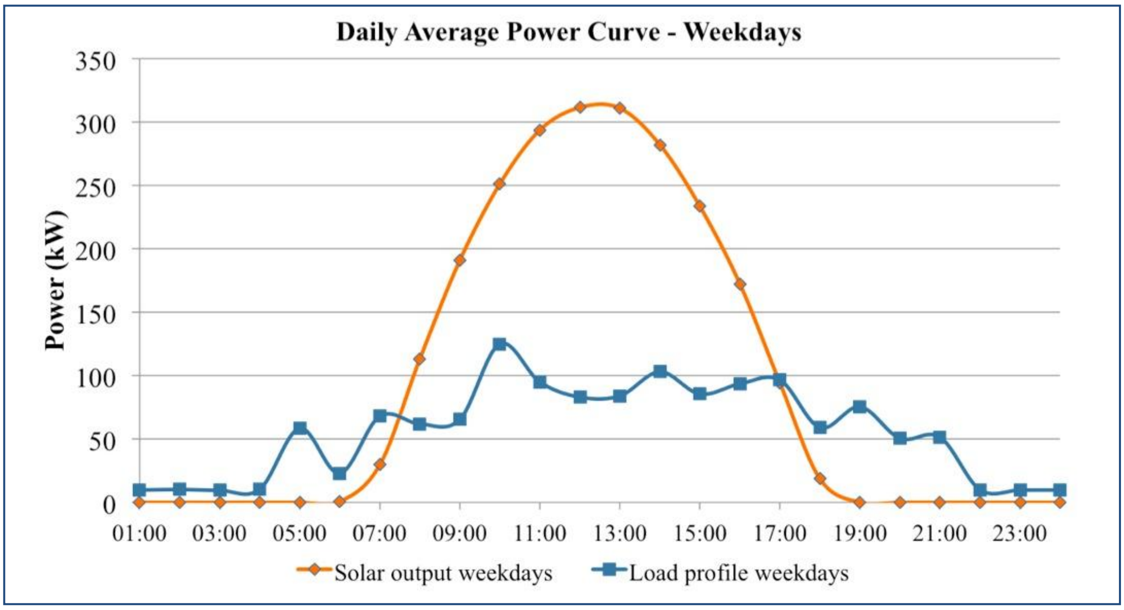
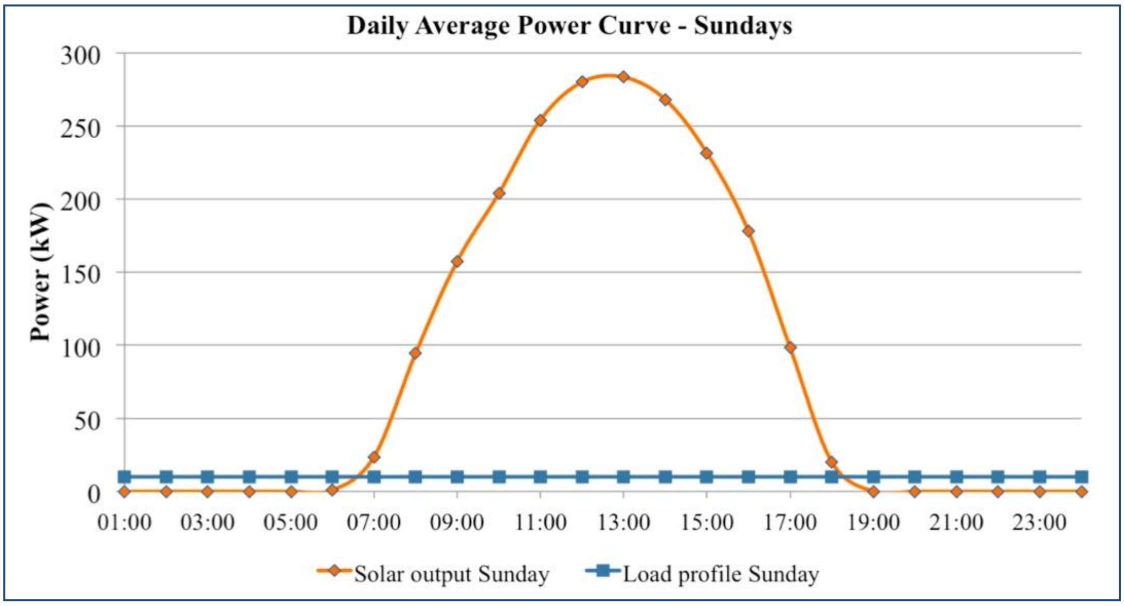


Figure 16: Case 3 (EDS) – Daily Average Power Curve (Sundays) and Solar Curve (478 kWp)



The weekday load curve shows that the factory operates basically from 4:00 to 22:00 and there are a lot of load fluctuations during the day. This might be related to the operation (on/off) of the compressor. The highest power load was noted as 108 kW in the interval 10:00 – 10:30. The night power consumption is quite steady, around 10 kW (lighting, server, etc.).

The same load profiles were calculated for each weekday, Saturday and Sunday for each month of the year, in order to compare it with the solar output. As the factory is not operating on Sundays, the assumption was made that the energy consumptions on these days is 10 kW as it is during night time. For the remaining days of the year (Monday to Saturday) there is little variation between days and months in the load profile.

According to the technical staff, the power supply is very stable, with no quality issues, power cut-offs or voltage drops.
There is no diesel generator onsite. One UPS is being used for the server of the company.
In the coming years, the production will be expanded with one more production line. However, currently there is no information about a potentially related increase of power consumption available.

3.3.3 Energy Efficiency and Energy Management

Energy efficiency measures: The factory has rather low power consumption. The main energy use is the air-compressed system with compressors of 75 kW. Some energy saving measures have been already implemented, such as:

- Skylight for production areas;
- Reflective tinted glazing for windows in the offices;
- Outdoor solar protection (horizontal shading) for production areas;
- Energy saving reminders to enhance employee awareness.

It is likely that other energy efficiency measures have been implemented, though no energy audit has been done so far.

Energy use and energy management: During the site visit, some aspects were identified as potential energy saving opportunities for the company:
- Currently, most of the lighting is based on T8 fluorescent tubes. The change of T8 tubes to T5 tubes with electronic ballast or LED (with a high lumen/watt ratio) could lower electricity consumption by 40%;
- When buying new equipment, the company management should check the VNEEP label and select only 5-star rated ones. Some of the current air-conditioners in the office rooms are still below 5-star;
- The installation of VSD and/or a leak detection system for the compressed air network should be considered, since this is the main energy use of the factory.
- The basic consumption at night (10 kW) could be assessed in more detail in order to be optimized.

The company is ISO 9001 and 14,001 certified. The management plans to implement ISO 50,001 in the near future.

3.3.4 Assessment of Building and Roof Structure

The company is a rather small industrial facility located in an industrial park in Binh Duong Province, Vietnam. The factory has been built 10 years ago and consists of one main building (and a very small one for the entrance area) with two types of roof:

- Metal sheet titled roof covering the manufacturing area;
- Concrete flat roof covering the office part (above the entrance area).

Roof selection: After the site visit and discussion with the technical staff, the metal sheet titled roof (3,936 m2) was identified to be suitable for installing the PV system. The management provided drawings of the roof structure.

After 10 years of operation, the roof is not in a very good condition. Therefore, the company management has decided to retrofit the roof in the near future (within 2016). This offers the opportunity of synergies with the installation of a PV system.

Metal sheet roof (manufacturing area):


Source: Artelia VN

Roof structure from inside the manufacturing area:


Source: Artelia VN

The potential locations for inverters could be:

- Next to the transformer of the site, inside a technical room to be built;
- On the concrete flat roof, next to the solar panels, with adequate protection from direct sunlight (or preferably inside a technical room to be built).

3.3.5 PV System Design

Following the load profile and current operational scheme of the company there are two business models and corresponding system designs possible:

- **'Self-consumption'** with a reduced PV system size of **131 kWp** with only little excess energy generated (currently on off-production Sundays).
- **'Net metering'** with the maximum possible PV system size of **478 kWp** with substantial amounts of excess energy generated.

PV System Design 'Self-Consumption (131 kWp)

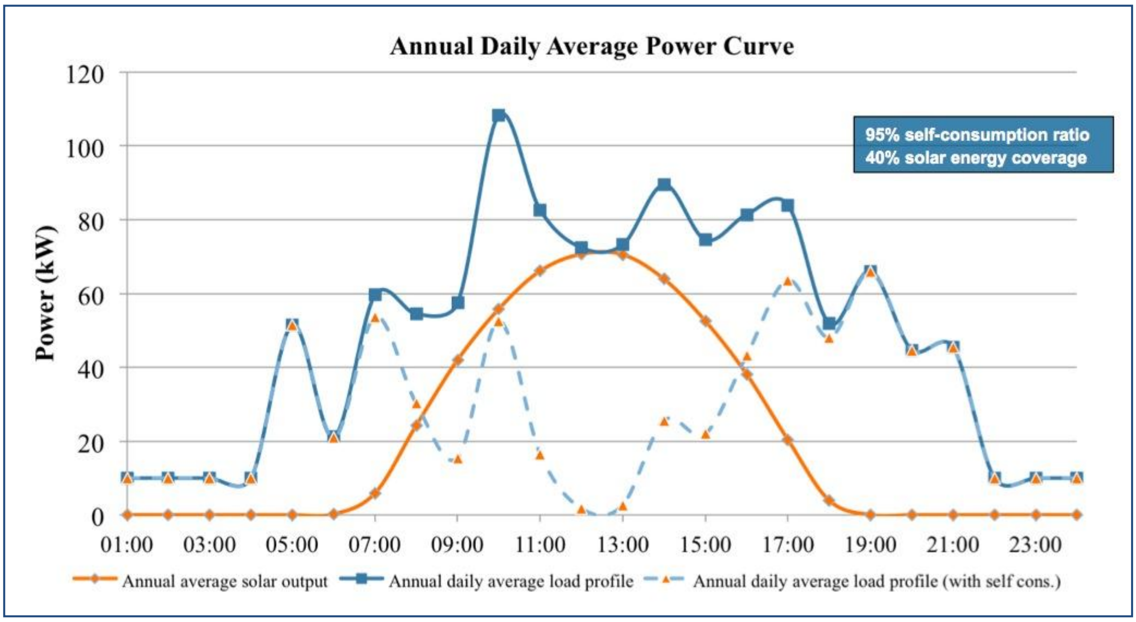
Table 20 summarizes the proposed PV system design optimised for self-consumption with a PV system size of 131 kWp. With this sizing the PV system would still generate around 20 MWh of excess energy per year (mainly on Sundays). However, this could change in future when the company expands manufacturing.

Table 20: Case 3 (EDS) - Overview of Proposed System Design 'Self-Consumption' (131 kWp)

Proposed PV System Design	
Peak power	131 kWp
Estimated number of solar panels (based on typical 150Wp multi-crystalline solar panels)	873
Type of inverter	100 and 50 kVA
Quantity of inverters	2 (including 1x50 kVa and 1x100 kVA)
DC array boxes	To be defined
AC control and monitoring panel	To be located between the inverters and electrical cabinet (to be defined)

The system is designed to minimise excess energy generation and reaches a 95% self-consumption ratio and a 40% solar energy coverage. Figure 17 shows the average annual daily power curve, the solar generation curve and the residual demand curve after self-consumption.

Figure 17: Case 3 (EDS) – Annual Daily Power Curve, Solar Curve (131 kWp) and Residual Load



The management of the company expressed a certain preference for a smaller system designed for self-consumption. However, the investment calculation will show that the investment data on capital return and equity payback time will improve substantially with the larger system that can benefit from the government support programme that remunerates excess energy on a level higher than the average electricity costs of the company (see following chapter 3.4.6).

PV System Design 'Net Metering (478 kWp)

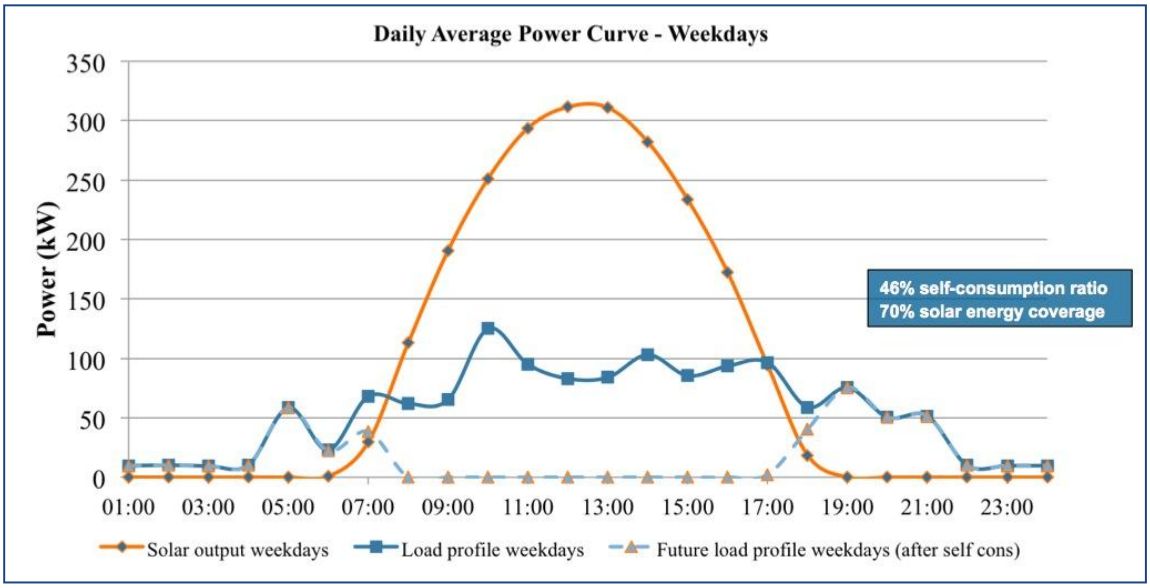
Table 21 summarizes the proposed PV system design optimised for net metering with a PV system size of 478 kWp. With this sizing the PV system will generate around 400 MWh of excess energy per year.

Table 21: Case 3 (EDS) - Overview of Proposed System Design 'Net Metering' (478 kWp)

Proposed PV System Design	
Peak power	478 kWp
Estimated number of solar panels (based on typical 150Wp multi-crystalline solar panels)	3,186
Type of inverter	100 kVA
Quantity of inverters	5
DC array boxes	To be defined
AC control and monitoring panel	To be located between the inverters and electrical cabinet (to be defined)

The system is designed to maximise excess energy generation and reaches a 46% self-consumption ratio and a 70% solar energy coverage. Figure 18 shows the average annual daily power curve, the solar generation curve and the residual demand curve after self-consumption.

Figure 18: Case 3 (EDS) – Annual Daily Power Curve, Solar Curve (478 kWp) and Residual Load



3.3.6 Results of Investment Calculation

The following section summarises the results of the investment calculation. Based on the load profile and the developed PV system design two possible business models have been calculated: 1. 'Self-consumption' system with 131 kWp and 2. 'Net metering' system with 478 kWp.

Project Report and Results of Investment Calculation (131 kWp)

Table 22 summarises the project information and main investment and performance parameter of the 'self-consumption' system with 131 kWp:

Table 22: Case 3 (EDS) – Project Report (131 kWp)

System Information	
Location	Binh Duong Province, Vietnam
Start of operation	January 2016
Operation lifetime	20 years
Installed capacity	131 kWp
Annual yield (first year)	192,177 kWh
Specific yield	1,467 kWh/kWp
Avoided CO_2-emissions*	102,077 kg/yr

* Average over system lifetime

Power Production and Demand	
Total annual power demand	434 MWh
Annual yield*	182 MWh
Self-consumed solar electr.*	172 MWh
Excess solar energy (sale to grid)*	10 MWh
Solar energy coverage*	39.5%
Self-consumption ratio*	94.5%
Avoided cost PV (first year)	1,968VND (8.83USDct)
Annual increase power tariff	5%
Annual increase of net metering credit	5%

* Average over system lifetime

Costs and Financing	100% Equity	30% Equity
Specific invest.	1,700 USD	1,700 USD
Total invest.	222,700 USD	222,700 USD
Equity	222,700 USD	66,810 USD
Operational costs (first year)	2,620 USD	2,620 USD
Operational costs per kWp	20USD/kWp	20USD/kWp
Debt	-	155,890 USD
Loan tenor	-	12 yrs
Loan interest rate	-	3%
Discount rate	5%	5%
Tax rate	20%	20%

Table 23: Case 3 (EDS) – Financial Report and Scenarios (131 kWp)

Main Results*	100% Equity	30% Equity
Equity IRR (before tax)	7.6%	10.6%
Project IRR (before tax)	7.6%	7.6%
Pay-back of equity	12.1yr	13.2yr
Pay-back of total investment	12.1yr	12.1yr
Capital reflux in % of equity	194.4%	378.2%
Capital reflux in % of total invest.	194.4%	194.4%
Solar LCOE	11.27ct/kWh	11.27ct/kWh
Average electricity tariff (over 20yrs)	14.60ct/kWh	14.60ct/kWh
Min. DSCR	-	0.88
Average DSCR	-	1.23

* Internal balance sheet funding (3% interest rate, 12yr loan term, 5% discount rate)

Annual Power Price Increase (30% Equity)	Low Increase 3%	Base Case 5%	High Increase 7%
Project IRR (before tax)	5.5%	7.6%	9.6%
Equity IRR (before tax)	7.3%	10.6%	13.8%
Pay-back of equity (yr)	14.7	13.2	12.0
Capital reflux in % of equity	259.7%	378.2%	529.2%
Solar LCOE (ct/kWh)	11.27	11.27	11.27
Av. electricity tariff (over 20yrs)	11.86	14.60	18.10
Min. DSCR	0.88	0.88	0.88
Average DSCR	1.10	1.23	1.39

* Increase of power purchase tariff and net metering credit in parallel, 30% equity financing

System Investment Costs* (USD/kWp)	Low Cost 1,500	Base Case 1,700	High Cost 1,900
Project IRR (before tax)	9.0%	7.6%	6.3%
Equity IRR (before tax)	13.6%	10.6%	8.5%
Pay-back of equity (yr)	12.1	13.2	14.2
Capital reflux in % of equity	455.7%	378.2%	316.2%
Solar LCOE (ct/kWh)	10.13	11.27	12.42
Av. electricity tariff (over 20yrs)	14.60	14.60	14.60
Min. DSCR	0.98	0.88	0.79
Average DSCR	1.37	1,23	1.12

* 30% equity financing

Table 24 shows the results for two different financing options (as described in chapter 3.1), assuming 1. an internal balance sheet funding with a low interest rate and a low corresponding discount rate and 2. a Vietnamese commercial lending model with high interest rates and a corresponding high internal discount rate.

Table 24: Case 3 (EDS) – Financing Scenarios (131 kWp)

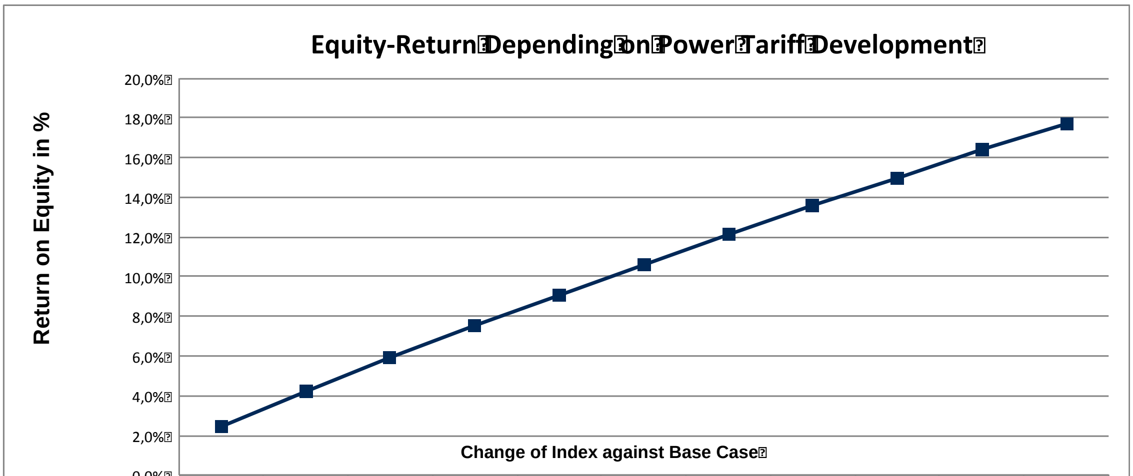
Financing Model (30% Equity)	Internal* 5% Discount Rate 3% Loan Interest	External** 10% Discount Rate 9% Loan Interest
Project IRR (before tax)	7.6%	7.6%
Equity IRR (before tax)	10.6%	6.7%
Pay-back of equity (yr)	13.2	15.4
Capital reflux in % of equity	378.2%	296.9%
NPV of project (USD)	29,517	-53,400
NPV rel. to project value	13.3%	-24.0%
NPV of equity (USD)	49,662	-40,450
NPV rel. to equity	74.3%	-60.5%
Solar LCOE (ct/kWh)	11.27	15.64
Av. electricity tariff (over 20yrs)	14.60	14.60
Min. DSCR	0.88	0.58
Average DSCR	1.23	1.00

* Internal corporate balance sheet funding, base case
** Vietnamese commercial lending, base case

Influence of Key Parameters

Looking at the key parameters that influence capital return shows that the assumptions on power tariff development are most influential (see figure 19). This is typical for a 100% self-consumption model and also reflects the influence of the currently low power tariffs that apply for industrial operations in Vietnam.

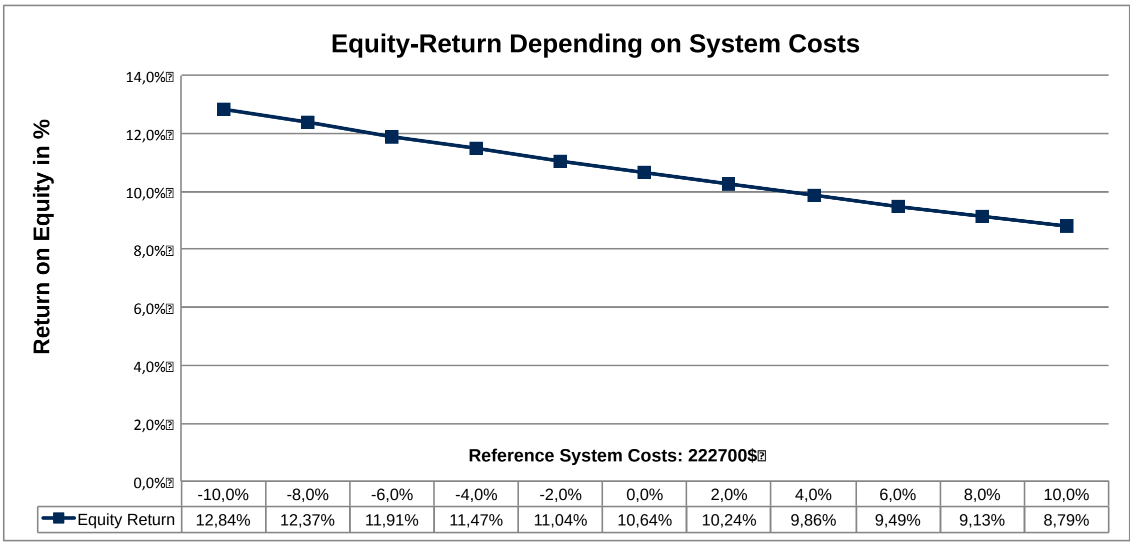
Figure 19: Case 3 (EDS) – Influence of Power Tariff Development on Equity Return (131 kWp)



	-5,0%	-4,0%	-3,0%	-2,0%	-1,0%	0,0%	1,0%	2,0%	3,0%	4,0%	5,0%
Equity Return	2,42%	4,20%	5,90%	7,53%	9,11%	10,64%	12,12%	13,57%	14,99%	16,38%	17,74%

Apart from power tariff development, the assumptions on investment costs have a strong influence on the results of the investment calculations. Figure 20 shows the sensitivity of equity return regarding investment costs.

Figure 20: Case 3 (EDS) – Influence of System Investment Costs (131 kWp)



Project Report and Results of Investment Calculation (478 kWp)

Table 25 summarises the project information and investment and performance parameter of the 'net metering' system with 478 kWp:

Table 25: Case 3 (EDS) – Project Report (478 kWp)

System Information	
Location	Binh Duong Province, Vietnam
Start of operation	January 2016
Operation lifetime	20 years
Installed capacity	478 kWp
Annual yield (first year)	701,226 kWh
Specific yield	1,467 kWh/kWp
Avoided CO_2-emissions*	374,992 kg/yr

* Average over system lifetime

Power Production and Demand	
Total annual power demand	434 MWh
Annual yield*	663 MWh
Self-consumed solar electr.*	304 MWh
Excess solar energy (sale to grid)*	359 MWh
Solar energy coverage*	70.0%
Self-consumption ratio*	45.8%
Avoided cost PV (first year)	1,968VND (8.83USDct)
Annual increase power tariff	5%
Annual increase of net metering credit	5%

* Average over system lifetime

Costs and Financing	100% Equity	30% Equity
Specific invest.	1,700 USD	1,700 USD
Total invest.	812,600 USD	812,600 USD
Equity	812,600 USD	243,780 USD
Operational costs (first year)*	9,560 USD	9,560 USD
Operational costs per kWp	20USD/kWp	20USD/kWp
Debt	-	568,820 USD
Loan tenor	-	12yrs
Loan interest rate	-	3%
Discount rate	5%	5%
Tax rate	20%	20%

Table 26: Case 3 (EDS) – Financial Report and Scenarios (478 kWp)

Main Results*	100% Equity	30% Equity
Equity IRR (before tax)	11.3%	17.7%
Project IRR (before tax)	11.3%	11.3%
Pay-back of equity	9.7yr	9.2yr
Pay-back of total investment	9.7yr	9.7yr
Capital reflux in % of equity	259.2%	594.2%
Capital reflux in % of total invest.	259.2%	259.2%
Solar LCOE	11.27ct/kWh	11.27ct/kWh
Average electricity tariff (over 20yrs)	14.60ct/kWh	14.60ct/kWh
Min. DSCR	-	1,13
Average DSCR	-	1.61

* Internal balance sheet funding (3% interest rate, 12yr loan term, 5% discount rate)

Annual Power Price Increase* (30% Equity)	Low Increase 3%	Base Case 5%	High Increase 7%
Project IRR (before tax)	9.3%	11.3%	13.4%
Equity IRR (before tax)	14.4%	17.7%	20.8%
Pay-back of equity (yr)	11.0	9.2	8.1
Capital reflux in % of equity	435.3%	594.2%	797.0%
Solar LCOE (ct/kWh)	11.27	11.27	11.27
Av. electricity tariff (over 20yrs)	11.86	14.60	18.10
Min. DSCR	1.13	1.13	1.13
Average DSCR	1.44	1.61	1.82

* Increase of power purchase tariff and net metering credit in parallel, 30% equity financing

Annual Net Metering Credit Increase (30% Equity)*	Low Increase 0%	Medium Increase 3%	Base Case 5%
Project IRR (before tax)	8.3%	10.0%	11.3%
Equity IRR (before tax)	12.6%	15.6%	17.7%
Pay-back of equity (yr)	12.2	10.3	9.2
Capital reflux in % of equity	373.4%	489.8%	594.2%

* Increase of power purchase tariff: base case (5%/yr)

System Investment Costs (USD/kWp)	Low Cost 1,500	Base Case 1,700	High Cost 1,900
Project IRR (before tax)	13.0%	11.3%	9.9%
Equity IRR (before tax)	21.2%	17.7%	14.9%
Pay-back of equity (yr)	7.6	9.2	10.9
Capital reflux in % of equity	700.5%	594.2%	510.3%
Solar LCOE (ct/kWh)	10.13	11.27	12.42
Av. electricity tariff (over 20yrs)	14.60	14.60	14.60
Min. DSCR	1.26	1.13	1.03
Average DSCR	1.81	1.61	1.46

* 30% equity financing

Table 27: Case 3 (EDS) – Financing Scenarios (478 kWp)

Financing Model (30% Equity)	Internal* 5% Discount Rate 3% Loan Interest	External** 10% Discount Rate 9% Loan Interest
Project IRR (before tax)	11.3%	11.3%
Equity IRR (before tax)	17.7%	12.9%
Pay-back of equity (yr)	9.2	12.3
Capital reflux in % of equity	594.2%	519.6%
NPV of project (USD)	396,520	-19,539
NPV rel. to project value	48.8%	-2.4%
NPV of equity (USD)	470,155	39,506
NPV rel. to equity	192.9%	16.2%
Solar LCOE (ct/kWh)	11.27	15.64
Av. electricity tariff (over 20yrs)	14.60	14.60
Min. DSCR	1.13	0.78
Average DSCR	1.61	1.32

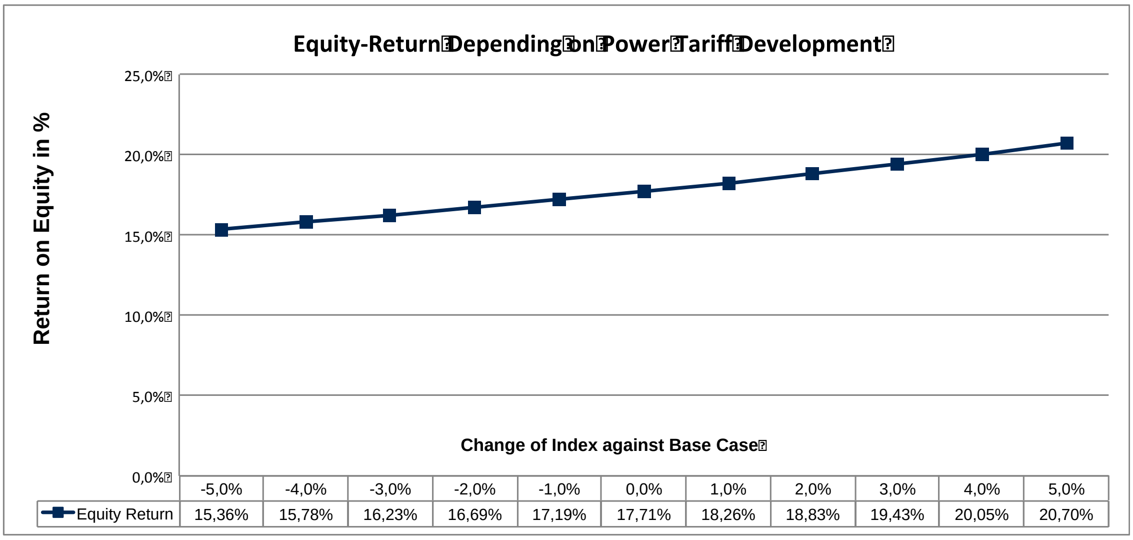
* Internal corporate balance sheet funding, base case
** Vietnamese commercial lending, base case

Table 27 shows the results for two different financing options (as described in chapter 3.1), assuming 1. an internal balance sheet funding with a low interest rate and a low corresponding discount rate and 2. a Vietnamese commercial lending model with high interest rates and a corresponding high internal discount rate.

Influence of Key Parameters

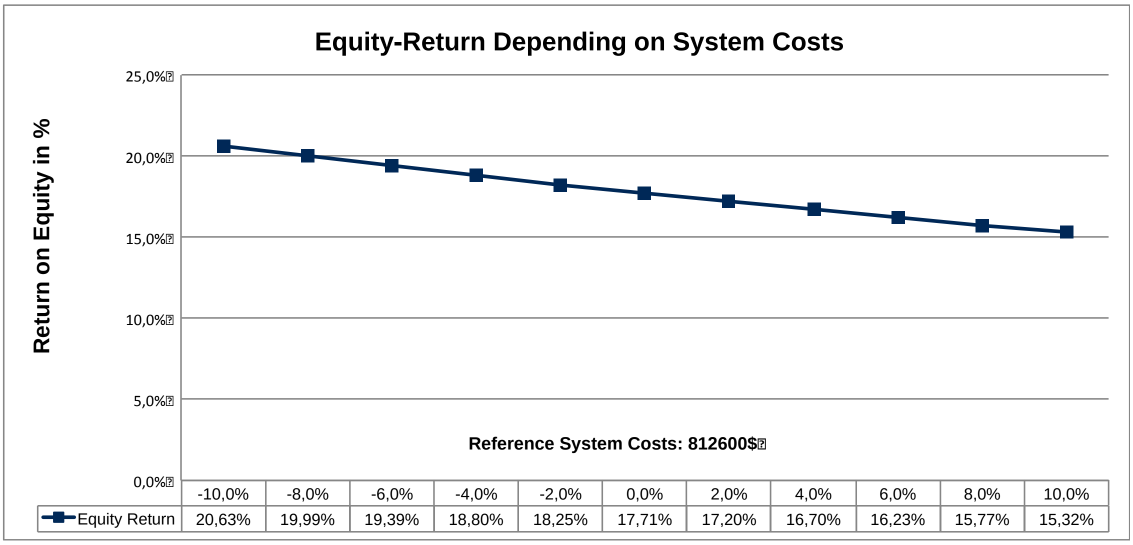
Looking at the key parameters that influence capital return shows that the assumptions on power tariff development are less influential compared to self-consumption systems (see figure 21). This is plausible since net metering business models rely less on revenues from electricity bill savings but benefit more from external revenues from excess power sales.

Figure 21: Case 3 (EDS) – Influence of Power Tariff Development on Equity Return (478 kWp)



Apart from power tariff development, the assumptions on investment costs have a strong influence on the results of the investment calculations. Figure 22 shows the sensitivity of equity return regarding investment costs.

Figure 22: Case 3 (EDS) – Influence of PV System Investment Costs (478 kWp)



Comparison of Business Cases – Net Metering vs. Self-Consumption

Comparing the results of the investment calculation for both business models shows that the additional financial revenues from the net metering support mechanism substantially improves the IRR and equity payback time for the respective investments. This is plausible since the net metering credit is higher than the average electricity costs of the company.

Table 28: Case 3 (EDS) - Comparison of Business Cases Self-Consumption vs. Net Metering

Main Results*	Self-Consumption (131 kWp)	Net-Metering (487 kwp)
Total investment (USD)	222,700	812,600
Equity (USD)	66,810	243,780
Equity IRR (before tax)	10.6%	17.7%
Pay-back of equity	13.2yr	9.2yr
Capital reflux in % of equity	378.2%	594.2%
Solar LCOE	11.27ct/kWh	11.27ct/kWh
Av. electricity tariff (over 20yrs)	14.60ct/kWh	14.60ct/kWh

*Base case, 30% equity

3.4 Case Study 4: Manufacturing (Consumer Products)

3.4.1 General Company Profile

The company has a manufacturing facility in an industrial park in Binh Duong province close to HCMC and produces consumer products.

The company was selected for the case study due to suitable roof area and infrastructure for a PV investment and high interest in energy efficiency and solar PV technology. The factory management has already considered solar PV investment and shows a high commitment to energy efficiency.

3.4.2 Load Profile and Cost Structure of Energy Demand

Power consumption: The total energy consumption of the company is rather high. The demand in 2014 and 2015 was 17.6 and 17.2 GWh respectively. The consumption in the first two months of 2016 was 2.2 GWh.

Main energy uses: The main energy uses are:

- Chillers and associated technical systems (AHU, pumps, cooling towers) for the air conditioning of the factory
- Lighting for production and offices
- Pumping and compressed air system
- Process

Power tariff: The company pays the EVN 'manufacturing' electricity tariff. The production site has a medium voltage grid connection ("from 22kV to 110kV"). The current electricity tariffs are:

- Normal (4:00-9:30; 11:30-17:00; 20:00-22:00): 1,405 VND/kWh (6.30USDct/kWh)
- Low (22:00-4:00): 902 VND/kWh (4.04USD$/kWh)
- High (9:30-11:30; 17:00-20:00): 2,556 VND/kWh (11.46USDct/kWh)

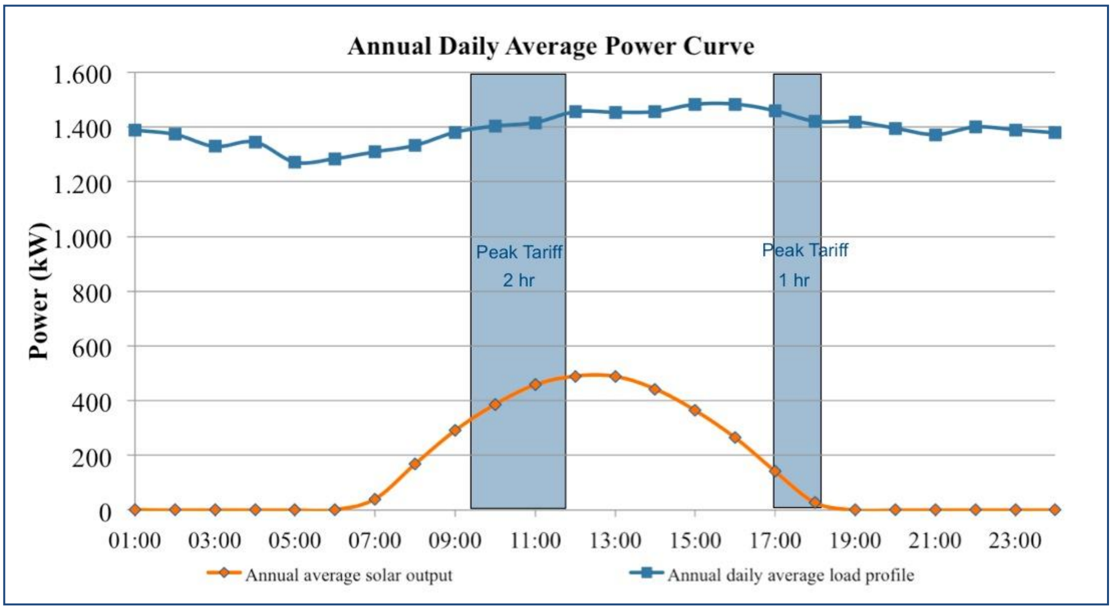
Avoided costs: The average avoided costs for the solar PV system are 1,665VND/kWh (7.47USDct/kWh).

Load profile: The factory operates 7 days per week 24 hours. The company management provided load profile data for one full month (March 2016). For the remaining time of the year, the load profile has been calculated based on further provided monthly consumption figures (from July 2013 to February 2016).

Figure 23 shows the average annual daily power curve and the solar generation curve for the assumed 946kWp PV system. Energy consumption is rather high but quite stable during the day, it ranges between roughly 1,200-1,500 kW over 24 hours. The highest consumption was noted in the interval 3:00 - 4:00 PM and the lowest consumption around 5:00 AM.

The same load profiles were calculated for each weekday, Saturday and Sunday for each month of the year, in order to compare it with the solar output. As the factory operates 24/24h and all days of the year, there is little variation between days and months in the load profile.

Figure 23: Case 4 (Consumer Products) – Daily Average Annual Power Curve and Solar Curve (946 kWp)



According to the technical staff of the facility, there are power cuts by EVN about once every month and about 8 hours of power cuts and a few voltage drops every quarter of a year.

The diesel generator of the factory operates every month consuming about 6,000 litres of diesel. There are three types of diesel generator depending on the supply demand: 1,000; 2,000 and 3,100 kVA.

In the near future, the factory management plans to build a covered carport with an area of 1,120 m^2 on the factory compound. This future carport is also taken into consideration for the PV system design of this case.

3.4.3 Energy Efficiency and Energy Management

Energy efficiency measures: The factory has comparatively high energy consumption, especially from the chiller & air conditioning, compressed air system and the manufacturing process. In general, the level of energy saving efforts is very high. A number of energy efficiency measures have already been implemented, such as:

- Installation of T5 fluorescent lamps;
- Installation of occupancy sensors for lighting in some areas;
- Installation of skylights on some of the building parts/roofs.

It is likely that other energy efficiency measures have been implemented, though no energy audit report has been provided.

Energy use and energy management: The site has a total energy use above 1000 TOE per year, therefore it has to follow the requirements from the Decree #21/2011/NĐ-CP (detailed regulations and measures for implementing the Law on Use of Energy Saving and Efficiency – issued March 29, 2011):

- Energy audit to be conducted every 3 years, by a specialized firm being trained by MOIT;
- Appoint an energy management officer;
- Develop and implement annual and 5-year plans for energy saving and efficiency;
- Comply with the provisions on energy saving and efficiency during the construction, upgrading or expansion of construction works.

The company is ISO 9001 certified.

3.4.4 Assessment of Building and Roof Structure

The facility is a rather large factory in an industrial park in Binh Duong Province, Vietnam. It was built 20 years ago and was renovated and retrofitted several times in these past 20 years. It has a number of different buildings with roofs/canopies:

- A carport;
- An office building;
- Four warehouses;
- The technical areas;
- Further production zones.

Roof selection: According to the site visit and the discussion with the site management, the roofs of two of the warehouses (a 1,756 m^2 tilted roof and a 4,906 m^2 tilted roof) were identified to be suitable for a solar PV installation. Both warehouse roofs have metal sheet profiles and have been renovated about 5 years ago.

In the near future, a carport will be built on an area that is currently used for other purposes. A PV system could be installed on this future carport canopy, as proposed by the company management. The peak power of the PV system is calculated for 946 kW in total. Warehouse roof and roof structure:

Source: Artelia VN

The potential location for inverters should be next to the transformers in the centre of the site. They are to be installed preferably inside a technical room. A monitoring display could be installed at the main entrance of the factory.

3.4.5 PV System Design

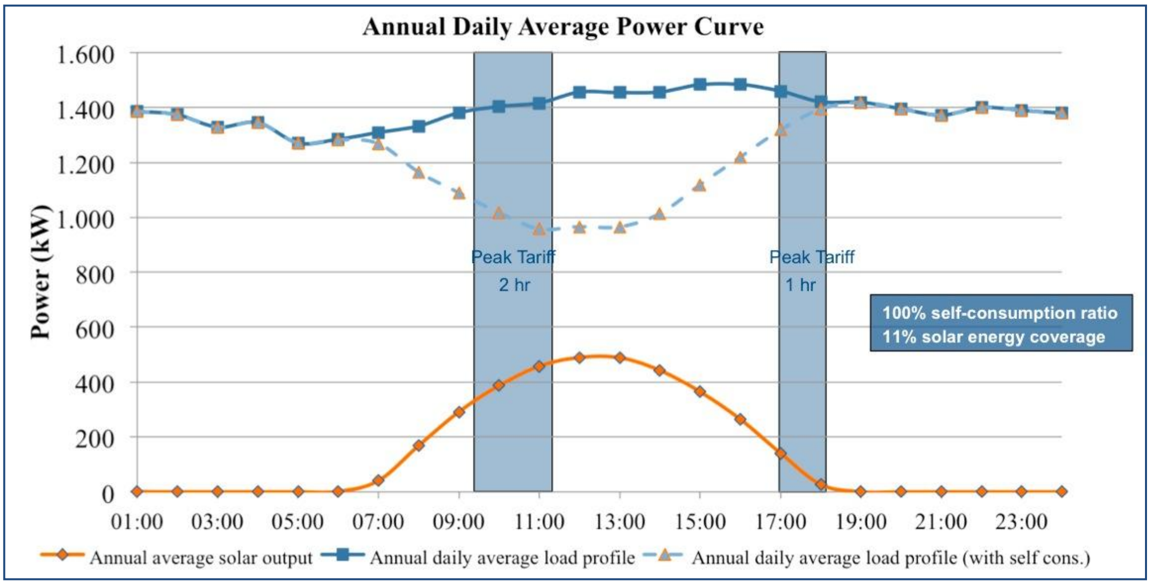
Based on the technical assessment of the roof and building structure as investigated on site, a provisional PV design was developed. Table 29 summarizes the proposed PV system design.

Table 29: Case 4 (Consumer Products) – Overview of Proposed System Design

Proposed PV System Design	
Peak power	946 kWp
Estimated number of solar panels (based on typical 150Wp multi-crystalline solar panels)	6,306
Type of inverter	50 and 100 kVA (To be installed preferably inside a technical room)
Quantity of inverters	15 (including 5x50 kVA for Warehouse 1; 7x100 kVA for Warehouse 2; 3x50 kVA for the carport)
DC array boxes	To be defined
AC control and monitoring panel	To be located between the inverters and electrical cabinet (to be defined)

The system is designed to maximise on-site energy consumption and reaches a 100% self-consumption ratio and 11% solar energy coverage. Figure 24 shows the average annual daily power curve, the solar generation curve and the residual demand curve after self-consumption.

Figure 24: Case 4 (Consumer Products) – Annual Daily Power Curve, Solar Curve (946 kWp) and Residual Load



3.4.6 Results of Investment Calculation

The following section summarises the results of the investment calculation. Based on the load profile and the developed PV system design with 946 kWp the only possible business model is self-consumption. There will be no excess energy that could be sold to the grid (see load profile in figure 24, chapter 3.4.5).

Since the company management has expressed their strong preference for a 100% equity financing model, the following calculations are all based on this model.

Project Report and Results of Investment Calculation (946 kWp)

Table 30 summarises the project information and main investment and performance parameter of the 'self-consumption' system with 946kWp:

Table 30: Case 4 (Consumer Products) – Project Report

System Information	
Location	Binh Duong Province, Vietnam
Start of operation	January 2016
Operation lifetime	20 years
Installed capacity	946 kWp
Annual yield (first year)	1,387,782 kWh
Specific yield	1,467 kWh/kWp
Avoided CO_2-emissions*	742,138 kg/yr

* Average over system lifetime

Power Production and Demand	
Total annual power demand	12,192 MWh
Annual yield*	1,312 MWh
Self-consumed solar electr.*	1,312 MWh
Excess solar energy (sale to grid)*	-
Solar energy coverage*	10.8%
Self-consumption ratio*	100%
Avoided cost PV (first year)	1,665VND (7.47USDct)
Annual increase power tariff (Base)	5%

* Average over system lifetime

Costs and Financing	100% Equity	30% Equity
Specific invest.	1,700 USD	1,700 USD
Total invest.	1,608,200 USD	1,608,200 USD
Equity	1,608,200 USD	482,460 USD
Operational costs (first year)*	18,920 USD	18,920 USD
Operational costs per kWp	20 USD/kWp	20 USD/kWp
Debt	-	1,125,740 USD
Loan tenor	-	12 yrs
Loan interest rate*	-	3%
Discount rate	5%	5%
Tax rate	20%	20%

*Internal balance sheet funding, linear amortization

Table 31: Case 4 (Consumer Products) – Financial Report and Scenarios

Main Results*	100% Equity	30% Equity
Equity IRR (before tax)	5.0%	5.0%
Project IRR (before tax)	5.0%	6.3%
Pay-back of equity	14.3 yr	15.6 yr
Pay-back of total investment	14.3 yr	14.3 yr
Capital reflux in % of equity	159.2%	257.9%
Capital reflux in % of total invest.	159.2%	159.2%
Solar LCOE	11.27ct/kWh	11.27ct/kWh
Average electricity tariff (over 20yrs)	12.35ct/kWh	12.35ct/kWh
Min. DSCR	-	0.66
Average DSCR	-	0.99

* Internal balance sheet funding (3% interest rate, 12 yr loan term, 5% discount rate)

Annual Power Price Increase* (100% Equity)	Low Increase 3%	Base Case 5%	High Increase 7%
Equity IRR (before tax)	2.9%	5.0%	7.1%
Pay-back of equity (yr)	16.1	14.3	13.0
Capital reflux in % of equity	129.8%	159.2%	196.8%
Solar LCOE (ct/kWh)	11.27	11.27	11.27
Av. electricity tariff (over 20yrs)	10.04	12.35	15.31

* 100% equity financing

System Investment Costs* (USD/kWp)	Very Low Cost 1,300	Low Cost 1,500	Base Case 1,700	High Cost 1,900
Equity IRR (before tax)	7.9%	6.3%	5.0%	3.9%
Pay-back of equity (yr)	12.0	13.2	14.3	15.4
Capital reflux in % of equity	202.1%	177.8%	159.2%	144.5%
Solar LCOE (ct/kWh)	8.98	10.13	11.27	12.42
Av. electricity tariff (over 20yrs)	12.35	12.35	12.35	12.35

* 100% equity financing

Very Optimistic Case*	1,500USD/kWp invest 7% power tariff p.a.
Equity IRR (before tax)	8.4%
Pay-back of equity (yr)	12.1
Capital reflux in % of equity	220.4%
Solar LCOE (ct/kWh)	10.13
Av. electricity tariff (over 20yrs)	15.31

* 100% equity financing

Table 32: Case 4 (Consumer Products) – Financing Scenarios

Financing Model (30% Equity)	Internal* 5% Discount Rate 3% Loan Interest	External** 10% Discount Rate 9% Loan Interest
Project IRR (before tax)	5.0%	5.0%
Equity IRR (before tax)	6.3%	3.0%
Pay-back of equity (yr)	15.6	18.1
Capital reflux in % of equity	257.9%	171.4%
NPV of project (USD)	-110,814	-590,206
NPV rel. to project value	-6.9%	-36.7%
NPV of equity (USD)	22,165	-521,920
NPV rel. to equity	4.6%	-108.2%
Solar LCOE (ct/kWh)	11.27	15.64
Av. power tariff (benchmark)	12.35	12.35
Min. DSCR	0.66	0.43
Average DSCR	0.99	0.80

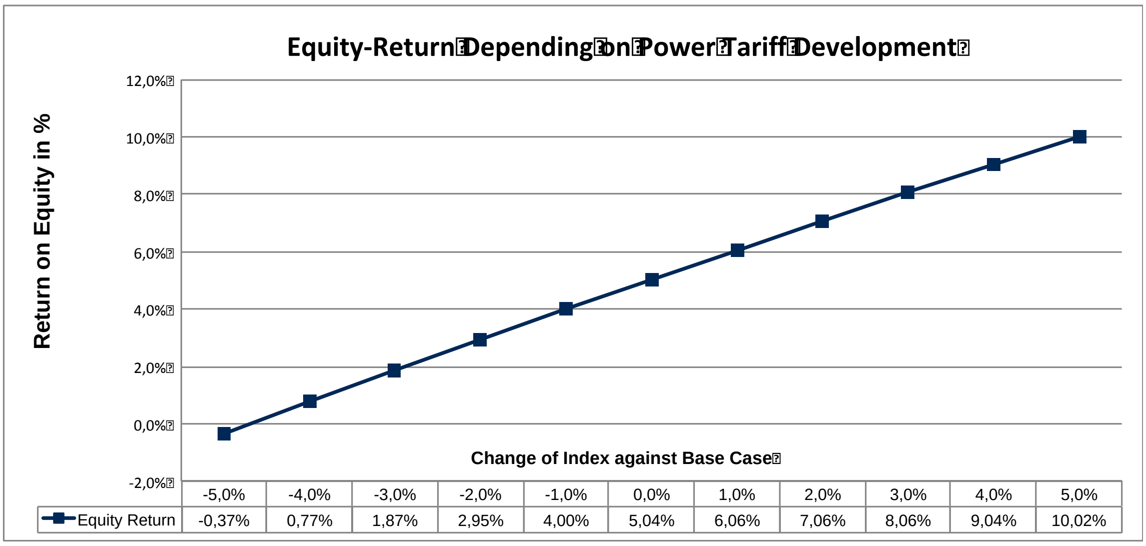
* Internal corporate balance sheet funding, base case
** Vietnamese commercial lending, base case

Table 32 shows the results for two different financing options (as described in chapter 3.1), assuming 1. an internal balance sheet funding with a low interest rate and a low corresponding discount rate and 2. a Vietnamese commercial lending model with high interest rates and a corresponding high internal discount rate.

Influence of Key Parameters

Looking at the key parameters that influence capital return shows that the assumptions on power tariff development are most influential (see figure 25). This is typical for a 100% self-consumption model and also reflects the influence of the currently low power tariffs that apply for industrial operations in Vietnam.

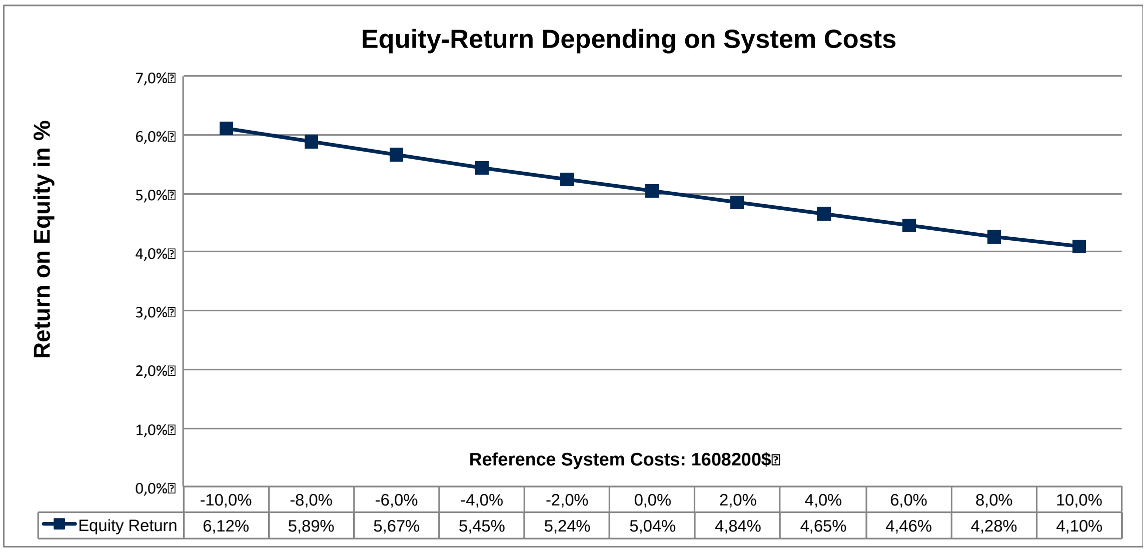
Figure 25: Case 4 (Consumer Products) – Influence of Power Tariff Development on Equity Return



	-5,0%	-4,0%	-3,0%	-2,0%	-1,0%	0,0%	1,0%	2,0%	3,0%	4,0%	5,0%
Equity Return	-0,37%	0,77%	1,87%	2,95%	4,00%	5,04%	6,06%	7,06%	8,06%	9,04%	10,02%

Apart from power tariff development, the assumptions on investment costs have a strong influence on the results of the investment calculations. Figure 26 shows the sensitivity of equity return regarding investment costs.

Figure 26: Case 4 (Consumer Products) – Influence of PV System Investment Costs



	-10,0%	-8,0%	-6,0%	-4,0%	-2,0%	0,0%	2,0%	4,0%	6,0%	8,0%	10,0%
Equity Return	6,12%	5,89%	5,67%	5,45%	5,24%	5,04%	4,84%	4,65%	4,46%	4,28%	4,10%

3.5 Case Study 5: Manufacturing (Automotive)

3.5.1 General Company Profile

The company is situated in an industrial park in Southern Vietnam and is manufacturing spare parts for the automotive industry.

The company was selected for the case study due to a large and suitable roof area and suitable infrastructure for PV installation and high interest in energy efficiency and solar PV technology. Furthermore, the company has already installed a small solar thermal (ST) domestic hot water system for the canteen. Since this system needs replacement this could be integrated into a solar PV project.

The company management has already considered a solar PV investment and is highly committed to energy efficiency and clean energy usage in general.

3.5.2 Load Profile and Cost Structure of Energy Demand

Power consumption: The total energy consumption of the facility is high. The demand in 2013 was 47.6 GWh, in 2014 59.6 GWh and in 2015 66.2 GWh. The consumption in the first three months of 2016 was 15.2 GWh.

Main energy uses: The main energy uses are:
- Chillers and associated technical systems (AHU, pumps, cooling towers) for the air conditioning of the factory;
- Compressed air system for workshops for control and cleaning;
- Lighting for production and offices;
- Water supply and water treatment system;
- Manufacturing process.

Power tariff: The company pays the EVN “manufacturing” tariff and has a medium voltage connection (“from 22kV to 110kV”) to the grid. Current electricity tariffs are:
- Normal (4:00-9:30; 11:30-17:00; 20:00-22:00): 1,405 VND/kWh (6.30USDct/kWh)
- Low (22:00-4:00): 902 VND/kWh (4.04USDct/kWh)
- High (9:30-11:30; 17:00-20:00): 2,556 VND/kWh (11.46USDct/kWh)

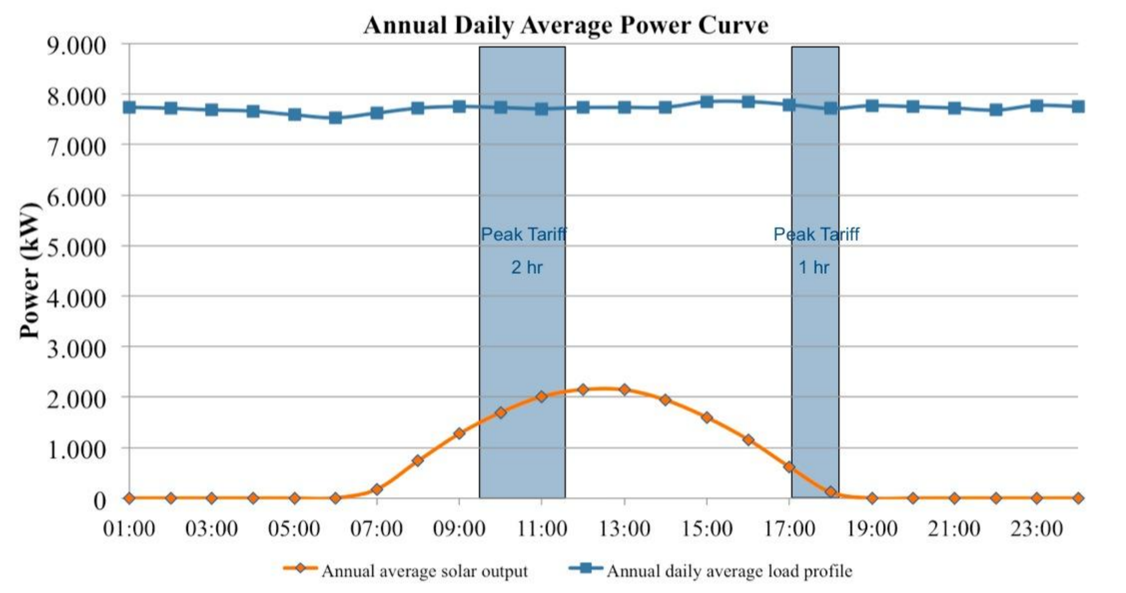
Avoided costs: The average avoided costs for the solar PV system are 1,665VND/kWh (7.47USDct/kWh).

Load profile: The load profile data from the building owner were provided for 7 weeks (from 1 March to 19 April 2016). For the remaining time of the year, it has been calculated based on further provided monthly data on consumption (from 2013 to 2016).

The factory operates 7 days per week for 24 hours. This load profile in figure 27 shows that the energy consumption is rather high and quite stable during the day and also high during night-time (manufacturing process and associated air conditioning).

The same load profiles were calculated for each weekday, Saturday and Sunday for each month of the year, in order to compare it with the solar output. As the factory operates 24/24h and all days of the year, there is little variation between days and months in the load profile.

Figure 27: Case 5 (Automotive) – Daily Average Annual Power Curve and Solar Curve (4 MWp)



According to the technical staff, the power supply of the facility is very steady and of generally good quality. However, there have been some minor issues (power outages or brownouts) in the past. These were all recorded in a 'Power quality issue report' that is summarized as below:

Table 33: Case 5 (Automotive) – Summery of Power Quality Report (2012-04/2016)

Year	Power cuts (planned by EVN)	hrs	Power cuts (unplanned)	hrs	Power dips/high voltage , ±25% of 400 V, within 1 s
2012	4	48	8	7.5	17
2013	2	24	3	3.7	32
2014	0	0	1	0.4	31
2015	0	0	0	0	22
Until Apr 2016	1	12	0	0	0

The factory has 2000 kVA diesel generators in operation. For 2015, no power cuts have been reported. In that year, the diesel consumption for testing the generators was 3,428 litres (about 285 litres for testing each month). In January 2016, EVN cut off the power for 12 consecutive hours at one day. The consumption of the generators in this month was 5,500 litres of diesel.

Currently, there is no substantial renovation or extension of the site planned for the coming years.

3.5.3 Energy Efficiency and Energy Management

Energy efficiency measures: The factory has high energy consumption, especially related to the manufacturing process, the chillers and air conditioning and the compressed air system.

In general, the implementation of energy saving measures is on a very high level. A number of energy efficiency measures have been implemented already, such as:

- Use of high efficient chillers, with COP of 5.07;
- Use of VSD for pumps and fans;

- Use of VSD for air compressing;
- Turning on/off the lighting by area.

Energy use: This site has a total energy use above 1000 TOE per year. Therefore it has to follow the requirements from the Decree #21/2011/NĐ-CP (Detailed Regulations and Measures for Implementing the Law on Use of Energy Saving and Efficiency – issued March 29, 2011):
- Energy audit to be conducted every 3 years, by a specialized firm being trained by MOIT;
- Appoint an energy management officer;
- Develop and implement annual and 5-year plans for energy saving and efficiency;
- Comply with the provisions on energy saving and efficiency during the construction, upgrading or expansion of construction works.

Energy Management: The site management provided an energy audit report (dated November 2013). In that report, several solutions are proposed, with detailed calculation on the investment and amount of energy saving, in order to enhance the energy saving of the whole factory, such as:
- Establishing energy management system;
- Control fresh air supply;
- Using VSD for exhaust air recovering pump;
- Replacing T8 fluorescent lamp by T5 type;

No energy consumption for each MEP system (lighting, HVAC, ventilation, etc.) was mentioned.

The factory is ISO 9001, ISO 14000 and ISO/TS 16949 certified.

3.5.4 Assessment of Building and Roof Structure

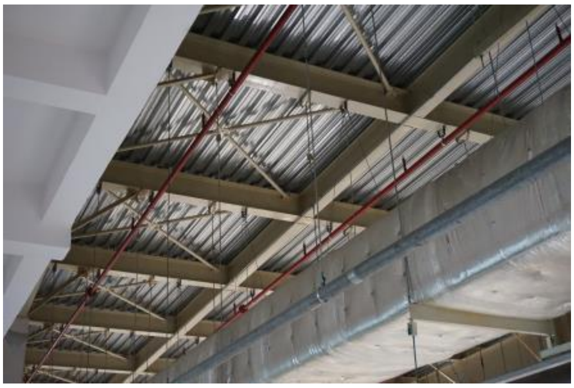
The facility is a large production factory located in Southern Vietnam. The facility was built in 2011 and includes different buildings/roofs. Among them are:
- The main building for production, with two types of roof: flat and tilted;
- An office building;
- A carport;
- A warehouse/technical area;
- A canteen.

Roof selection: According to the site visit and discussions with the company management, the main manufacturing building was chosen for the PV installing. Main building roof (metal sheet):


Source: Artelia VN

This main building roof has a metal sheet profile, with 30,746 m^2 of tilted roof and 4,576 m^2 of flat roof. A structure calculation report was also provided and shows that the roof is designed for 5.7 kN/m^2 (live load) and 1.5 kN/m^2 (suspended load) so could stand the installation of PV arrays. The maximum peak power is calculated with 3,983 kW in total.

Structure of the main roof:

Source: Artelia VN

The carport canopy was identified as another potential roof for a solar PV installation (metal roof). It would only be suitable for a very small system capacity of app. 58 kWp.

Carport canopy and canteen roof (ST system):


Source: Artelia VN

Furthermore, a walkway from the main building to the canteen could be covered for shading purposes and used for a small PV installation of a few kWp.

The potential location for inverters and monitoring display is to be determined during further investigation. Since the PV system in this case study was designed very large, a specific technical room for DC/AC inverters should be considered.

The PV system was designed for 3 building parts that are powered by 8 transformers in total. It is proposed that the PV system will be divided into 8 sub-systems (8 DC/AC inverters) in order to connect to all transformers of these three building parts.

3.5.5 PV System Design

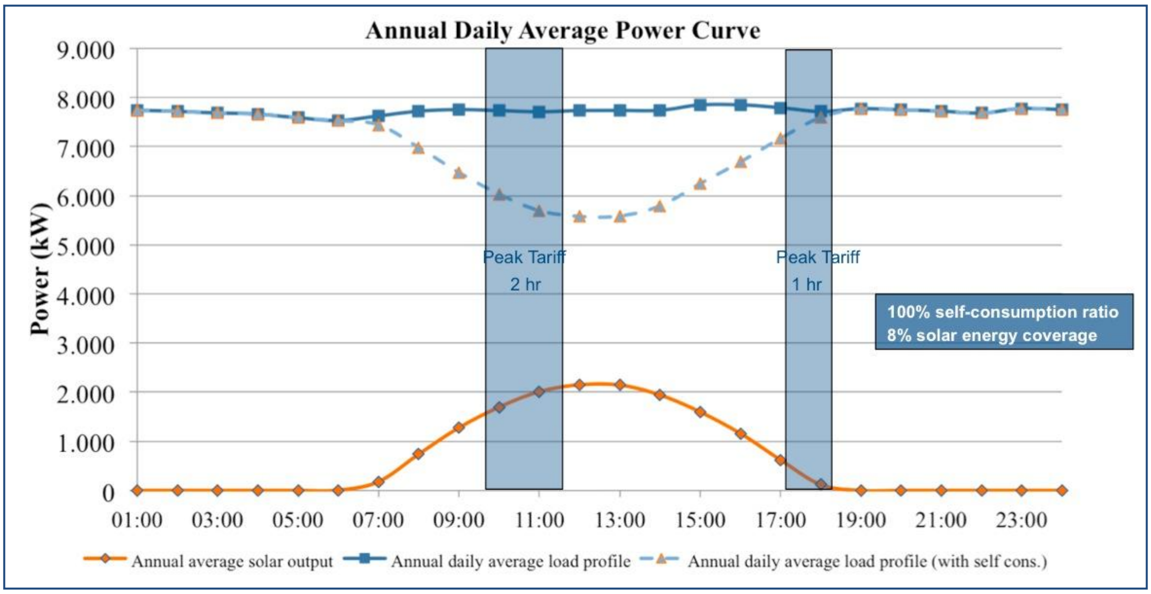
Based on the technical assessment of the roof and building structure as investigated on site, a provisional PV design was developed. Table 34 summarizes the proposed PV system design.

Table 34: Case 4 (Automotive) – Overview of Proposed System Design (4 MWp)

Proposed PV System Design	
Peak power	3,983 kWp
Estimated number of solar panels	26,553
(based on typical 150Wp multi-crystalline solar panels)	
Type of inverter	500 kVA
	(to be installed preferably inside a technical room)
Quantity of inverters	8
DC array boxes	To be defined
AC control and monitoring panel	To be located between the inverters and electrical cabinet (to be defined)

The system is designed to maximise on-site energy consumption and use the full available roof space. The system reaches a 100% self-consumption ratio and 8% solar energy coverage. Figure 28 shows the average annual daily power curve, the solar generation curve and the residual demand curve after self-consumption.

Figure 28: Case 5 (Automotive) – Annual Daily Power Curve, Solar Curve (4 MWp) and Residual Demand



Since the company management explicitly asked for the option of a smaller system, a second system design was developed using only a small part of the factory roof. This smaller system was calculated with 247 kWp system capacity.

However, the investment calculation will show that the investment data on capital return and equity payback time will improve substantially with the larger system that will most likely benefit from substantially lower specific investment costs per kWp.

PV System Design 'Small System' (247 kWp)

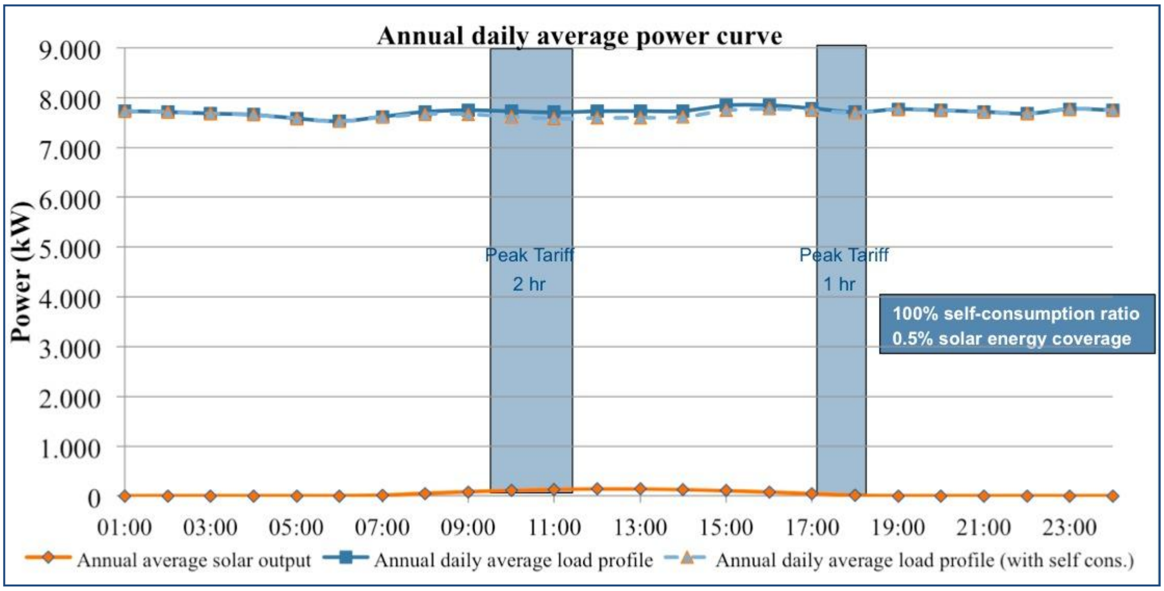
Table 35 summarizes the proposed PV system design of the smaller 247 kWp system.

Table 35: Case 4 (Automotive) – Overview of Proposed System Design (247 kWp)

Proposed PV System Design	
Peak power	247 kWp
Estimated number of solar panels (based on typical 150Wp multi-crystalline solar panels)	1,647
Type of inverter	100 kVA (to be installed preferably inside a technical room)
Quantity of inverters	3
DC array boxes	To be defined
AC control and monitoring panel	To be located between the inverters and electrical cabinet (to be defined)

The system is designed to maximise on-site energy consumption. The system reaches a 100% self-consumption ratio and 0.5% solar energy coverage. Figure 29 shows the average annual daily power curve, the solar generation curve and the residual demand curve after self-consumption.

Figure 29: Case 5 (Automotive) – Annual Daily Power Curve, Solar Curve (247 kWp) and Residual Demand



3.5.6 Results of Investment Calculation

The following section summarises the results of the investment calculation. Based on the load profile and the developed PV system design with 4MWp the only possible business model is self-consumption. There will be no excess energy that could be sold to the grid (see load profile in figure 28, chapter 3.6.5). The same applies to the smaller system with 247 kWp.

Project Report and Results of Investment Calculation (4 MWp)

Table 36 summarises the project information and main investment and performance parameter of the large 4 MWp system:

Table 36: Case 5 (Automotive) – Project Report (4 MWp)

System Information	
Location	Industrial Park, Southern Vietnam
Start of operation	January 2016
Operation lifetime	20 years
Installed capacity	3,983 kWp
Annual yield (first year)	5,843,061 kWh
Specific yield	1,467 kWh/kWp
Avoided CO_2-emissions*	3,124,670 kg/yr

* Average over system lifetime

Power Production and Demand	
Total annual power demand	67,603 MWh
Annual yield*	5,524 MWh
Self-consumed solar electr.*	5,524 MWh
Excess solar energy (sale to grid)*	-
Solar energy coverage*	8.2%
Self-consumption ratio*	100%
Avoided cost PV (first year)	1,665VND (7.47USDct)
Annual increase power tariff (Base)	5%

* Average over system lifetime

Costs and Financing	100% Equity	30% Equity
Specific invest.	1,500 USD	1,500 USD
Total invest.	5,974,500 USD	5,974,500 USD
Equity	5,974,500 USD	1,792,350 USD
Operational costs (first year)*	59,745 USD	59,745 USD
Operational costs per kWp	15USD/kWp	15USD/kWp
Debt	-	4,128,150 USD
Loan tenor	-	12 yrs
Loan interest rate*	-	3%
Discount rate	5%	5%
Tax rate	20%	20%

*Internal balance sheet funding, linear amortization

Table 37: Case 5 (Automotive) – Financial Report and Scenarios (4 MWp)

Main Results (Base Case)*	100% Equity	30% Equity
Equity IRR (before tax)	6.8%	9.2%
Project IRR (before tax)	6.8%	6.8%
Pay-back of equity	12.8yr	13.9yr
Pay-back of total investment	12.8yr	12.8yr
Capital reflux in % of equity	184.0%	343.0%
Capital reflux in % of total invest.	184.0%	184.0%
Solar LCOE	9.72ct/kWh	9.72ct/kWh
Average power tariff (benchm.)	12.35ct/kWh	12.35ct/kWh
Min. DSCR	-	0.79
Average DSCR	-	1.15

* Internal balance sheet funding (3% interest rate, 12yr loan term, 5% discount rate)

Annual Power Price Increase*	Low Increase 3%	Base Case 5%	High Increase 7%
Project IRR (before tax)	4.7%	6.8%	8.8%
Equity IRR (before tax)	5.9%	9.2%	12.3%
Pay-back of equity (yr)	15.6	13.9	12.7
Capital reflux in % of equity	231.6%	343.0%	285.1%
Solar LCOE (ct/kWh)	9.72	9.72	9.72
Av. power tariff (benchmark)	10.04	12.35	15.31
Min. DSCR	0.79	0.79	0.79
Average DSCR	1.03	1.15	1.29

* 30% equity financing, internal balance sheet funding

System Investment Costs* (USD/kWp)	Very Low Cost 1,100	Low Cost 1,300	Base Case 1,500	High Cost 1,700
Project IRR (before tax)	10.4%	8.4%	6.8%	5.5%
Equity IRR (before tax)	15.7%	12.0%	9.2%	7.0%
Pay-back of equity (yr)	10.4	12.6	13.9	15.1
Capital reflux in % of equity	542.5%	427.8%	343.0%	277.1%
Solar LCOE (ct/kWh)	7.43	8.57	9.72	10.86
Av. electricity tariff (over 20yrs)	12.35	12.35	12.35	12.35
Min. DSCR	1.05	0.91	0.79	0.70
Average DSCR	1.51	1.30	1.15	1.03

* 30% equity financing, internal balance sheet funding

Optimistic Case*	1,100USD/kWp invest 7% power tariff p.a.
Project IRR (before tax)	12.4%
Equity IRR (before tax)	18.9%
Pay-back of equity (yr)	9.1
Capital reflux in % of equity	763.2%
Solar LCOE (ct/kWh)	7.43
Av. power tariff (benchmark)	15.31
Min. DSCR	1.05
Average DSCR	1.70

* 30% equity financing

Table 38: Case 5 (Automotive) – Financing Scenarios (4 MWp)

Financing Model (30% Equity)	Internal* 5% Discount Rate 3% Loan Interest	External** 10% Discount Rate 9% Loan Interest
Project IRR (before tax)	6.8%	6.8%
Equity IRR (before tax)	9.2%	5.5%
Pay-back of equity (yr)	13.9	16.2
Capital reflux in % of equity	343.0%	259.5%
NPV of project (USD)	413,221	-1,685,119
NPV rel. to project value	6.9%	-28.2%
NPV of equity (USD)	942,858	-1,371,109
NPV rel. to equity	52.6%	-76.5%
Solar LCOE (ct/kWh)	9.72	13.58
Av. electricity tariff (over 20yrs)	12.35	12.35
Min. DSCR	0.79	0.52
Average DSCR	1.15	0.93

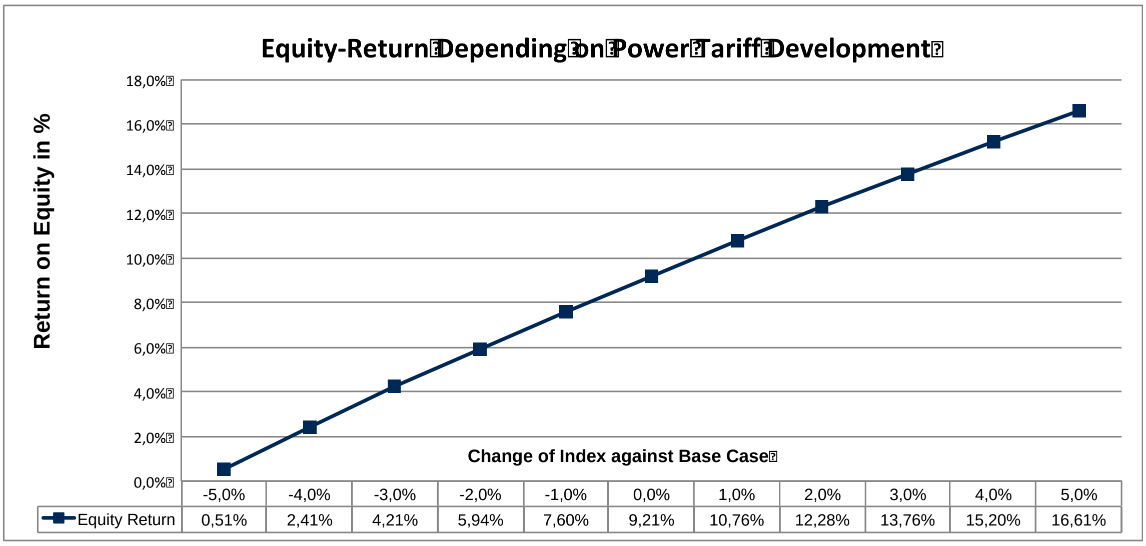
* Internal corporate balance sheet funding, base case
** Vietnamese commercial lending, base case

Table 38 shows the results for two different financing options (as described in chapter 3.1), assuming 1. an internal balance sheet funding with a low interest rate and a low corresponding discount rate and 2. a Vietnamese commercial lending model with high interest rates and a corresponding high internal discount rate.

Influence of Key Parameters

Looking at the key parameters that influence capital return shows that the assumptions on power tariff development are most influential (see figure 30). This is typical for a 100% self-consumption model and also reflects the influence of the currently low power tariffs that apply for industrial operations in Vietnam.

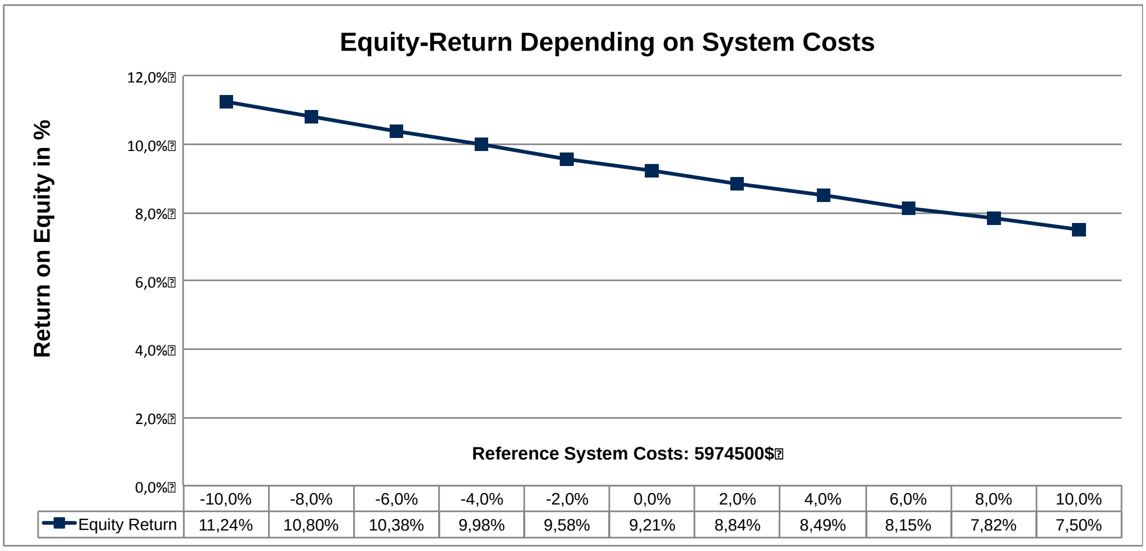
Figure 30: Case 5 (Automotive) – Influence of Power Tariff Development on Equity Return (4 MWp)



	-5,0%	-4,0%	-3,0%	-2,0%	-1,0%	0,0%	1,0%	2,0%	3,0%	4,0%	5,0%
Equity Return	0,51%	2,41%	4,21%	5,94%	7,60%	9,21%	10,76%	12,28%	13,76%	15,20%	16,61%

Apart from power tariff development, the assumptions on investment costs have a strong influence on the results of the investment calculations. Figure 31 shows the sensitivity of equity return regarding investment costs.

Figure 31: Case 5 (Automotive) – Influence of PV System Investment Costs (4 MWp)



	-10,0%	-8,0%	-6,0%	-4,0%	-2,0%	0,0%	2,0%	4,0%	6,0%	8,0%	10,0%
Equity Return	11,24%	10,80%	10,38%	9,98%	9,58%	9,21%	8,84%	8,49%	8,15%	7,82%	7,50%

Project Report and Results of Investment Calculation (247 Wp)

Table 39 summarises the project information and main investment and performance parameter of the smaller 247 kWp system. After discussion with the company management the financing model was defined as a 100% equity model.

Table 39: Case 5 (Automotive) – Project Report (247 kWp)

System Information	
Location	Industrial Park, Southern Vietnam
Start of operation	January 2016
Operation lifetime	20 years
Installed capacity	247 kWp
Annual yield (first year)	362,349 kWh
Specific yield	1,467 kWh/kWp
Avoided CO_2-emissions*	193,772 kg/yr

* Average over system lifetime

Power Production and Demand	
Total annual power demand	67,603 MWh
Annual yield*	343 MWh
Self-consumed solar electr.*	343 MWh
Excess solar energy (sale to grid)*	-
Solar energy coverage*	0.5%
Self-consumption ratio*	100%
Avoided cost PV (first year)	1,665VND (7.47USDct)
Annual increase power tariff (Base)	5%

* Average over system lifetime

Costs and Financing	100% Equity	30% Equity
Specific invest.	1,700 USD	1,700 USD
Total invest.	419,900 USD	419,900 USD
Equity	419,900 USD	125,970 USD
Operational costs (first year)*	4,940 USD	4,940 USD
Operational costs per kWp	20USD/kWp	20USD/kWp
Debt	-	293,930 USD
Loan tenor	-	12 yrs
Loan interest rate*	-	3%
Discount rate	5%	5%
Tax rate	20%	20%

*Internal balance sheet funding, linear amortization

Table 40: Case 5 (Automotive) – Financial Report and Scenarios (247 kWp)

Annual Power Price Increase (100% Equity)	Low Increase 3%	Base Case 5%	High Increase 7%
Equity IRR (before tax)	2.9%	5.0%	7.1%
Pay-back of equity (yr)	16.1	14.3	13.0
Capital reflux in % of equity	129.8%	159.2%	364.4%
Solar LCOE (ct/kWh)	11.27	11.27	11.27
Av. electricity tariff (over 20yrs)	10.04	12.35	15.31

* 100% equity financing

System Investment Costs* (USD/kWp)	Low Cost 1,500	Base Case 1,700	High Cost 1,900
Equity IRR (before tax)	6.3%	5.0%	3.9%
Pay-back of equity (yr)	13.2	14.3	15.4
Capital reflux in % of equity	177.8%	159.2%	144.5%
Solar LCOE (ct/kWh)	10.13	11.27	12.42
Av. electricity tariff (over 20yrs)	12.35	12.35	12.35

* 100% equity financing

Optimistic Case*	1,500USD/kWp invest 7% power tariff p.a.
Equity IRR (before tax)	8.4%
Pay-back of equity (yr)	12.1
Capital reflux in % of equity	220.4%
Solar LCOE (ct/kWh)	10.13
Av. electricity tariff (over 20yrs)	15.31

* 100% equity financing

Comparison – 4 MWp vs. 247 kWp

Table 41: Case 5 (Automotive) – Comparison 4 MWp vs. 247 kWp

Main Results – Base Case*	Large System (4 MWp)	Smaller System (247 kWp)
Total investment (USD)	5,974,500	419,000
Equity (USD)	1,792,350	-
Equity IRR (before tax)	9.2%	5.0%
Pay-back of equity	13.9yr	14.3yr
Capital reflux in % of equity	343.0%	159.2%
Solar LCOE	9.72ct/kWh	11.27ct/kWh
Av. electricity tariff (over 20yrs)	12.35ct/kWh	12.35ct/kWh

*Base case 4MWp: 1,500USD/kWp specific invest costs and 15USD/kWp/yr OPEX, 30% equity
Base case 247kWp: 1,700USD/kWp specific invest costs and 20USD/kWp/yr OPEX, 100% equity

3.6 Case Study 6: Manufacturing (Machinery)

3.6.1 General Company Profile

The company is located in Central Vietnam nearby Danang and produces machinery parts for export markets. The company was selected for the case study due to suitable roof area and infrastructure for solar PV and high interest in energy efficiency and solar PV technology.

The company management has already considered a solar PV investment and is generally committed to energy efficiency and clean energy usage for manufacturing.

3.6.2 Load Profile and Cost Structure of Energy Demand

Energy use: The total energy consumptions of the facility is rather high. The consumption in 2015 and in the first three months of 2016 was 9.8 GWh and 2.3 GWh respectively.

Power tariff: The company is paying the EVN 'manufacturing' electricity tariff. The factory has a medium voltage grid connection ("from 22kV to 110kV").

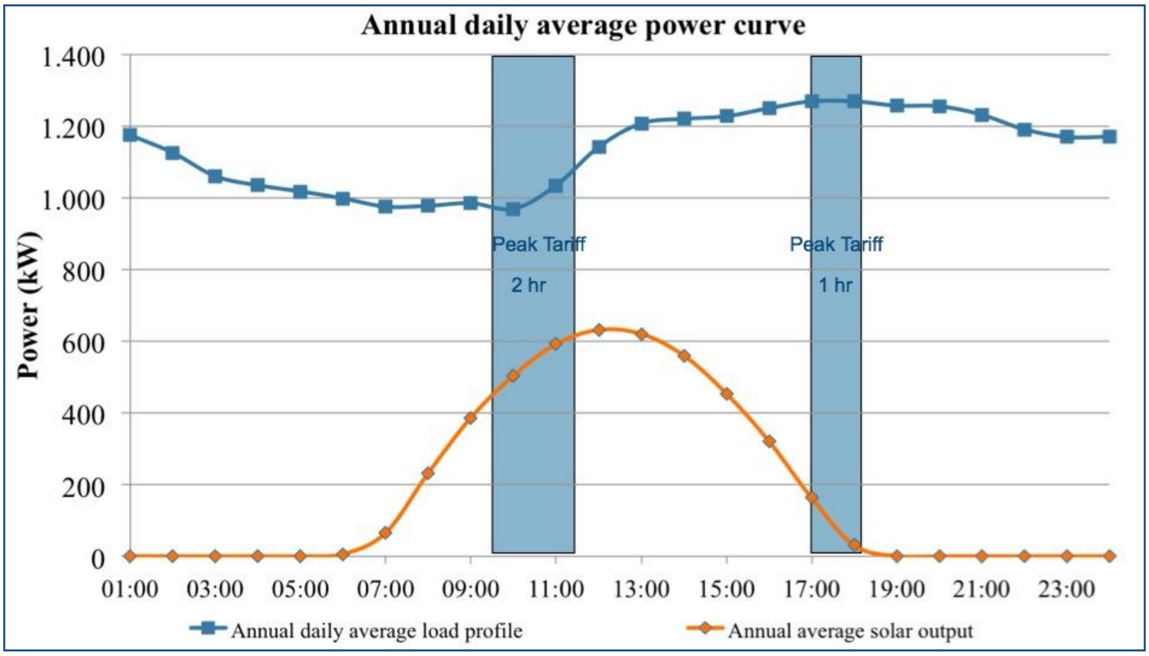
The current electricity tariff is the following:

- Normal (4:00-9:30; 11:30-17:00; 20:00-22:00): 1,405 VND/kWh (6.30USDct/kWh)
- Low (22:00-4:00): 902 VND/kWh (4.04USDct/kWh)
- High (9:30-11:30; 17:00-20:00): 2,556 VND/kWh (11.46USDct/kWh)

Avoided cost: The average avoided cost for the solar PV system is 1,666VND/kWh (7.47USDct/kWh).

Load profile: Data from the monitoring system were provided for a full year, with the total power of the site, being recorded every 15 minutes.

Figure 32: Case 6 (Machinery) – Daily Average Annual Power Curve and Solar Curve (1,476 kWp)



The load profile in figure 32 shows that the power use of the facility is quite steady. It operates 24h per day, mainly from 11:00 to 23:00 and maintains power consumption at about 1,000 kW for the remaining period of the day. The highest power consumption was noted at 1,269 kW in the interval 17:00 – 18:00.

The same load profiles were calculated for each weekday, Saturday and Sunday for each month of the year, in order to compare it with the solar output. The factory is not producing on Sundays and maintains the power use at minimum level, at around 640 kW. There is little variation between days and months in the load profile.

No regular power outages or brownouts were mentioned in the data provided by company management. No information exists about planned renovations or extensions of the site in the coming years.

3.6.3 Energy Efficiency and Energy Management

Energy efficiency measures: At the time of writing this report there was no detailed information about the energy efficiency situation as well as the energy management of the company available. However, the collected data show that the site follows a very high building standard (3 layer glass, high overall quality of building materials, etc.).

Energy management: This site has an annual total energy use approximately equal to 1,000 TOE tons of oil equivalent. Therefore the building owner should pay attention to the requirements from the Decree #21/2011/NĐ-CP (Detailed regulations and measures for implementing the Law on Use of energy saving and efficiency, issued March 29, 2011), applied for sites having a total energy use above 1,000 TOE per year. In this case, it has to follow:

- Energy audit to be conducted every 3 years, by a specialized firm being trained by MOIT;
- Appoint an energy management officer;
- Develop and implement annual and 5-year plans for energy saving and efficiency;
- Comply with the provisions on energy saving and efficiency during the construction, upgrading or expansion of construction works.

According to the technical staff, there were less than 24hr of power cuts in 2015 and no issues regarding power quality.

3.6.4 Assessment of Building and Roof Structure

The company has a large manufacturing site, located in an industrial zone in Central Vietnam.

This site has been built in 2011 and consists of several buildings/roofs:
- The main building (tilted roof, metal sheet profile);
- The parking area (tilted roof, metal sheet profile);
- The technical areas;
- The canteen.

Roof selection: After the site visit and discussion with the company management, the roofs of the main building (10,710 m^2) and of the parking area (1,440 m^2) were identified to be suitable for installing a solar PV system.

The main roof was planned to resist 150 km/h typhoons but damage occurred during the typhoon in 2014 (cat.1). This revealed a construction fault that will be repaired within the year 2016. The final roof cover will then have to be checked before the installation of a solar PV system.

The maximum peak power using the main factory roof and the carport canopy has been calculated with 1,476 kWp in total.

Using the carport canopy only allows for a smaller system with only 175 kWp.

Main factory roof (metal sheet):

Source: Artelia VN

Roof structure (main factory roof):

Source: Artelia VN

Carport canopy:

Source: Artelia VN

The potential location for inverters and monitoring display is to be determined during further investigation.

3.6.5 PV System Design

Following the load profile and current operational scheme of the company the only business model possible is self-consumption. Even with the full use of the available roof size the PV system would produce not enough solar excess energy to generate net metering credits within the projected support mechanism framework. However, to give the investor two different options there is the possibility to only use the carport canopy for a small PV system as an alternative to the large system:

- **'Self-consumption'** with a reduced PV system size of **175 kWp** (carport system) with no excess energy generated.
- **'Self-consumption** with the maximum possible PV system size of **1,476 kWp** with no relevant excess energy generated for the net metering credit scheme.

PV System Design 'Self-Consumption Small' (175kWp)

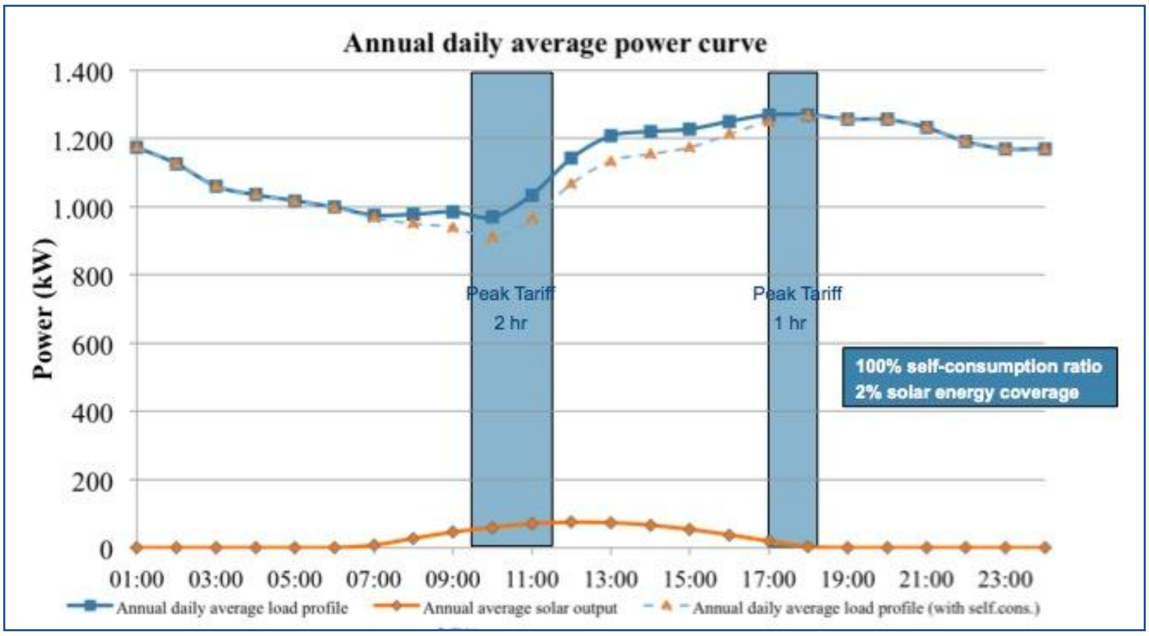
Table 42 summarizes the proposed PV carport system design for self-consumption with a PV system size of 175 kWp. With this sizing the PV system would generate no excess energy.

Table 42: Case 6 (Machinery) - Overview of Proposed System Design 'Self-Consumption Small' (175 kWp)

Proposed PV System Design	
Peak power	175 kWp
Estimated number of solar panels (based on typical 150Wp multi-crystalline solar panels)	1,167
Type of inverter	100 kVA
Quantity of inverters	2
DC array boxes	To be defined
AC control and monitoring panel	To be located between the inverters and electrical cabinet (to be defined)

The system reaches a 100% self-consumption ratio and 2% solar energy coverage. Figure 33 shows the average annual daily power curve, the solar generation curve and the residual demand curve after self-consumption.

Figure 33: Case 6 (Machinery) – Annual Daily Power Curve, Solar Curve (175 kWp) and Residual Load



PV System Design 'Self-Consumption Large' (1,476 kWp)

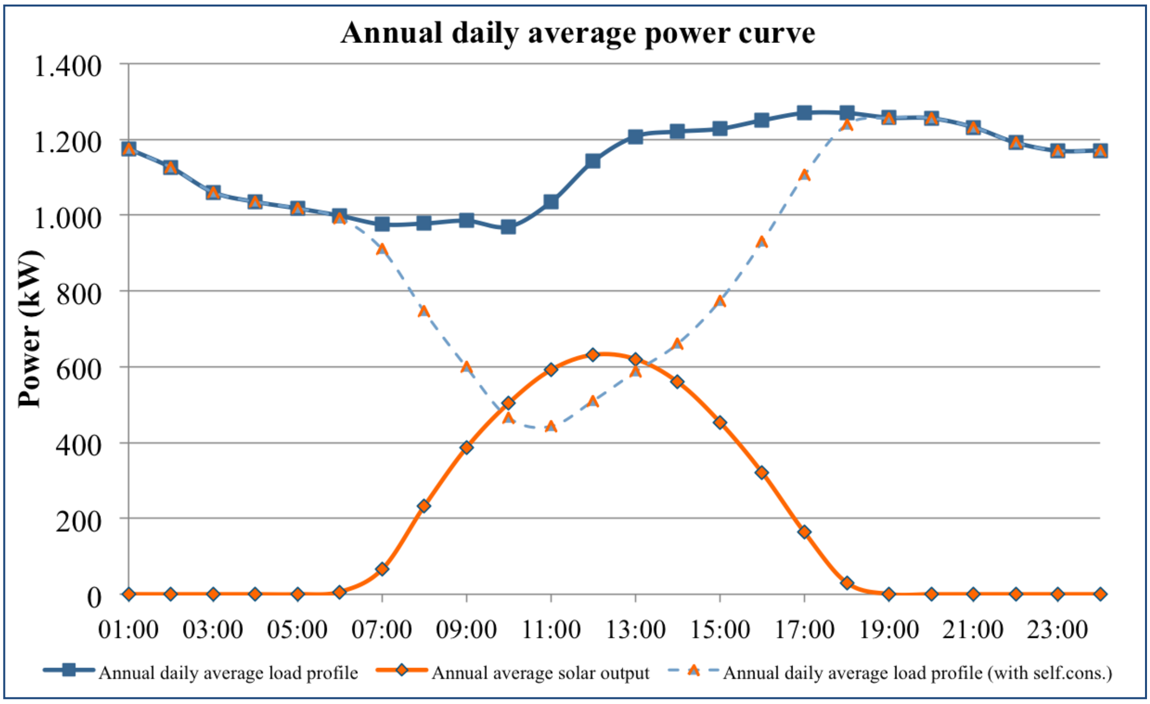
Table 43 summarizes the proposed PV system design optimised for the utilisation of the whole available roof space on the main factory roof and the carport canopy with a total PV system size of 1,476 kWp. With this sizing the PV system will generate a limited amount of excess energy, in particular on off-production Sundays. However, applying the proposed net metering scheme with a billing of the monthly balance of excess solar energy and total power demand, there will be no substantial excess energy left to be remunerated with the net metering credit (the excess solar energy produced on Sundays and "stored" in the grid is fully consumed/reimported from the grid within the following weekdays. Consequently, the net metering system increases the self-consumption rate of the system to 100%).

Table 43: Case 6 (Machinery) - Overview of Proposed System Design 'Self-Consumption Large' (1,476 kWp)

Proposed PV System Design	
Peak power	1,476 kWp
Estimated number of solar panels (based on typical 150Wp multi-crystalline solar panels)	9,840
Type of inverter	100 and 500 kVA
Quantity of inverters	5 including 2x100 kVA (carport canopy) and 3x500 kVA (main roof)
DC array boxes	To be defined
AC control and monitoring panel	To be located between the inverters and electrical cabinet (to be defined)

The system is designed to maximise roof space utilisation and reaches a 100% self-consumption ratio and 16% solar energy coverage. Figure 34 shows the average annual daily power curve, the solar generation curve and the residual demand curve after self-consumption.

Figure 34: Case 6 (Machinery) – Annual Daily Power Curve, Solar Curve (1,476 kWp) and Residual Load



3.6.6 Results of Investment Calculation

The following section summarises the results of the investment calculation. Based on the load profile and the developed PV system design one possible business model with two different system sizes have been calculated: 1. 'Self-consumption (small)' system with 175 kWp and 2. 'Self-consumption (large)' system with 1,476 kWp.

It has to be noted at this point that the results differ substantially from comparable manufacturing cases in Southern Vietnam due to the lower solar irradiation in this central part of the country.

Project Report and Results of Investment Calculation (175 kWp)

Table 44 summarises the project information and main investment and performance parameter of the small 'self-consumption' system with 175 kWp. After discussion with the company management there was a 100% equity financing model chosen for the small PV system layout.

Table 44: Case 6 (Machinery) – Project Report (175 kWp)

System Information	
Location	Central Vietnam
Start of operation	January 2016
Operation lifetime	20 years
Installed capacity	175 kWp
Annual yield (first year)	197,750 kWh
Specific yield	1,130 kWh/kWp
Avoided CO_2-emissions*	105,750 kg/yr

* Average over system lifetime

Power Production and Demand	
Total annual power demand	9,334 MWh
Annual yield*	187 MWh
Self-consumed solar electr.*	187 MWh
Excess solar energy (sale to grid)*	-
Solar energy coverage*	1.9%
Self-consumption ratio*	100%
Avoided cost PV (first year)	1,665VND (7.47USDct)
Annual increase power tariff (Base)	5%

* Average over system lifetime

Costs and Financing	100% Equity	30% Equity
Specific invest.	1,700 USD	1,700 USD
Total invest.	297,500 USD	297,500 USD
Equity	297,500 USD	89,250 USD
Operational costs (first year)*	3,500 USD	3,500 USD
Operational costs per kWp	20USD/kWp	20USD/kWp
Debt	-	208,250 USD
Loan tenor	-	12 yrs
Loan interest rate*	-	3%
Discount rate	5%	5%
Tax rate	20%	20%

*Internal balance sheet funding, linear amortization

Table 45: Case 6 (Machinery) – Financial Report and Scenarios (175 kWp)

Main Results*	100% Equity	30% Equity
Equity IRR (before tax)	2.1%	1.6%
Project IRR (before tax)	2.1%	2.1%
Pay-back of equity	17.5yr	19.0yr
Pay-back of total investment	17.5yr	17.5yr
Capital reflux in % of equity	121.8%	121.8%
Capital reflux in % of total invest.	121.8%	128.6%
Solar LCOE	14.63ct/kWh	14.63ct/kWh
Average electricity tariff (over 20yrs)	12.35ct/kWh	12.35ct/kWh
Min. DSCR	-	0.48
Average DSCR	-	0.74

* Internal balance sheet funding (3% interest rate, 12yr loan term, 5% discount rate)

Annual Power Price Increase* (100% Equity)	Low Increase 3%	Base Case 5%	High Increase 7%
Equity IRR (before tax)	0.0%	2.1%	4.2%
Pay-back of equity (yr)	21.0	17.5	15.6
Capital reflux in % of equity	98.5%	121.8%	150.9%

* 100% equity financing

System Investment Costs* (USD/kWp)	Low Cost 1,500	Base Case 1,700	High Cost 1,900
Equity IRR (before tax)	3.3%	2.1%	1.2%
Pay-back of equity (yr)	16.1	17.5	18.7
Capital reflux in % of equity	135.9%	121.8%	110.3%
Solar LCOE (ct/kWh)	13.15	14.63	16.12
Av. electricity tariff (over 20yrs)	12.35	12.35	12.35

* 100% equity financing

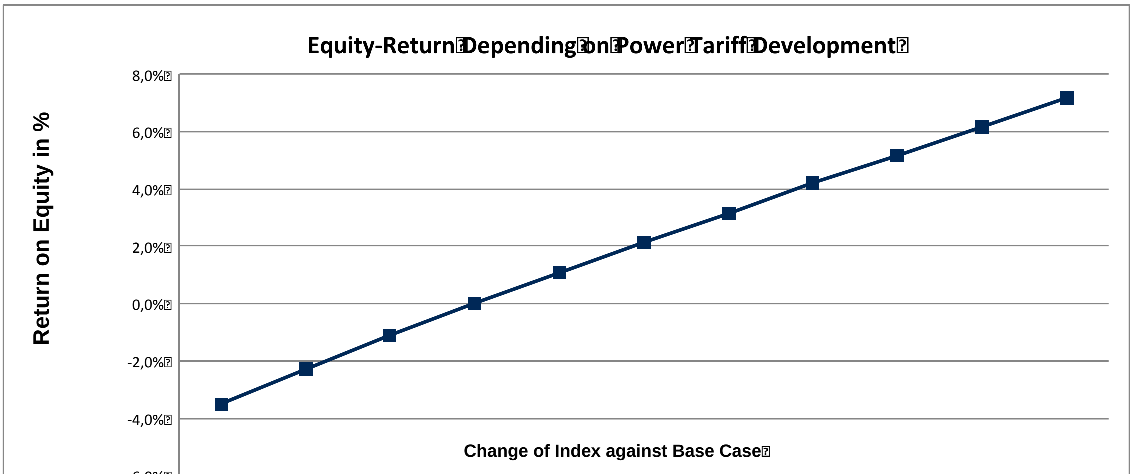
Optimistic Case*	1,500USD/kWp invest 7% power tariff p.a.
Equity IRR (before tax)	5.3%
Pay-back of equity (yr)	14.5
Capital reflux in % of equity	168.8%
Solar LCOE (ct/kWh)	13.15
Av. electricity tariff (over 20yrs)	15.31

* 100% equity financing

Influence of Key Parameters

Looking at the key parameters that influence capital return shows that the assumptions on power tariff development are most influential (see figure 35). This is typical for a 100% self-consumption model and also reflects the influence of the currently low power tariffs that apply for industrial operations in Vietnam.

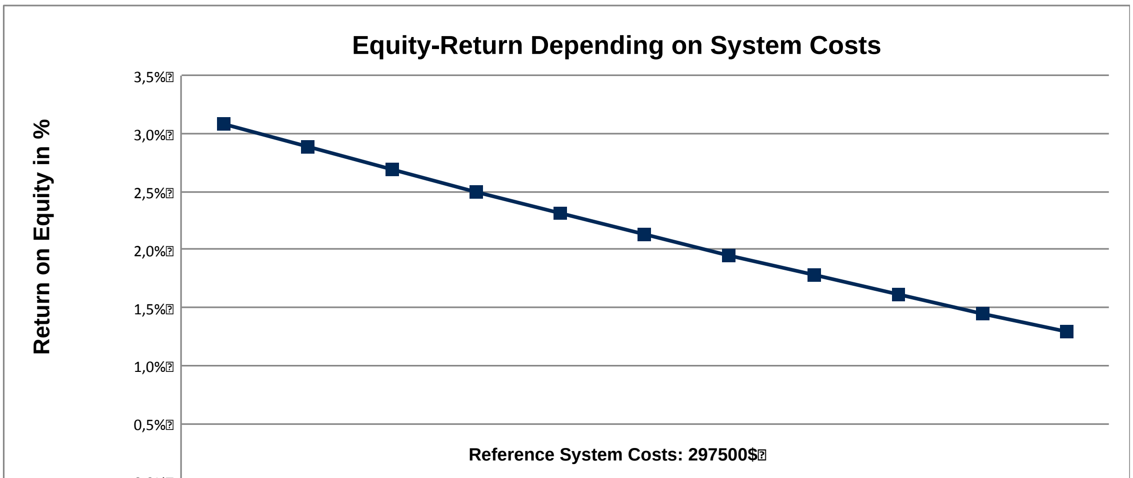
Figure 35: Case 6 (Machinery) – Influence of Power Tariff Development on Equity Return (175 kWp)



	-5,0%	-4,0%	-3,0%	-2,0%	-1,0%	0,0%	1,0%	2,0%	3,0%	4,0%	5,0%
Equity Return	-3,50%	-2,29%	-1,13%	-0,01%	1,07%	2,13%	3,16%	4,18%	5,18%	6,17%	7,15%

Apart from power tariff development, the assumptions on investment costs have a strong influence on the results of the investment calculations. Figure 36 shows the sensitivity of equity return regarding investment costs.

Figure 36: Case 6 (Machinery) – Influence of PV System Investment Costs (175 kWp)



	-10,0%	-8,0%	-6,0%	-4,0%	-2,0%	0,0%	2,0%	4,0%	6,0%	8,0%	10,0%
Equity Return	3,08%	2,88%	2,69%	2,49%	2,31%	2,13%	1,95%	1,78%	1,61%	1,45%	1,29%

Project Report and Results of Investment Calculation (1,476 kWp)

Table 46 summarises the project information and main investment and performance parameter of the large ‘self-consumption’ system with 1,476 kWp.

Table 46: Case 6 (Machinery) – Project Report (1,476 kWp)

System Information	
Location	Central Vietnam
Start of operation	January 2016
Operation lifetime	20 years
Installed capacity	1,476 kWp
Annual yield (first year)	1,667,880 kWh
Specific yield	1,130 kWh/kWp
Avoided CO_2-emissions*	891,925 kg/yr

* Average over system lifetime

Power Production and Demand	
Total annual power demand	9,934 MWh
Annual yield*	1,577 MWh
Self-consumed solar electr.*	1,577 MWh
Excess solar energy (sale to grid)*	-
Solar energy coverage*	15.9%
Self-consumption ratio*	100%
Avoided cost PV (first year)	1,666VND (7.47USDct)
Annual increase power tariff (base case)	5%

*Average over system lifetime

Costs and Financing	100% Equity	30% Equity
Specific invest.	1,500 USD	1,500 USD
Total invest.	2,214,000 USD	2,214,000 USD
Equity	2,214,000 USD	664,200 USD
Operational costs (first year)*	29,520 USD	29,520 USD
Operational costs per kWp	20USD/kWp	20USD/kWp
Debt	-	1,549,800 USD
Loan tenor	-	12 yrs
Loan interest rate*	-	3%
Discount rate	5%	5%
Tax rate	20%	20%

*Internal balance sheet funding, linear amortization

Table 47: Case 6 (Machinery) – Financial Report and Scenarios (1,476 kWp)

Main Results*	100% Equity	30% Equity
Equity IRR (before tax)	3.3%	3.4%
Project IRR (before tax)	3.3%	3.3%
Pay-back of equity	16.1yr	17.6yr
Pay-back of total investment	16.1yr	16.1yr
Capital reflux in % of equity	135.8%	177.2%
Capital reflux in % of total invest.	135.8%	135.8%
Solar LCOE	13.15ct/kWh	13.15ct/kWh
Average electricity tariff (over 20yrs)	12.35ct/kWh	12.35ct/kWh
Min. DSCR	-	0.54
Average DSCR	-	0.83

* Internal balance sheet funding (3% interest rate, 12yr loan term, 5% discount rate)

Annual Power Price Increase* (30% Equity)	Low Increase 3%	Base Case 5%	High Increase 7%
Project IRR (before tax)	1.1%	3.3%	5.3%
Equity IRR (before tax)	-0.1%	3.4%	6.6%
Pay-back of equity (yr)	21.0	17.6	15.6
Capital reflux in % of equity	89.2%	177.2%	288.0%
Min. DSCR	0.54	0.54	0.54
Average DSCR	0.73	0.83	0.95

* 30% equity financing

System Investment Costs* (USD/kWp)	Very Low Cost 1,100	Low Cost 1,300	Base Case 1,500	High Cost 1,700
Project IRR (before tax)	6.3%	4.6%	3.3%	2.1%
Equity IRR (before tax)	8.4%	5.6%	3.4%	1.6%
Pay-back of equity (yr)	14.3	16.0	17.6	19.0
Capital reflux in % of equity	323.7%	239.8%	177.2%	128.6%
Solar LCOE (ct/kWh)	10.17	11.66	13.15	14.63
Av. electricity tariff (20yrs)	12.35	12.35	12.35	12.35
Min. DSCR	0.74	0.62	0.54	0.48
Average DSCR	1.10	0.95	0.83	0.74

* 30% equity financing

Very Optimistic Case*	1,100 USD/kWp invest 7% power tariff p.a.
Project IRR (before tax)	8.5%
Equity IRR (before tax)	11.7%
Pay-back of equity (yr)	13.0
Capital reflux in % of equity	473.1%
Solar LCOE (ct/kWh)	10.17

* 30% equity financing

Table 48: Case 6 (Machinery) – Financing Scenarios (1,476 kWp)

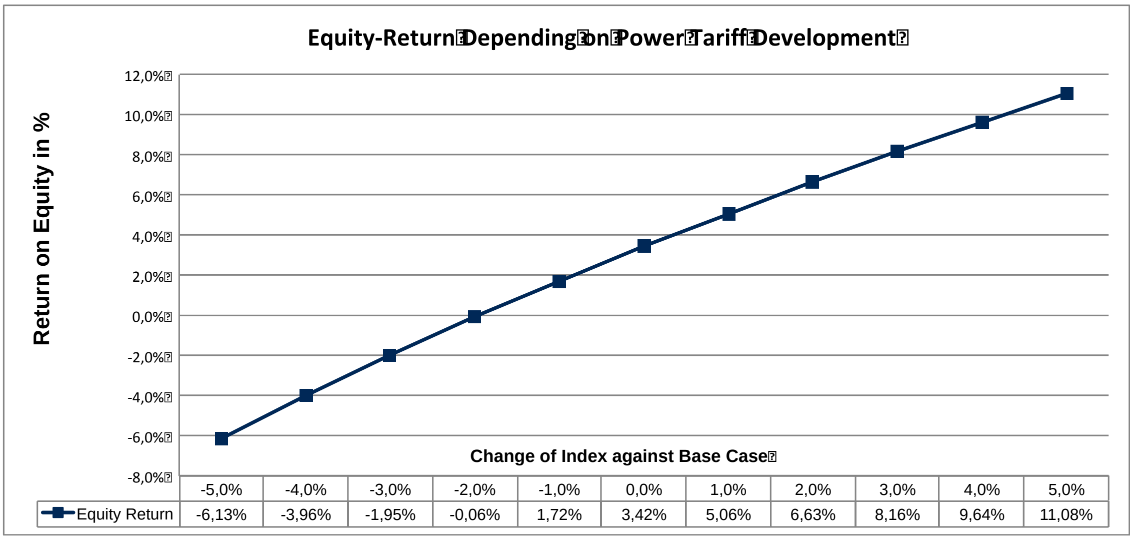
Financing Mode (30% Equity)	Internal* 5% Discount Rate 3% Loan Interest	External** 10% Discount Rate 9% Loan Interest
Project IRR (before tax)	3.3%	3.3%
Equity IRR (before tax)	3.4%	0.4%
Pay-back of equity (yr)	17.6	21.0
Capital reflux in % of equity	177.2%	88.4%
NPV of project (USD)	-441,985	-992,411
NPV rel. to project value	-20.0%	-44.8%
NPV of equity (USD)	-275,035	-918,139
NPV rel. to equity	-41.4%	-138.2%
Solar LCOE (ct/kWh)	13.15	18.15
Av. electricity tariff (over 20yrs)	12.35	12.35
Min. DSCR	0.54	0.35
Average DSCR	0.83	0.67

* Internal corporate balance sheet funding, base case
** Vietnamese commercial lending, base case

Influence of Key Parameters

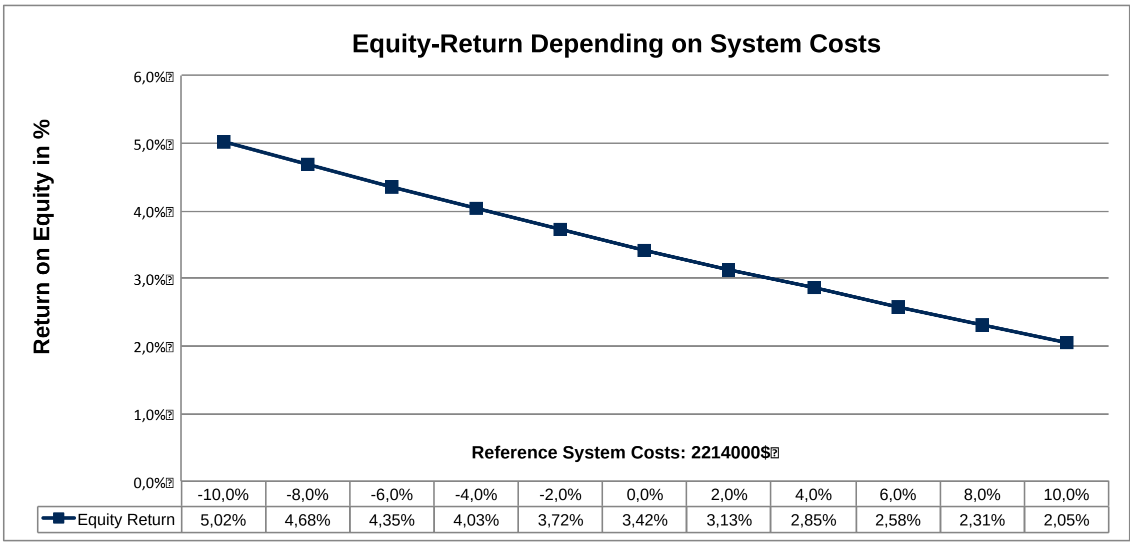
Looking at the key parameters that influence capital return shows that the assumptions on power tariff development are most influential (see figure 37). This is typical for a 100% self-consumption model and also reflects the influence of the currently low power tariffs that apply for industrial operations in Vietnam.

Figure 37: Case 6 (Machinery) – Influence of Power Tariff Development on Equity Return (1,476 kWp)



Apart from power tariff development, the assumptions on investment costs have a strong influence on the results of the investment calculations. Figure 38 shows the sensitivity of equity return regarding investment costs.

Figure 38: Case 6 (Machinery) – Influence of PV System Investment Costs (1,476 kWp)



Comparison Small vs. Large System

Table 49: Case 6 (Machinery) – Comparison 1,476 kWp vs. 175 kWp

Main Results – Base Case*	Large System (1,476kWp)	Smaller System (175kwp)
Total investment (USD)	2,214,000	297,500
Equity (USD)	664,200	-
Equity IRR (before tax)	3.4%	2.1%
Pay-back of equity	17.6yr	17.5yr
Capital reflux in % of equity	177.2%	121.8%
Solar LCOE	13.15ct/kWh	14.63ct/kWh
Av. power tariff (benchmark)	12.35ct/kWh	12.35ct/kWh

*Base case 1,476kWp: 1,500USD/kWp specific invest costs, 30% equity
Base case 175kWp: 1,700USD/kWp specific invest costs, 100% equity

Opportunities and Key Challenges for Solar PV Investments in Vietnam

Opportunities for Solar PV Rooftop Investments in Vietnam

The pre-feasibility studies for the six commercial and industrial cases have shown that there are attractive investment opportunities for solar PV rooftop in the Vietnamese industry sector. However, they also show that the current low level of electricity tariffs in Vietnam is a big challenge and makes assumptions on the future increase of retail power tariffs a critical factor for investment calculations.

The Case Studies – Overview of Results

Table 50 gives an overview of key results of the investment calculations. It summarises the investment cases in two different scenarios, a base case scenario and a scenario with low investment costs. For case 3 with more than one possible business model, the more beneficial 'net metering' model is displayed.

Table 50: Overview of Case Study Results

Case Study	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6
Type of business	Supermarket	Cold Storage	Manufacturing	Manufacturing	Manufacturing	Manufacturing
PV system size (kWp)	280	123	478	946	3,983	1,476
Business model	Self-Cons.	Self-Cons.	Net Met.	Self-Cons.	Self-Cons.	Self-Cons.
Specific yield (kWh/kWp)	1,423	1,334	1,467	1,467	1,467	1,130
Solar coverage	6.6%	2%	70%	11%	8%	16%
Self-consumption	100%	100%	46%	100%	100%	100%
Avoided cost tariff (USDct/kWh)	11.82	9.84	8.83	7.47	7.47	7.47
Av. electr. tariff (USDct/kWh)*	19.54	16.27	14.60	12.35	12.35	12.35
Base Case**						
Specific invest (USD/kWp)	**1,700**	**1,700**	**1,700**	**1,700**	**1,500**	**1,500**
Equity IRR (before tax)	15.9%	10.0%	17.7%	5.0%	9.2%	3.4%
Pay-back of equity (yr)	10.3	13.5	9.2	14.3	13.9	17.6
Capital reflux (% equity)	545.6%	365.9%	594.2%	257.9%	343.0%	177.2%
Solar LCOE (USDct/kWh)	11.62	12.40	11.27	11.27	9.72	13.15
Low investment Cost Case**						
Specific invest (USD/kWp)	**1,500**	**1,500**	**1,500**	**1,300**	**1,100**	**1,100**
Equity IRR (before tax)	19.1%	12.5%	21.2%	7.9%	15.7%	8.4%
Pay-back of equity (yr)	8.5	12.4	7.6	12.0	10.4	14.3
Capital reflux (% equity)	645.5%	442.2%	700.5%	202.1%	542.5%	323.7 %
Solar LCOE (USDct/kWh)	10.44	11.14	10.13	8.98	7.43	10.17

* Average electricity tariff over 20yr project lifetime
** 30% equity financing (internal balance sheet funding with 3% interest rate, 5% discount rate), 5% power tariff and net metering credit increase p.a., (only case 4 with 100% equity)

Electricity Tariffs Matter – Comparison of Business Sectors

The results show that the there is a divide in results between business sectors that pay the 'business' and 'manufacturing' electricity tariffs of EVN. This applies for both business models, but even more for the self-consumption model that relies the most on revenues from electricity cost savings. Since there are only a few exceptions of companies being not categorised in one of the two EVN-tariff categories[60], this specific retail tariff structure gives some orientation for investors and solar companies approaching potential customers.

It can be summarised that:

- Only one case could generate enough excess power to apply the net-metering business model and benefit from a governmental support programme for net metering (as was foreseen in the rejected draft legislation of 2015/2016). This reflects the usually high power demand of companies in the manufacturing and commercial sector.[61]
- Equity IRRs (before tax) reach double-digit values even in base case scenarios in those cases that are either underlying the EVN business tariff (ideally case 1) or underlie the EVN manufacturing tariff but are able to benefit from the net-metering support mechanism (case 3). In those cases equity payback times are below or close to 10yrs.
- The 'Manufacturing' cases not benefiting from the net metering support only reach single-digit IRR return rates and equity payback times of around 14 years. Case 6 as a 'Manufacturing' case has less attractive results due to the lower solar irradiation in Central Vietnam.

Table 51 directly compares two of the self-consumption cases, the supermarket with the EVN-Business tariff and the manufacturer of consumer products with the EVN-Manufacturing tariff. Both cases are calculated with the same assumptions on investment costs and power tariff increase and differ only slightly in their specific yield. The difference of results is quite substantial.

Table 51: Comparison of Business Sectors – Commercial vs. Industry (Self-Consumption)

Project Features	Case 1 'Commercial'	Case 4 'Industrial'
Type of Business	Supermarket	Manufacturing (consumer products)
EVN Tariff	"Business"	"Manufacturing"
Avoided cost tariff (USDct/kWh)	**11.82**	**7.47**
Average electricity tariff (USDct/kWh)*	19.54	12.35
PV system size (kWp)	280	946
Specific yield (kWh/kWp)	1,423	1,467
Self consumption ratio	100%	100%

* Over 20 years

Financial Results**		
Equity IRR (before tax)	15.9%	5.0%
Pay-back of equity	10.3yr	14.2r
Capital reflux in % of equity	545.6%	257.9%
Solar LCOE	11.62ct/kWh	11.27/kWh

**Both cases: Base case (self-consumption), 30% equity, 1,700USD/kWp investment costs, 5% annual increase of power tariffs

[60] There are only a few industrial parks in Vietnam providing own power generation facilities (mainly thermal coal or gas power plants) and power utility services for their clients. According to some differences in tariff structure the solar PV avoided costs are slightly higher than those cases with the normal EVN-Manufacturing tariff (compare Case 3 with the other manufacturing cases).

[61] However, this in return implies that investment opportunities in those industrial sectors with low and medium power demand and large available roof areas would offer attractive returns on investment due to additional benefits from the net metering credit system.

The Benefits of the Net Metering Support – Comparison of Business Cases

Looking at the case comparison another key result comes into focus: The projected net metering support scheme would improve investment cases substantially for those PV system designs that allow for excess energy generation. The net metering credit for excess solar energy as foreseen in the draft support law is substantially higher than the avoided costs of solar PV achievable in the industrial as well as the commercial cases.

Table 52 compares the two business cases of self-consumption and net metering for case 3 (manufacturer 'electronic distribution system') with the same set of key assumptions. The results of the net metering business model are still better if no increase of the net metering credit is assumed over the lifetime of the system.

Table 52: Case 3 (Electrical Distribution System – Influence of Business Model and Annual Increase of Net Metering Credit

Main Results*	Self-Consumption (131 kWp)	Net Metering (478 kWp) 0% Credit Increase	Net Metering (487 kWp) 5% Credit Increase
Self-consumption ratio	95%	46%	46%
Excess energy (MWh/a)	10	359	359
Equity IRR (before tax)	10.6%	12.6%	17.7%
Pay-back of equity	13.2yr	12.2yr	9.2yr
Capital reflux in % of equity	378.2%	373.4%	594.2%

* Base case, 30% equity, 1,700USD/kWp invest costs, 5% annual power tariff increase

It can be summarised that:

- Although the details of the potential net metering scheme are still unknown, it is most likely that with the projected value of the credit of approximately 15USDct/kWh of the first draft of 2015/2016 it would improve investments for those cases with potential for excess solar energy generation substantially.

- However, the real extend of the net metering benefit will depend on the details of implementation, in particular on the question of indexation with the overall electricity tariff development as well as the design of the billing periods. For the effectiveness of the final legislation it will make a major difference whether the billing is kWh consumption vs. kWh of production at the specific time or a monthly average comparison. For this study, we assumed a monthly billing period as was foreseen in the initial draft. The results further lead to the conclusion of a limited impact of the government scheme in the initial draft legislation. The (monthly) billing period would simply make the net-metering scheme applicable only in a very limited number of cases.

Identifying the Added Value of Solar PV for the Customer – Investment Motivation

Evaluating the mere figures and results of the investment calculations highly depends on the investor's expectations. Typical for developing or emerging markets with generally more difficult financing conditions, higher interest rates and lower levels of legal security, investors usually expect very short equity payback times.

The interviews with the companies of the whole survey and previous research in the private sector[62] show that this also applies to Vietnam, in particular to Vietnamese owned companies. However, the feedback from the interviewed companies also shows that – and this particularly applies to German and other international corporations – there are a number of factors that can help to make 10 year equity payback times feasible for many investors. These factors are related to different "added values" of a solar PV investment. Some of the interviewed companies were already aware of these "added values", others not but gained awareness on these aspects in the course of the project.

[62] See GIZ (2015).

These “added value” factors can be summarised as follows:

- **Green certification:** For many companies a very tangible added value of solar PV investments is the associated contribution to green building certifications. In particular, certain business sectors such as the textile and garment industry are focusing more and more on international (LEED) and local Vietnamese (LOTOS) certifications that reward the inclusion of renewable energy sources into production processes.

- **Contributions to corporate programmes/goals:** Many, in particular larger corporations, have corporate programmes implemented with specific targets for CO_2-reduction or even renewable energy shares for their operations. Solar PV systems can contribute to these targets.

- **Greening the product/service:** An increasing number of industries experiences pressure from their customer groups to guarantee sustainable, i.e. environmentally and socially sound origin of their products or services. This includes the production of the end product but also the whole upstream value chain. This applies in particular to the textile and garment industry but increasingly to other manufacturers and distributers of a variety of consumer products (food and beverage, cosmetics, life style products and even automotive etc.). A solar PV system on the roof of the outsourced Southeast Asian production facility can actually contribute to improve sustainability of production but can also be an important and “visible” contribution to the communication and marketing strategy of the respective company.

- **Being front-runner in the industry:** Related to the previous point it can be observed that for a number of foreign and local industries it is attractive to pursue a “front-runner” strategy to improve the market positioning of their product or service. Being the first company of the industry or industry sector with a “green factory” and a solar PV system can similarly contribute to the marketing strategy of the company.

- **Security of energy supply:** An argument that some of the interviewed companies had in mind is the goal to achieve a high share of solar energy coverage for the respective operation or factory and related to this to substantially improve the security of energy supply. This potential motivation for a solar PV investment becomes less relevant with the fact that in most cases the PV systems reaches only limited energy coverage, in particular in manufacturing companies with higher loads. Furthermore, the quality of energy supply in Vietnam has improved substantially in the last years and interviewed companies report decreasing use of their backup diesel generators.

- **PV system mobility:** For a few companies it was an added value that in general the solar PV system, at least with its main components, can be moved from one production facility to another. This applies to some industries that often move manufacturing to newly evolving markets, e.g. tanneries.

Key Challenges for Investments and Market Entry

The analysis of the framework conditions for solar PV investments (see chapter 2) as well as previous experience with solar PV rooftop investments in the Vietnamese commercial and industrial sector show that, despite the very promising opportunities, there are a number of challenges to be tackled.[63]

Uncertainty of Legal-Administrative Framework

At the time of writing this report, the draft Solar PV Support Law was rejected by the Prime Minister for further study. The first draft of 2015/2016 still leaved some room for interpretation regarding the details of the net metering scheme as well as other provisions such as technical or administrational guidelines. Further than that and following the results of the case calculation it can be expected that a net metering support scheme will only have limited impact on investments since it applies to only a limited number of suitable cases with relevant amounts of excess solar power generation.

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[63] For a practitioner’s insight see e.g. Carsten Aschoff (2016). *Business Models and Market Segments of Photovoltaics in Vietnam.* Presentation at the Information Workshop “Photovoltaics in Vietnam: Freefield and net metering before breakthrough?” June 2, 2016 in Berlin. Download available at: https://www.giz.de/fachexpertise/html/21026.html (GER). Live recording: https://www.youtube.com/watch?v=PXZmdj39AaQ&feature=youtu.be

Low Level of Electricity Tariffs and Uncertainty about Energy Market Development

Vietnam is one of the emerging solar markets with the lowest electricity tariffs. The case calculations have shown that despite outstanding solar resources the low retail tariffs for electricity are a real challenge for investments. This applies in particular for manufacturing companies that are subject to the lower EVN "manufacturing" tariff. Along with the low level of tariffs comes the uncertainty about the future development of electricity prices. There is no political roadmap or official development scenario that could give guidance for investors or project developers. The Vietnamese power market is in a transition and process of liberalisation. The outcome and the timeline of this process is yet unknown. This has at least two impacts on potential investors:

- With the low electricity tariffs in mind (that have been one reason for many foreign companies to invest in Vietnam in the first place), many commercial/industrial power consumers have only **low motivation to invest in an own power generation** facility.

- Many investors still regard **equity payback times of 7-10 years** as **too long**. This particularly applies to many Vietnamese owned companies but certainly also for some international companies.

However, most indicators lead to the assumption that power tariffs will increase substantially over the next two decades.

Access to External Financing Sources

A key feature of and challenge related to solar PV investments are the high up-front investment cost for the system (and comparatively low operation and maintenance costs for the time of system operation). In an undeveloped market like Vietnam these costs are likely to be even higher than in mature solar markets. In addition, due to lack of experience and local capacities, financing is a more difficult and sensitive issue than it would be in developed market environments.

The survey of companies included in this study suggests that many companies, larger foreign owned corporations in particular, are willing to finance small and medium sized PV rooftop systems solely with own equity or have access to low interest rate loans at international capital markets. However, for other companies, local Vietnamese or foreign owned, access to financing or even additional funding sources is of high relevance. Furthermore, some of the interviewed companies showed interest in leasing models to avoid high up-front investments.

Since there has not been any experience with financing solar PV projects in Vietnam yet (neither rooftop nor ground-mounted), local financing institutions lack knowledge about the technology in general and risk assessment for PV projects in particular. Local development banks such as the Vietnamese Development Bank (VDB) or some of the commercial banks have already gained some experience with financing clean energy and energy efficiency projects in the private sector.[64] However, they still have to build up knowledge and capacities for financing solar PV projects.

Finding Reliable Local Partners

Finding and motivating potential companies to invest in solar PV needs a lot of marketing and sales efforts. Furthermore, once investors are found, it might be necessary to involve local partners for construction work etc. to reach an efficient price structure for the project. Be it for project acquisition or for construction, finding a reliable local partner is a challenge in Vietnam. Firstly, there is not much experience with renewable energy in general and solar PV in particular among potential partners or respective industries. And secondly, the language barrier and cultural differences can make this process even more difficult.[65]

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[64] E.g. the International Finance Corporation (IFC) works together with Vietinbank and Sacombank to develop their sustainable energy portfolio and help financing clean energy and energy efficiency investments in the commercial sector. For more information see: http://www.ifc.org/wps/wcm/connect/region__ext_content/regions/east+asia+and+the+pacific/countries/eap-vietnam-eecp+project

[65] For a practitioner's insight see e.g. Frank Zimmermann (2016).*PV Freefield in Vietnam: Desire or Reality?* Presentation at the Information Workshop "Photovoltaics in Vietnam: Freefield and net metering before breakthrough?" June 2, 2016 in Berlin. Download available at: https://www.giz.de/fachexpertise/html/21026.html (GER). Live recording (min. 30:00 onwards): https://www.youtube.com/watch?v=PXZmdj39AaQ&feature=youtu.be

Unawareness about Solar PV Technology

Solar PV is a new technology in Vietnam and many potential customers lack knowledge about the technology and its possible contributions to the energy supply of a commercial or industrial operation.[66] The public debate on the governmental support mechanism that started in 2015 has raised awareness among private sector stakeholders to some extend. However, approaching potential costumers and investors requires extensive knowledge building and explaining the very basics of solar PV contributions regarding energy supply and investment economics.

Key Recommendations for Market Entry

Entering the newly emerging Vietnamese solar market offers great opportunities. With an average GDP growth rate of 6.5% per year in the last 15 years and an average of 4 billion USD of annual Foreign Direct Investments solar PV faces a steadily growing commercial and industrial target sector in Vietnam. High solar irradiation in the economic centre of Southern Vietnam and the upcoming governmental support mechanism for solar PV investments make a good ground for market development in the commercial and industrial rooftop segment.

However, the analysis of previous experience with PV investments and the identified challenges allow some key recommendations for market entry:

- **Use available information and support from GIZ and business associations:** The GIZ Energy Support Programme, being the donor organisation with the most experience with and knowledge about renewable energy investments in Vietnam, will help with any questions regarding contacts, experience and reference points in the solar sector.[67] Furthermore, local, such as the VCCI,[68] and international business associations such as GIC-AHK[69], the GBA[70] or EuroCham[71] are first contact points to get information on business operations and potential investors in the sector.

- **Analyse cost-structure of potential investors/customers:** The specifics of the commercial/industrial electricity tariffs are a big challenge for solar PV investments. On the other hand, due to their limited variety and simple categorisation, they allow for good forecast and predictability of customer energy cost structures. Commercial operations that are subject to the EVN "Business" tariff will have the highest tariffs and opportunities for cost savings by solar self-consumption.

- **First, focus on international corporations:** German and international companies might be the first starting point when looking for potential investors in PV rooftop systems. These companies are more likely to have the financial background and necessary long-term investment perspective for a PV investment. Furthermore, less barriers regarding language and culture can be expected. Finally, financing issues might be less relevant in this investor group.

- **Find good local partners:** Good and reliable local partners can be of great importance in different phases of the investment project. They can support (or take over) customer/investor acquisition, help lowering costs in the construction phase or take over operation and maintenance tasks as well as after sales service. In some cases, a reliable local partner can be an important "intermediate" or even "mediator" who helps trouble shooting or building up trust to local investors or potential customers.

- **Be present and operate on site:** Since Vietnam is a new and immature market, finding investors and customers demands a lot of communication and direct contact on site. Furthermore, making business in Vietnam is much about building trust and a good relationship. A reliable local partner can take over much of this work but certainly not all of it.

- **Identify the "added value" of customers/investors:** Since the mere economics of a solar PV rooftop investment, regarding IRR and equity payback time, might not be convincing enough for many investors, it is crucial to identify the individual "added

[66] Some of the interviewed companies even had the expectation to be able to fully supply their high energy intensive factory with the solar PV system.
[67] GIZ Energy Support Programme Vietnam: https://www.giz.de/en/worldwide/28291.html
[68] Vietnam Chamber of Commerce and Industry (VCCI): http://www.vcci.com.vn
[69] GIC-AHK Vietnam/ Delegate of German Industry and Commerce in Vietnam: http://www.vietnam.ahk.de
[70] German Business Association in Vietnam (GBA): http://www.gba-vietnam.org
[71] European Chamber of Commerce in Vietnam (EuroCham): http://www.eurochamvn.org

value" of solar PV for the respective investor. Arguments might range from contributions to a green building certification to enhanced security of energy supply (see previous section of this chapter).

- **Emphasise on quality:** Vietnamese investors value quality and technology from reference markets, in particular technology and engineering "made in Germany". International investors may do so even more. Furthermore, the emerging Vietnamese solar market needs good quality PV systems as reference points and best practice for further growth and development. However, the promises of cheap investment costs that allow higher returns are tempting. But a few low-quality flaw systems causing trouble could lead to a loss of reputation and trust in the whole technology before solar PV even starts off in the market.

- **Help developing the market and capacity building:** Not only related to the previous point, every new commercial solar PV investment should be used to raise awareness for the technology and develop local capacities. Partners such as the GIZ Energy programme not only help with finding local partners or building up networks, they can also use commercially successful projects to build capacities in the whole sector, including the promotion of political support and knowledge in central and local governments as well as the development of capacities of local industry partners or financing institutions.

- **Use support for financing:** National and multilateral financing institutions as well as GIZ can offer support for financing solar PV projects. The German funded DeveloPPP.de programme for example, supports innovative projects in developing countries and emerging markets while generating long-term benefits for the local population or business sector. The programme assist in planning, financing and roll out of investments and commercial activities in partner countries such as Vietnam, among others through government grants.[72]

[72] For more information contact GIZ Energy Support Programme Vietnam and see: https://www.developpp.de/en

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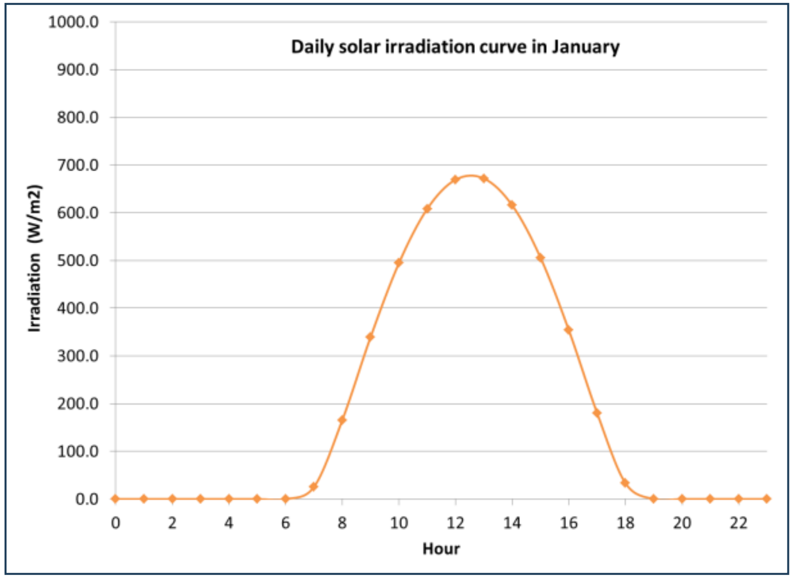
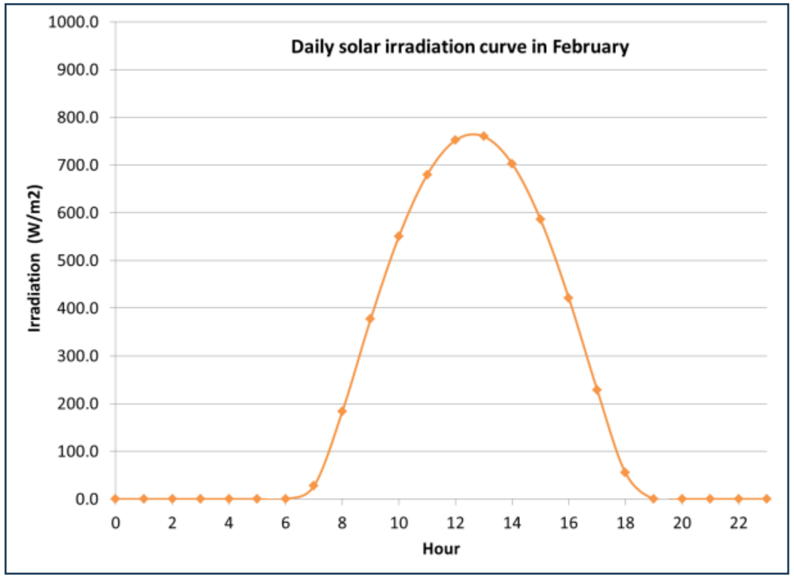
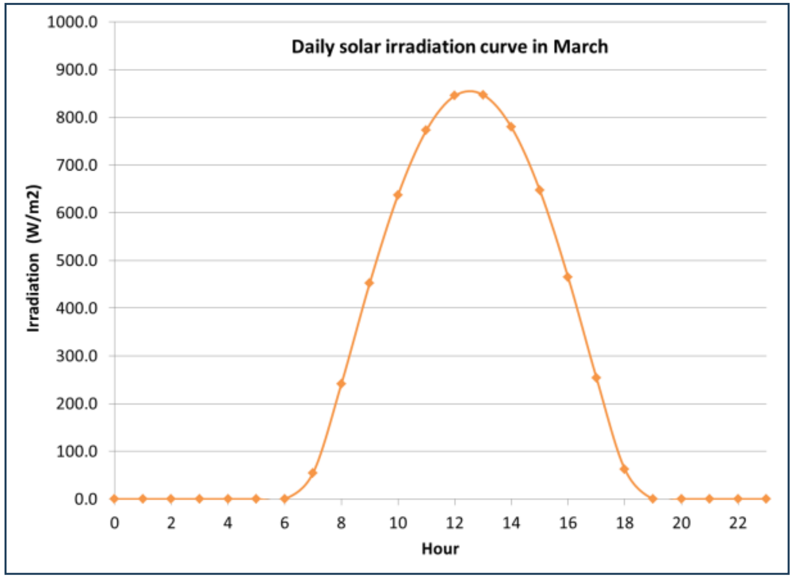
Annex

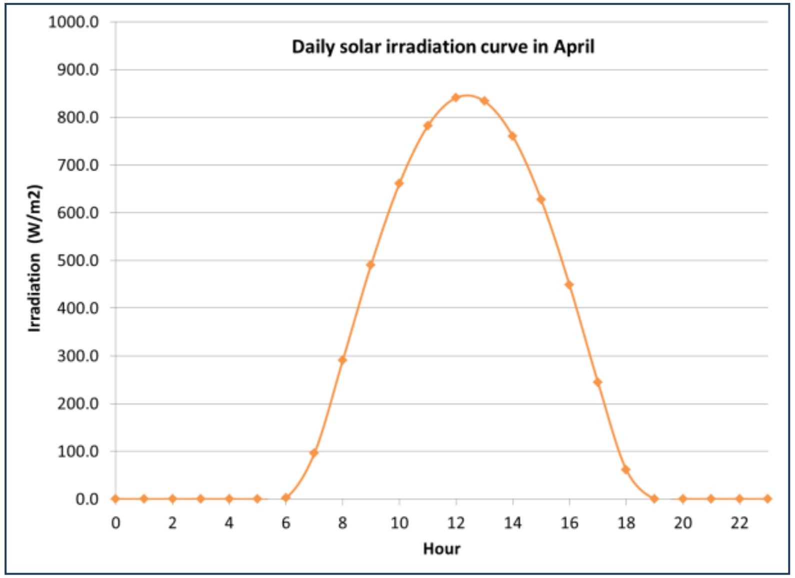
- 12 monthly solar irradiation curves (standardised for HCMC)
- 12 monthly solar irradiation curves (standardised for Danang)

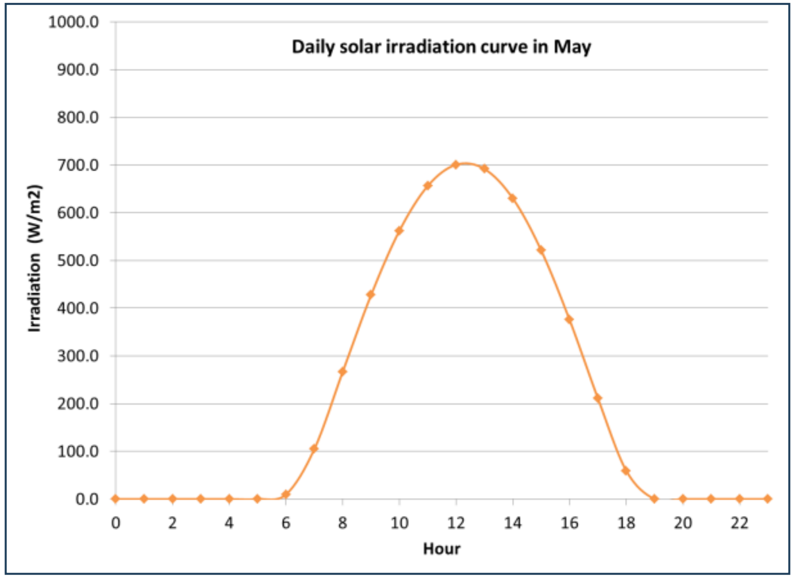
Monthly Solar Irradiation Curves – HCMC










Daily solar irradiation curve in May
Irradiation (W/m2)
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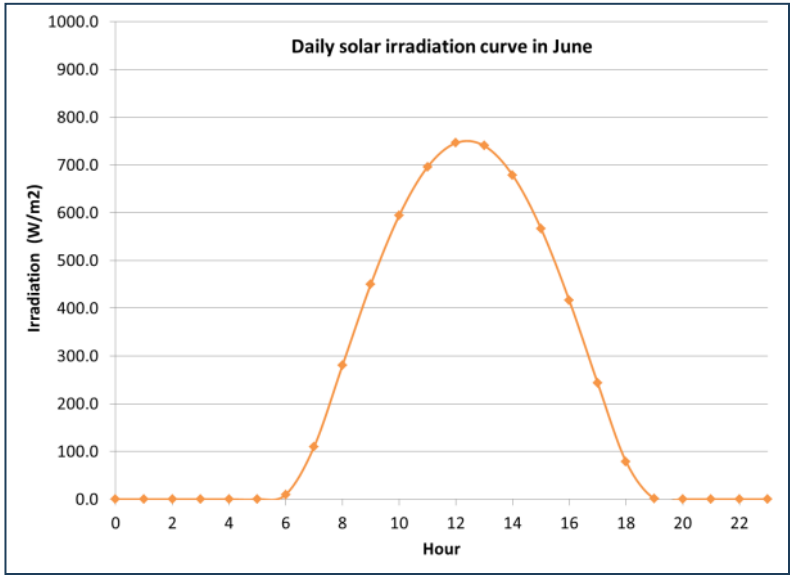
Daily solar irradiation curve in June
Irradiation (W/m2)
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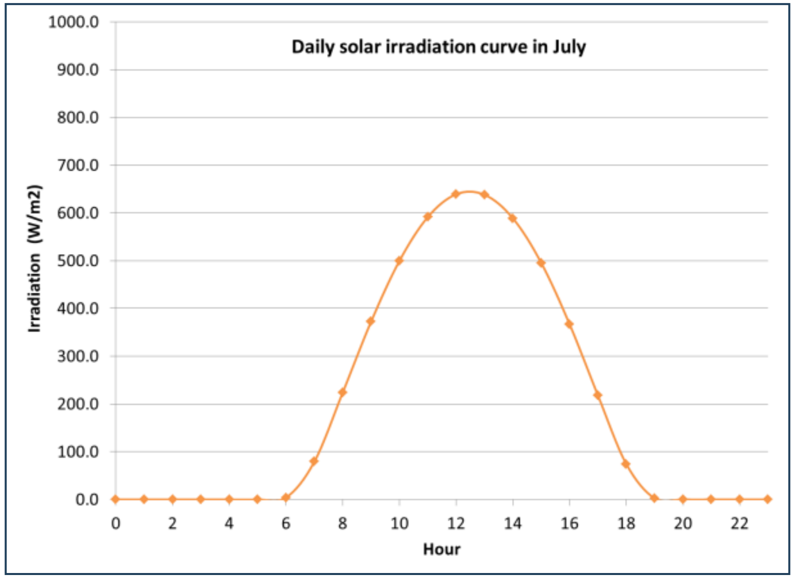
Daily solar irradiation curve in July
Irradiation (W/m2)
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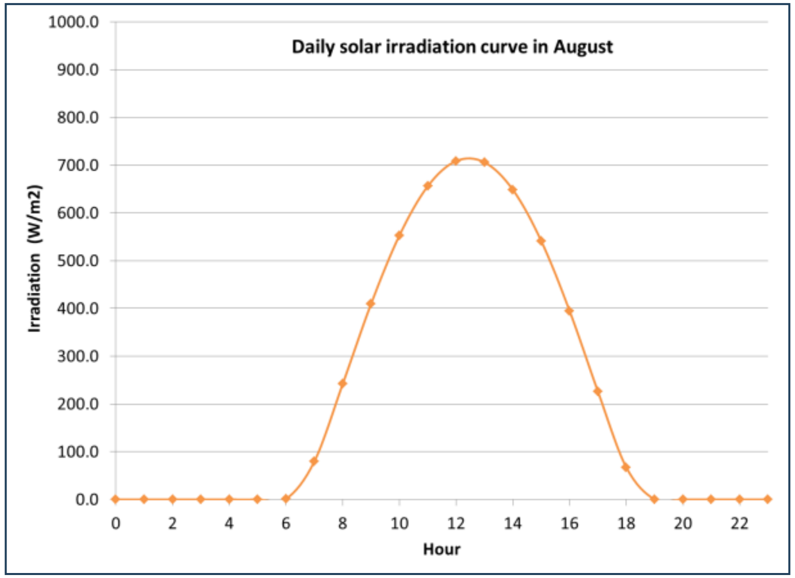
Daily solar irradiation curve in August
Irradiation (W/m2)
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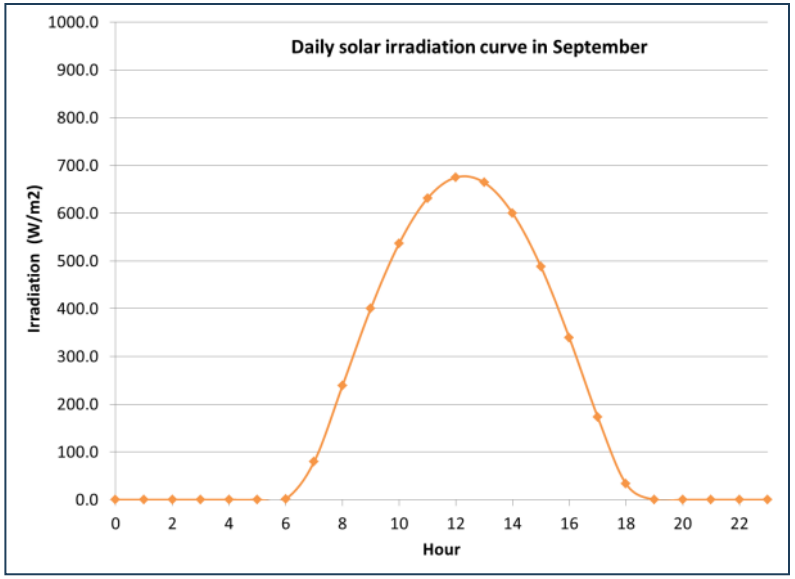
Daily solar irradiation curve in September
Irradiation (W/m2)
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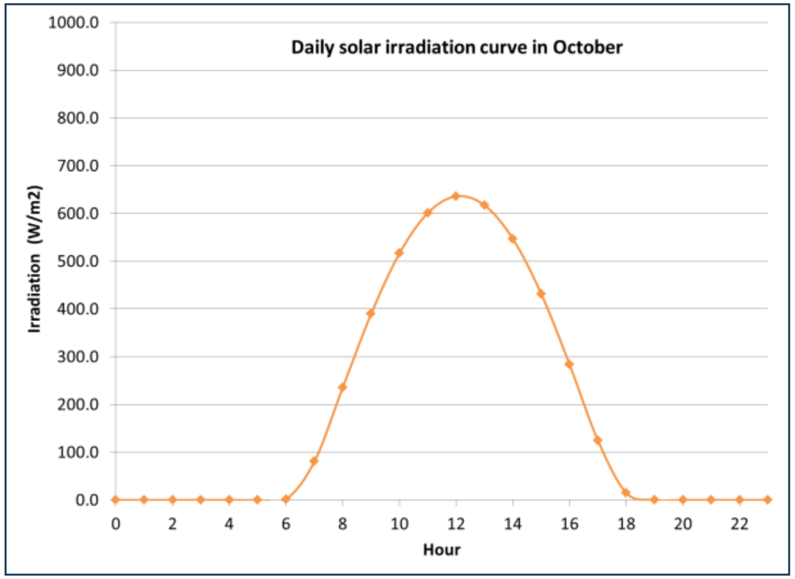
Daily solar irradiation curve in October
Irradiation (W/m2)
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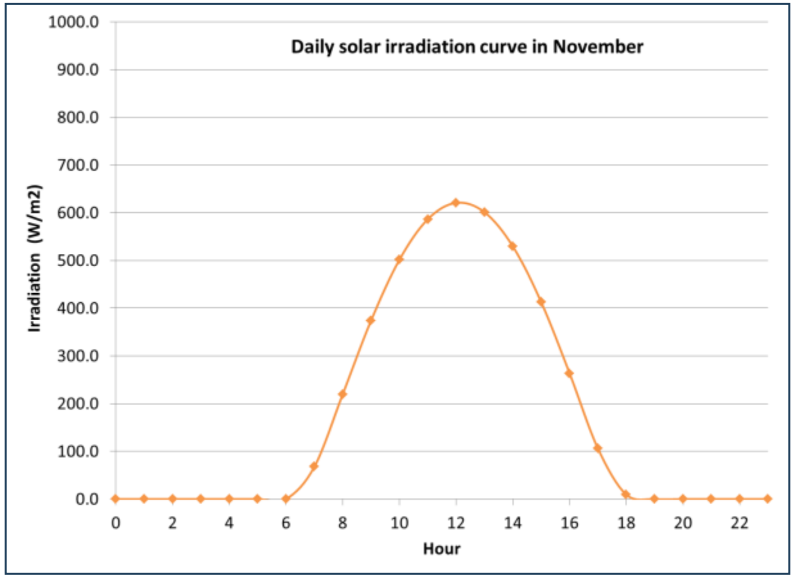
Daily solar irradiation curve in November
Irradiation (W/m2)
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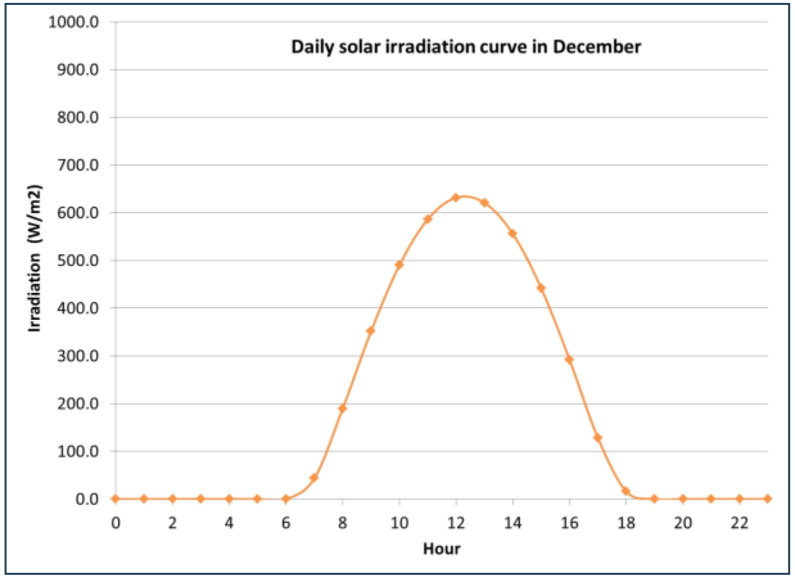
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Irradiation (W/m2)
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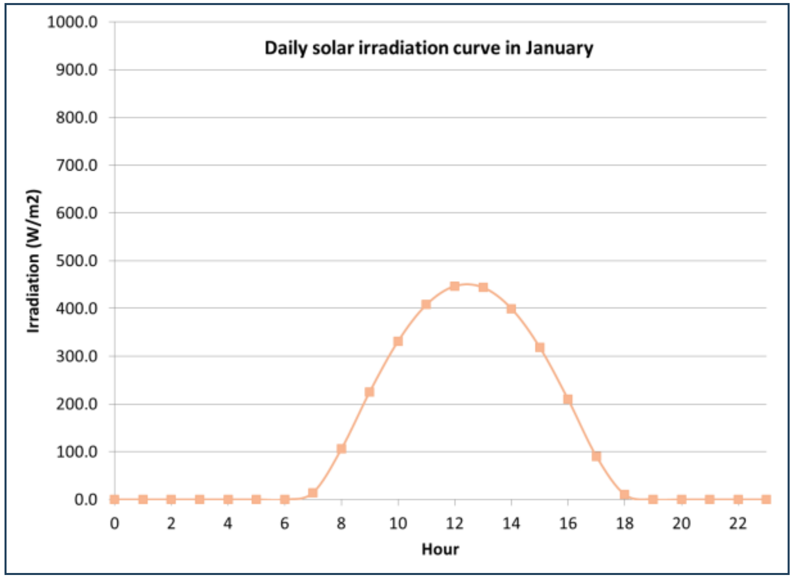
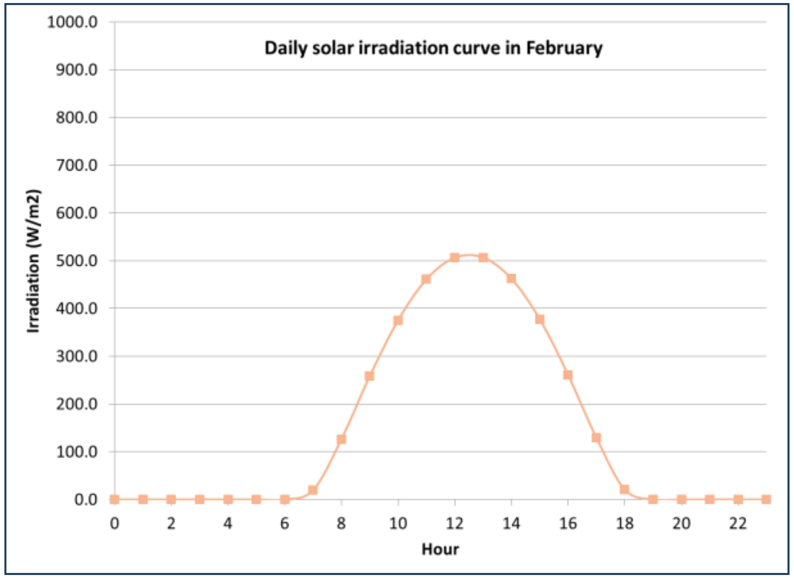
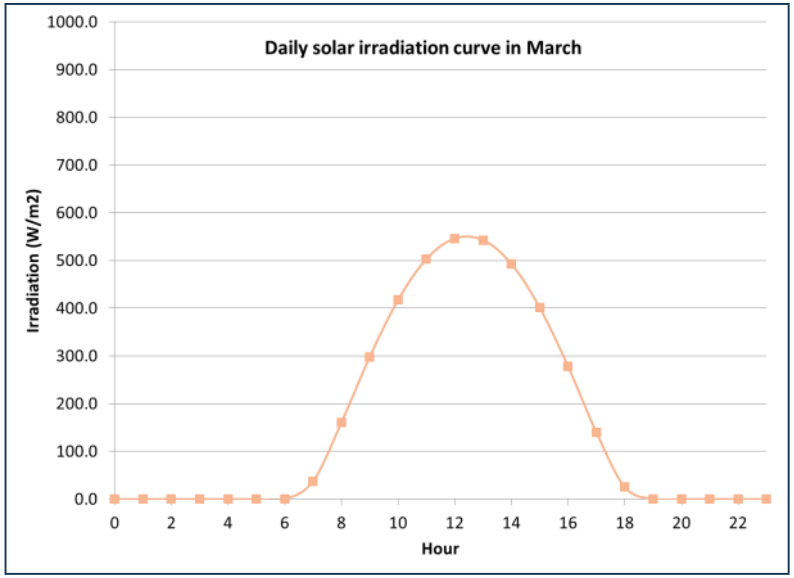
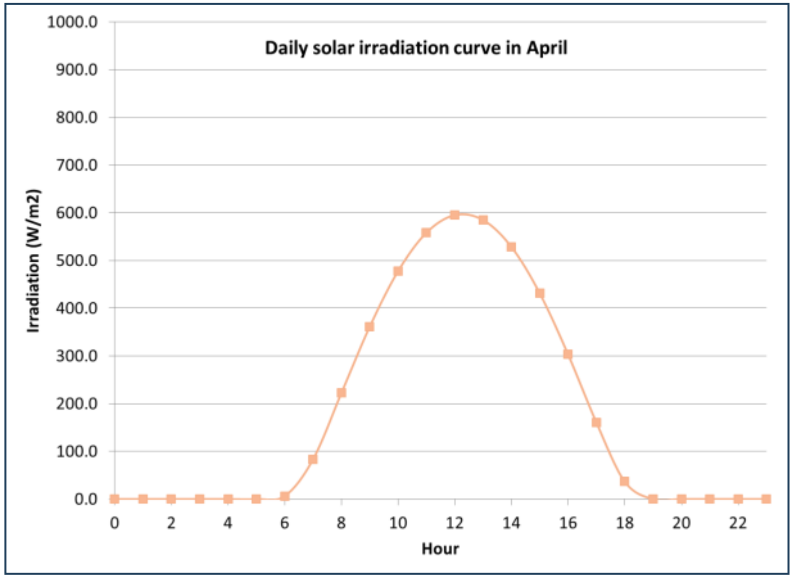
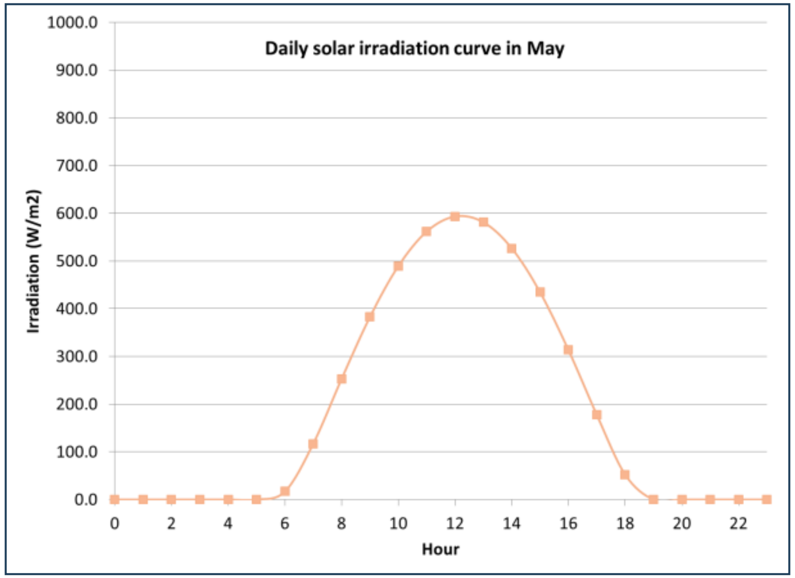
Monthly Solar Irradiation Curves – Danang










Daily solar irradiation curve in May
Irradiation (W/m2)
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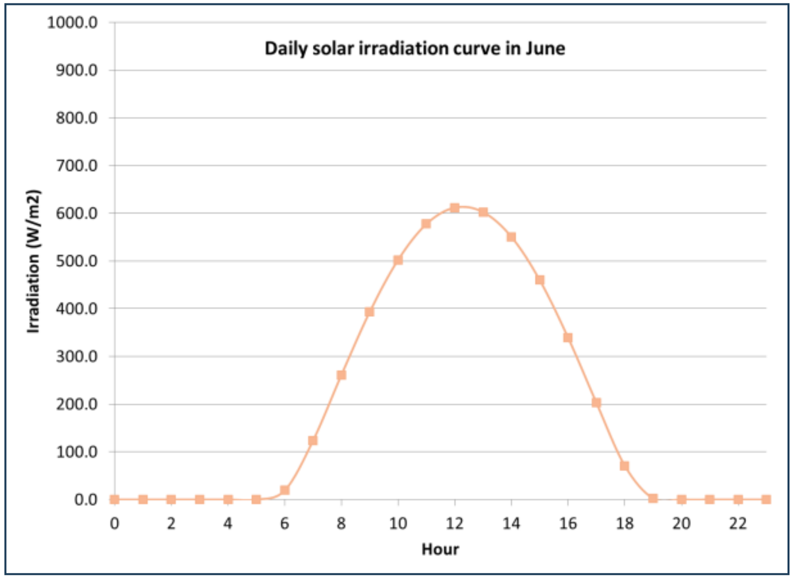
Daily solar irradiation curve in June
Irradiation (W/m2)
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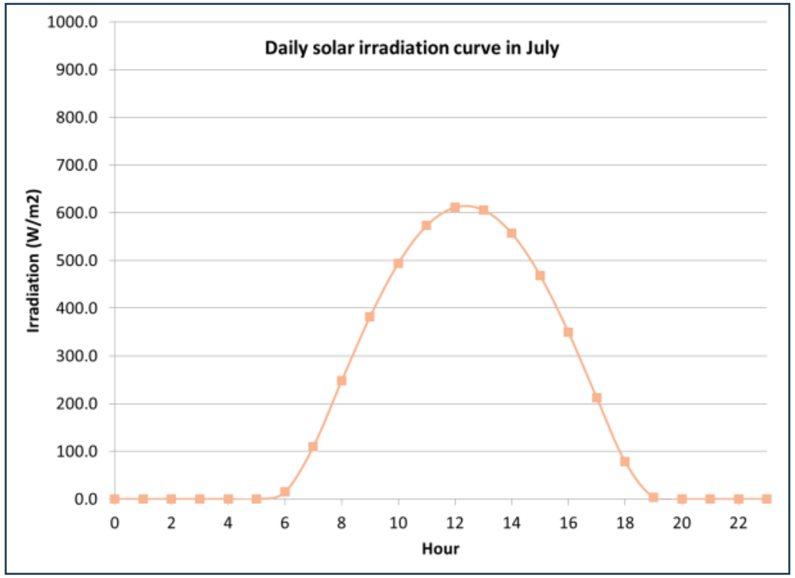
Daily solar irradiation curve in July
Irradiation (W/m2)
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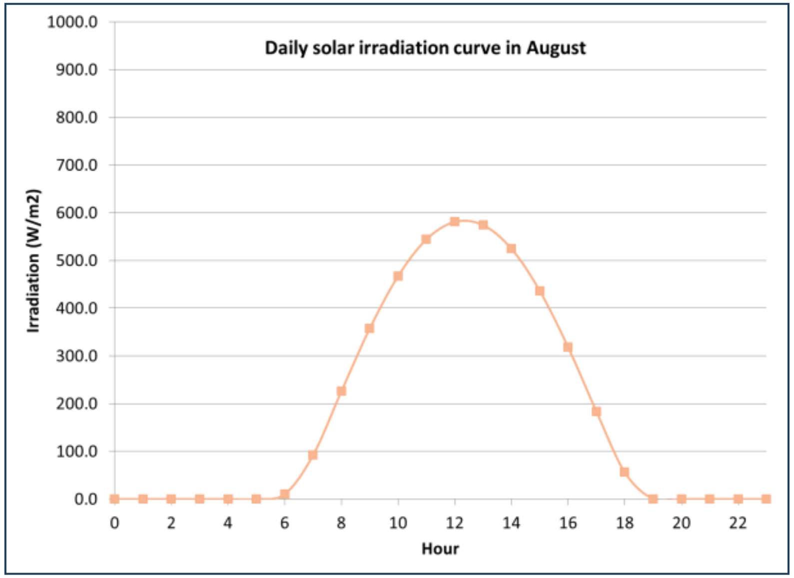
Daily solar irradiation curve in August
Irradiation (W/m2)
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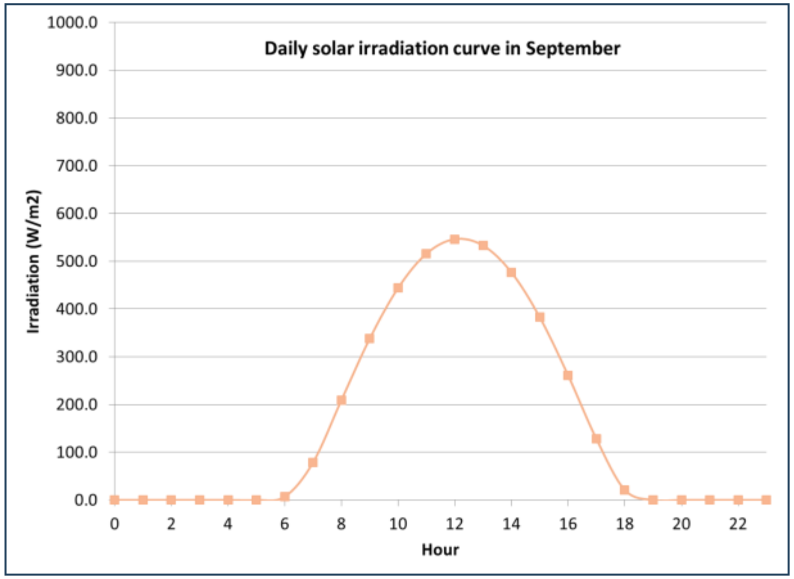
Daily solar irradiation curve in September
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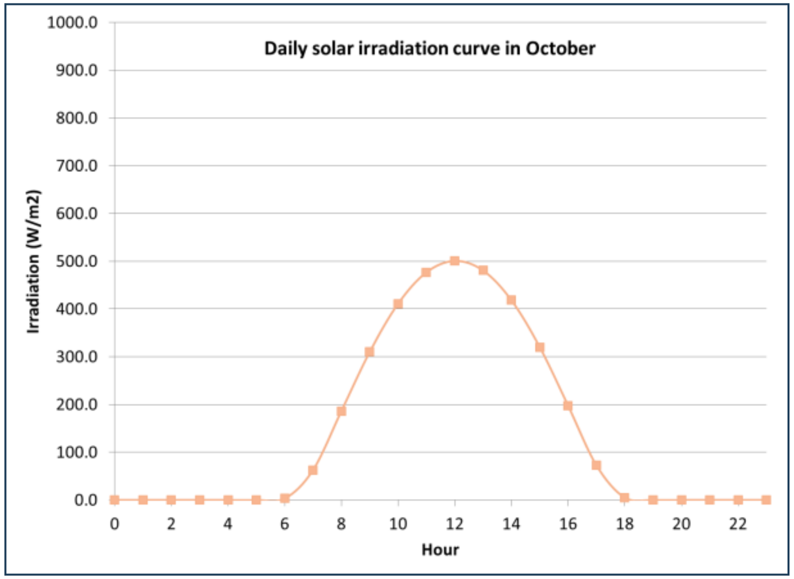
Daily solar irradiation curve in October
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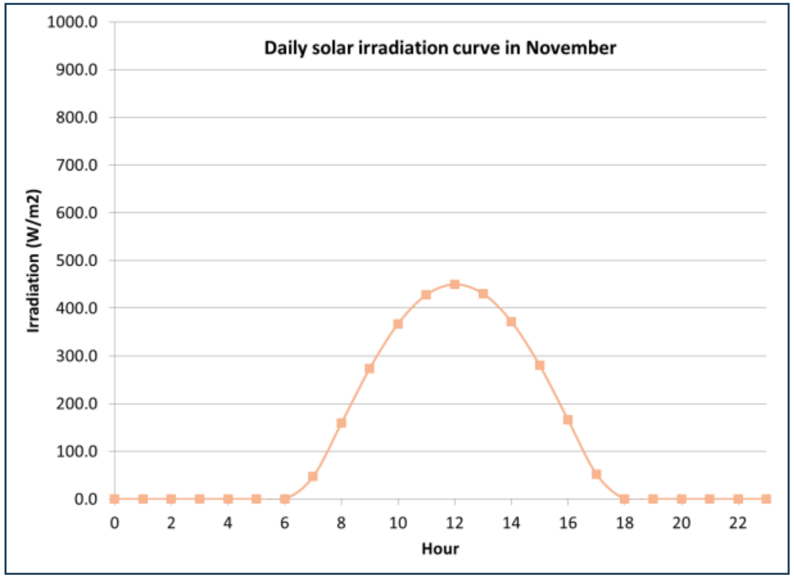
Daily solar irradiation curve in November
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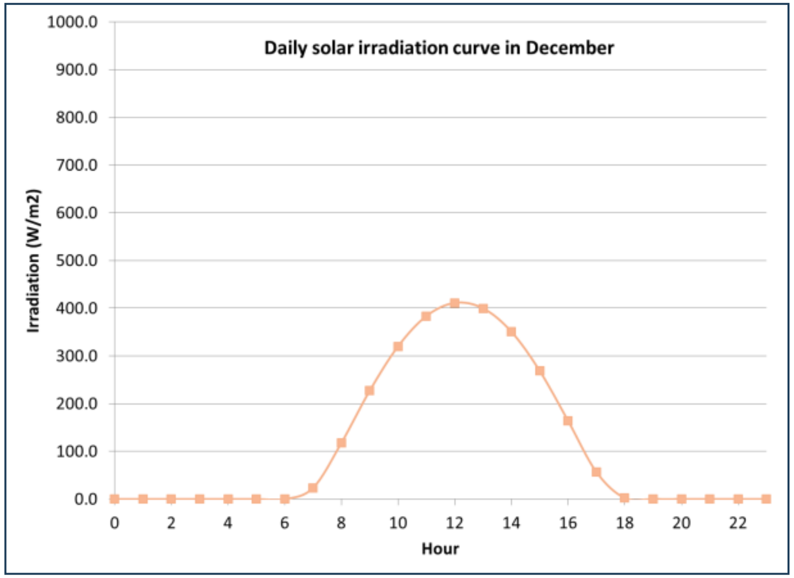
Daily solar irradiation curve in December
Irradiation (W/m2)
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