Framework Assessment for the Promotion of Solar Energy in Viet Nam

A Market Survey and Stakeholder Mapping of the Vietnamese Solar Energy Sector

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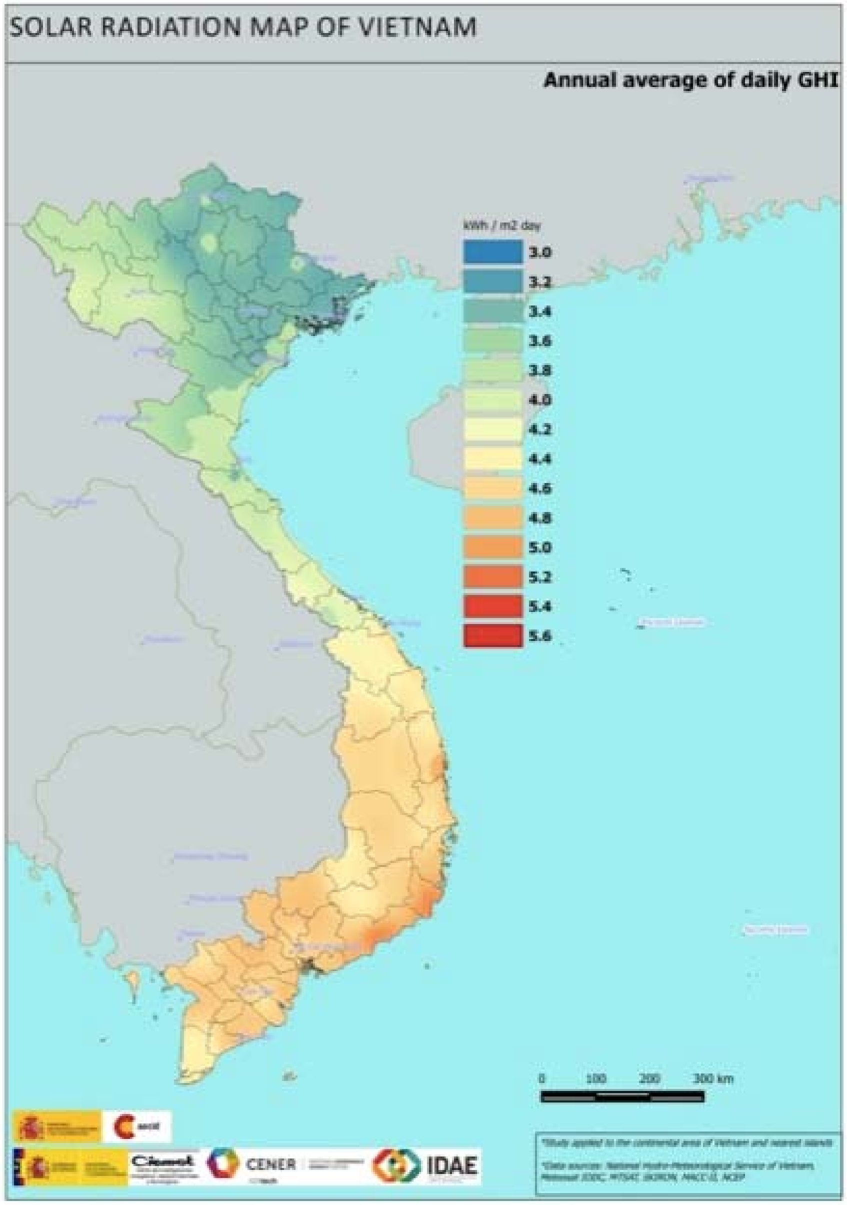

"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that."

(Thomas Alva Edison, 1847-1931)

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Abbreviations

ASEAN	Association of Southeast Asian Nations
BOS	Balance of System
BOT	Build Operate Transfer
BTS	Base Tranceiver Station
IEA	International Energy Agency
CFC	Chlorofluorocarbons
CSP	Concentrated Solar Power
DNI	Direct Normal Irradiation
DP	(Power/Energy) Development Plans
EJ	Exajoule
ERAV	Electricity Regulatory Authority Viet Nam
EPC	Engineering, Procurement, Construction
ESCO	Energy Service Company
ETC	Evacuated Tube Collector
EUR	Euro
EVN	Electricity of Viet Nam
FIT	Feed-in Tariff
FPC	Flat Plate Collector
GDE	General Directorate of Energy
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiation
HCMC	Ho Chi Minh City
HFC	Hydrofluorocarbons
IoE	Institute of Energy
IPP	Independent Power Producers
IRENA	International Renewable Energy Agency
kWh	Kilowatt Hour
kWp	Kilowatt Peak
LDU	Local Distribution Utility
LCOE	Levelized Costs of Electricity
MoIT	Ministry of Industry and Trade

MWh	Megawatt Hour
MWp	Megawatt Peak
ODA	Official Development Assistance
O&M	Operation and Maintenance
PDP	Power Development Plan
PV	Photovoltaic
SME	Small and Medium Size Enterprise
SOE	State Owned Enterprise
ST	Solar Thermal
USD	US Dollar
VAST	Vietnamese Academy of Science and Technology
VND	Vietnamese Dong

Executive Summary

Viet Nam's fast growing economy and steadily increasing demand for energy are posing a 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, Viet Nam has to secure its energy sector's sustainable and green development and contribute to international efforts to tackle climate change. To accomplish this, the Vietnamese government has set itself clear targets for green growth and the development of renewable energy.

This study aims to analyze to what extent the application of solar energy in the power and heat sector could contribute to Green Growth and to sustainable energy strategies, and which solar market segments and applications Viet Nam should specifically focus on when developing its solar energy strategy.

Following this main objective, the study analyzes the main energy market structures and potential for different solar energy applications and the related political framework conditions, as well as stakeholder needs. As a preliminary scoping study, it subsequently recommends strategic focus areas, further fields for in-depth analysis and potential future steps of action for the Vietnamese government. The main findings of this study are summarized as follows:

Huge potential for solar energy in Viet Nam

- Viet Nam has **expansive solar resources** that could be used to successfully develop the solar energy sector, including both solar photovoltaic (PV) power as well as solar thermal (ST) applications for hot water and commercial/industrial process heat generation. Current scientific estimates of the overall solar resources in Viet Nam state **an average of 4-5 kWh/m^2/day** in most regions of Southern, Central and partially even Northern Viet Nam (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**)[1]. These solar irradiation levels for Viet Nam 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.
- **PV capacity potentials** should be analyzed in greater depth. As a starting point, initial estimates calculate a potential of **2-5 Gigawatt (GW)** for **residential** and **commercial rooftops** for the next two decades and **more than 20 GW** for **ground-mounted PV power plants**[2].
- **Capacity potentials** for ***solar thermal*** hot water and process heat applications seem to be of a **similar dimension** regarding residential and commercial or industrial use; although these potentials are more closely tied to the demand of the specific energy users and buildings for hot water or heat since there is usually no grid for excess energy feed-in. The ongoing urbanization and industrial development processes are increasing the demand for domestic hot water and heat for industrial processes, which could be met by solar thermal energy.

[1] For details on the estimates, please refer to Chapter 2.1 and the study by CIEMAT et al, 2015.

[2] See Chapter 4.7.2 for details on these estimates.

- Currently, **the utilization of solar PV applications** is in a very early stage of development in Viet Nam. The current solar PV market is thus considered to be in its **"inception stage"**.[3] At the end of 2014, approximately **4.5 MWp of solar PV capacity** was installed throughout the country.
- 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, around 900 kWp, is **connected to the grid, through a few medium and large size systems of more than 50 kWp.**
- The **current *solar thermal* market** is more developed and considered in the **"take-off stage"**. Approximately 30,000 to 40,000 domestic solar hot water systems have been installed annually in residential and smaller commercial applications over the last 3-4 years, totalling an **estimated 100,000 operational systems** nationwide, which corresponds to an **installed capacity of approximately 280 MW_{th}** with an **annual yield of 340 GWh_{th}**. Although these figures have to be interpreted with great caution due to limited access to validated market data, this demonstrates the development of a substantial market without the implementation of subsidies or major support measures.

Framework conditions do not benefit solar energy development yet

- The **current political and market framework conditions** for solar PV in Viet Nam are not benefitial and severly **restrict investments** in on-grid and off-grid applications. Solar energy is **not yet integrated into political energy development strategies,** such as the national Power Development Plan (PDP). However, it looks like solar energy will be included in the ongoing development of the revised PDP VII.
- Furthermore, **financial or fiscal support measures** (such as Feed-in-Tariffs or the possibility of net-metering or net-billing), which could close the gap between the PV levelized costs of electricity (LCOE) and retail electricity tariffs, are **lacking or insufficient**. In addition, there is **neither a standardized interconnection code** (grid code) **nor connection procedures** for the development and implementation of PV systems. Furthermore, there are **no standards for solar power sales** to the grid or third party off-takers of energy, such as a standardized power purchase agreements (PPA). A promising and innovative project aims to develop an interconnection standard for PV on-grid systems and a net-metering scheme. Last but not least, due to the lack of market experience, **public awareness** of solar energy is very low, regarding both technological characteristics and potentials as well as investment opportunities and business models.
- Regarding the cost competitiveness of *PV on-grid applications*, Viet Nam's **low electricity tariffs** are a **major barrier for investments**, especially in the residential sector and to a lesser extent for privat enterprises due to higher commercial electricity tariffs. With tariffs continuing to rise and the costs of solar energy generation declining,

[3] For a description of the different development stages of renewable energies, see footnote 14.

this barrier to investment will become less significant. However, at this early stage of market development support measures are still necessary in order to offset the existing competitiveness gap.

- ***PV off-grid*** applications face a small and **diminishing "market"** since the country has **already achieved a 98% electrification rate** for urban and rural households and power consumers. The Government has set the national target to achieve 100% electrification by 2020. While grid-connection is supposed to be the main means of electrification as part of the Government's electrification strategy, renewable energies – including PV and PV hybrid systems – are also supposed to play a relevant role. In particular, the supply of **off-grid solar power to islands** where the costs of power generation are high (such as for diesel-generated electricity) creates a **viable business scenario** for larger-scale PV or PV hybrid systems.
- In this context, the **strong governmental and donor support is partly discouraging private investments** in *PV off-grid* applications. To a certain extent, the grid expansion is "competing" with investments in renewable energy in rural areas. To date, there seem to be **no viable business models** for the implementation of commercial small-scale PV applications. The deployment of these systems is predominantly driven by the Government and/or donor money, or as part of Corporate Social Responsibility (CSR) programs.
- **Framework conditions** for ***solar thermal*** **applications** are less restrictive, but there are no substantial support mechanisms in place. There is currently **no political target** for renewable heat, and the inclusion of renewable heat technologies in the national energy efficiency strategy is insufficient. Most solar thermal applications (except solar thermal cooling) seem to be **largely cost competitive,** with return on investment periods **(ROI) of 3-5 years** for commercial and industrial hot water or process heating applications, without major subsidies or financial support measures.
- In general, **no substantial market or regulatory barriers** were identified that could restrict or hamper the further market **development for *solar thermal* applications**. The main and most effective barrier to market development is a l**ack of awareness and knowledge** on the technology with regard to technological characteristics and potentials, investment opportunities and business models, and **limited industry capacities.**

Multiple potential benefits of solar energy development in Viet Nam

- A **variety of benefits** can be derived from the further development of solar energy applications: First of all, the identified potentials for renewable energy development could contribute substantially to Viet Nam's Green Growth and sustainable energy strategies and help **achieve the renewable energy targets** set out in the PDP. Solar energy could soon become a **sustainable and cost competitive energy technology** that significantly contributes to **GHG-emission reductions** as well as the **external costs** for the environment and health related to the energy sector.
- Solar energy has the potential to **reduce the reliance on fossil fuel imports** in the future. Viet Nam will most probably become a coal importer by year 2017, which will have a substantial impact on power generation costs. Based on initial estimations, the future price of power generation using imported coal will amount to or even exceed USD

0.10/kWh once CO_2-prices of USD 5-10/ton are included. In comparison, **estimates on** the achievable **PV LCOE range from USD 0.11 to USD 0.17/kWh** for a 10 MW reference system in Southern Viet Nam. Once external costs, such as environmental and health costs, are taken into account and included in retail power tariffs, solar energy becomes immediately cost competitive compared to fossil energy sources.

- Furthermore, *solar PV and solar thermal* energy generation has the **potential to match the peak power demands** caused by cooling and airconditioning needs in the residential and commercial sector, as well as the general power demands of commercial and industrial processes. Thus, solar energy has the potential to substantially **reduce the demand for high cost peak power generation capacities** and the need for the expansion of transmission grids in order to deliver power to the country's growing urban, commercial and industrial centres.

- Regarding the possible costs of the large-scale deployment and **grid integration of *distributed PV***, international experience and cost estimates can be indicative: There are **no insurmountable technical hurdles** to the integration of the various solar PV technologies, and the **additional system costs** that could exceed the LCOE **are modest**. This applies in particular to the deployment of renewable energy in countries where solar and wind power does not exceed a 20-40% share in national networks.

- ***Off-grid PV***, at least in larger-scale stand-alone or hybrid applications, e.g. on islands, has the potential to **become a cost competitive alternative to the diesel-generated power supply** and could therefore substantially reduce power generation costs in these areas. With an LCOE of USD 0.20/kWh to USD 0.40/kWh and more for diesel, the "**hybridization**" of existing diesel gensets with PV would reduce costs and environmental harm connected to the burning of fossil fuels.

- Furthermore, the electrification of rural areas using off-grid or mini-grid solutions in Viet Nam's mountainous regions or on remote islands would provide 550,000 households with **access to energy**. These households are often located within poor and marginalized communities or ethnic minority households. This electrification is a political priority for the Government of Viet Nam.

- ***Solar thermal* technologies** are compatible with nearly all sources of back-up heat and are almost **universally applicable** due to their ability to deliver hot water, hot air and cold air. Solar thermal hot water or process heat generation has the potential to substantially **decrease import dependencies** related to fossil fuels, especially coal imports, and to **increase resilience against rising energy prices**.

- **Cost competitive investments** in ***solar thermal*** residential and commercial domestic hot water and industrial heat applications are **already possible** in Viet Nam and can therefore contribute to the supply of **cost efficient, secure and green energy in the heat sector** if scaled up further.

- Furthermore, *solar thermal* energy can also **help to reduce the electrical network peaks** associated with conventional (electrically powered) heating or cooling.

- With regard to **industry effects**, solar energy has the potential to create a sustainable solar energy sector in Viet Nam with **positive job effects** along the entire value chain, but mainly in the field of engineering, procurement, construction/installation, the manufacturing of key system components and the development of energy services, including new fields of business opportunities for the national utility company EVN. Based on international data and experience, estimations reckon that a PV market with an annual installed capacity of 300 to 500 MW, Viet Nam's ***solar PV* sector could generate 15,000 to 25,000 green jobs** in the medium term (including jobs related to export manufacturing). The application of international data and experience to Viet Nam's solar thermal potentials estimates that doubling or tripling the current ***solar thermal* market could create 9,000 to 13,000 green jobs for the sector** in the medium term**.**

- **Mapping the stakeholders** in the solar energy sector revealed **a small but promising solar industry** with domestic enterprises already covering most parts of the value chain, from the manufacturing of key system components, such as PV modules and ST collectors, 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 energy applications **are still limited**, and one of the main focuses of the sector's development strategy should be placed on capacity building.

Promising solar market segments and applications for Viet Nam

- The **assessment** of the most promising market segments was based on the following **criteria**
    1. **Development potential** – mainly the potential to increase the share of renewable energies in power capacities and power generation;
    2. **Readiness for business case** – mainly the level of competitiveness that a solar application has reached in Viet Nam so far; this also means that an application with a high readiness for business case would need limited or no financial support to trigger market development and investment);
    3. **Existing framework conditions** – mainly political framework conditions and the prevailing market environment;
    4. **Co-benefits for Viet Nam** – mainly possible industry and job effects as well as co-benefits for the energy system, such as peak demand reduction etc.
- The analysis and comparative assessment of the different solar PV and solar thermal market segments and applications **identified the following market segment potentials** (for a summary of this assessment see **Chapter 5** and the matrix overview in **Annex I**):
    - Two market segments with a **high development potential**: Solar Thermal commercial hot water applications and PV commercial applications;
    - Two market segments with a **medium development potential**: solar thermal commercial/industrial heat applications and PV ground-mounted utility scale;
    - One market segment with a **medium-low potential**: PV large-scale off-grid applications, in particular on islands.
- Two other other solar market segments, namely **PV on-grid residential applications** and **PV off-grid small-scale applications** were found to have a lower development potential regarding the selected assessment criteria.

- Due to the fact that there are limited resources available for the development of solar energy in Viet Nam, **this study recommends concentrating on the prioritized solar market segments** with a high or medium development potential when shaping the political framework for solar energy in Viet Nam and when developing related support measures. Thus, **a market development strategy**, including political and market-related development measures, is recommended for the above-mentioned segments with a high or medium development potential. Section 5.2 (and the overview provided by Annex II) provides recommendations regarding future action.
- Due to the similarities between **solar thermal commercial hot water** and **industrial process heat** applications, both in technical and marketing terms, it is recommended to develop an **integrated strategy** for these two segments.
- **Large-scale PV off-grid applications,** especially on islands, have a **high political significance** due to the Government of Viet Nam's aim to increase access to energy and supply islands in particular with cost-efficient and clean energy sources.

Future action needs an integrated and market segment specific approach

- An integrated and incremental development strategy for each of the prioritized solar market segments could be divided into **four different phases**, including related measures (for an overview of these recommended measures see the **matrix overview in Annex II**):

  1. The **in-depth stocktaking phase** should include efforts to obtain more detailed and validated data on the **market and/or energy demand potentials** of various consumer or investor groups. This data enables the **pre-selection of high-potential and suitable business sectors** that further development and support measures should focus on.
  2. **Further feasibility studies** for selected solar applications can help understand the development potentials and needs for support in the related market segments. This should include an assessment of the different business models and available financing mechanisms. Supporting a small number of **pilot projects to raise awareness** and provide **technical training** in the context of subsequent capacity building measures is also recommended.
  3. The third phase is the **development of a supportive political framework** with the development (and implementation) of corresponding political support measures or adjustments to the legal-administrative framework. This can include an in-depth **analysis of international political best practices** as well as extensive political dialogues and **exchanges with key stakeholders,** especially in the private sector.
  4. Lastly, an extensive **capacity building phase** should accompany the implementation of political support measures or adjustments to the legal framework, with measures **tailored to the specific needs of the different solar market segments** or parts of the solar value chain. This should include **industry development** in selected parts of the value chain (e.g. EPC and technical system planning capacities for commercial and industrial solar thermal applications), quality issues related to solar components, system design and operational or business model development.

- Furthermore, priority should be given to **awareness-raising and knowledge transfer** with regard to technical (technical potential of solar energy in different applications) and economic issues (economic feasibility of solar energy applications, business models etc).
- With such an **integrated development strategy**, combined with the strong political commitment of the Government of Viet Nam to solar energy and the utilization of international best practices and experience, Viet Nam's vast and promising potentials in the field of solar energy could be tapped.

1. Assignment, Methodology and Introductory Note

Assignment

The main objective of this "Framework Assessment for the Promotion of Solar Energy in Viet Nam" is to provide a preliminary analysis of Viet Nam's energy market structures as a basis for the development of solar energy applications and to develop a stakeholder map of the country's existing solar energy sector. The assessment prioritizes potential solar market segments and applications for the future development of solar energy in Viet Nam, as well as providing recommendations for future action and further in-depth analysis of the prioritized solar technologies and applications.[4]

In order to prevent overlaps with existing research and cooperation projects in the sector, this study incorporates the ongoing efforts of other organizations, including the key findings and solar irradiation maps of the Spanish Consortium[5] and the findings of the UNDP Fossil Fuel Fiscal Policy Project.[6]

Methodology

The findings of this study are based on desk research and a number of stakeholder interviews and consultations that were conducted in Viet Nam, as well as with international experts outside of Viet Nam, between January and March 2015. In addition to these individual interviews, two multi-stakeholder consultations took place in Ha Noi - one on 23 October 2014 and another on 10 February 2015 - with representatives of donor organizations and the private sector who are concerned with solar energy issues in Viet Nam.

For a list of the interview and consultation partners, see Annex III.

Since this is a preliminary assessment with limited available resources and a short timeframe, its analysis was conducted by extrapolating existing data, as well as international experience, rather than being a holistic and empirical country-wide assessment. It therefore mainly utilized secondary data to provide a comprehensive context for further in-depth research to be undertaken in the solar energy sub-sector.

Introductory Note: Solar Energy - An Answer to Viet Nam's Energy Challenge?

Viet Nam's fast growing economy will be the main driver for the country's electricity demand over the next decade. In order to secure energy supply and reduce energy related

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[4] Future research should only be undertaken after consulting with GDE/MoIT in order to ensure that the research focus is in line with Government priorities and planning.

[5] See the final report "Maps of Solar Resource and Potential in Vietnam" (January 2015) published by the Spanish research consortium consisting of CIEMAT, CENER and IDAE, and promoted by the Spanish Agency for International Development Cooperation (AECID) in colaboration with the General Directorate of Energy (GDE) under the Ministry of Industry and Trade (MoIT) of Viet Nam.

[6] UNDP Policy Research and Dialogue on Fossil Fuel Fiscal Policy Reform. Phase III: Fiscal Policy Reform and Other Incentives to Limit Growth in Coal Fired Power and Support Non-Hydro Renewable Energy Development. For general information see:
http://www.vn.undp.org/content/vietnam/en/home/library/environment_climate/green_growth_and_fossil_fuel_fiscal_policies_in_viet_nam.html

greenhouse gas (GHG) emissions, the Government of Viet Nam has set itself ambitious targets for renewable energy development. According to the National Power Development Plan (PDP VII, currently under revision), Viet Nam aims to increase the share of renewable energy in power production from 3.5% in 2010 to 4.5% in 2020 and 6% in 2030[7]. Moreover, the National Green Growth Strategy aims to reduce GHG emissions in the energy sector by at least 20% (voluntary) and up to 30% (conditional upon provision of international support) compared to the business-as-usual (BAU) scenario by 2030.[8]

While considerable efforts have already been undertaken to foster bioenergy and wind energy, the country's vast potential for solar energy has not yet been tapped into. With an average solar irradiation (global horizontal irradiation, GHI) of 4-5 kWh/m^2 per day[9] in large parts of the country, Viet Nam has abundant solar resources for the supply of green electricity to industrial, commercial and residential consumers. With daily solar irradiation almost equal to the daily electricity peak loads, solar resources could contribute substantially to peak load management and, consequently, to energy security. Furthermore, photovoltaic (PV) system prices have decreased tremendously over the past decade (a trend which is continuing) and solar levelized costs of electricity (LCOE) are nearly equal to those for fossil fuel generated electricity in many parts of the world. It is therefore expected that the need for support in introducing solar energy in Viet Nam will be manageable.

Developing solar energy in Viet Nam in general promises great benefits for the regional and national economy in terms of increased energy supply security, reduced fossil fuel imports and decreased levels of overall emissions. In addition, international experience shows that the decentralized deployment of solar energy systems and solar power plants triggers regional economic development and boosts the emergence of the solar and related industry sectors, thereby contributing to economic growth and employment in the respective target areas.

With rising consumer prices for electricity and decreasing PV LCOE, economically viable business models for solar applications in Viet Nam are now within reach. Nevertheless, there are some serious barriers that could hinder the development of solar energy, such as low (subsidized) electricity prices and the lack of common standards, regulations and codes for the connection of photovoltaic systems. While the lack of funding itself is not considered a major barrier, the current regulatory framework for renewable energies does not incentivize the attraction of domestic and foreign investment in solar energy in Viet Nam. The development and implementation of an appropriate and supportive regulatory framework is needed.

This study aims to identify and address the most appropriate and potentially most beneficial market segments in light of international experiences as well as the Vietnamese framework conditions. It furthermore examines the needs and interests of key stakeholders that should be taken into consideration for the development and implementation of the national solar energy strategy.

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[7] Decision No. 1208/QĐ-TTg dated 21/7/2011, PDP VII

[8] Decision No. 1393/QĐ-TTg dated 25/9/2012, Green Growth Strategy

[9] As a rough comparison, these levels are comparable to the solar irradiation levels of most parts of Spain or Italy.

2. Solar Energy in Viet Nam: Potentials, Current Utilization and Regulatory Framework

The success of the market development and deployment of solar energy capacities and its different technologies and applications strongly depends upon the available solar resources on the one hand and the regulatory framework and general energy market conditions on the other hand. This chapter analyzes the solar potentials in Viet Nam, the current general utilization of solar technologies and the existing overall regulatory framework for solar investments. Chapter 3 follows with a more detailed focus on the energy market conditions and the sector's stakeholders.

2.1 Solar Energy Resources in Viet Nam

In general, Viet Nam can be considered as a country with a vast solar energy potential. The solar resources are comparable to those of some of the most „successful“ solar markets (in terms of capacity deployment and technology development) around the world, such as Italy and Spain, or China and Thailand in the region.

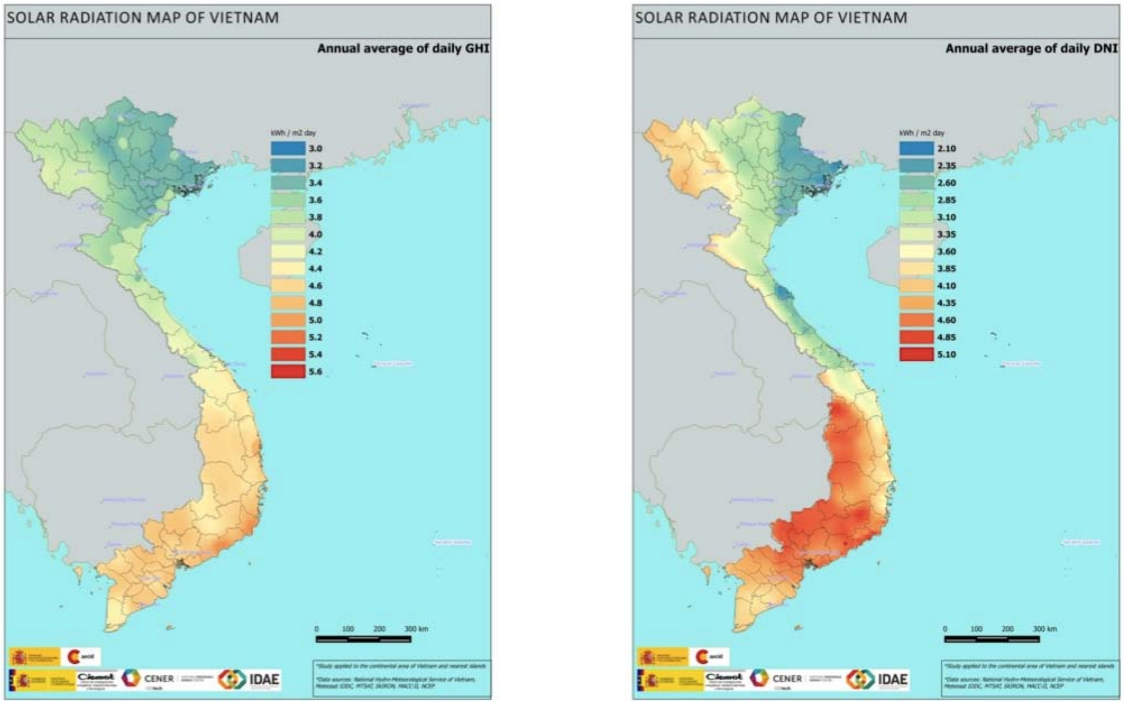
The most up-to-date and scientifically comprehensive assessment of solar resources in Viet Nam was recently undertaken by a Spanish research consortium, led by the Spanish Research Centre for Energy, Environment and Technology (CIEMAT) with support from the Spanish Government in collaboration with the Vietnamese Ministry of Industry and Trade.[10] As a result of these efforts, detailed maps of Viet Nam's solar resources are now available for policy makers, investors and researchers (CIEMAT et al, 2015).

These mappings include measurements of global horizontal irradiation (GHI) and normal direct irradiation (DNI, see Figure 1.), as well as theoretical and technical potentials.[11]

[10] See Footnote 2.

[11] 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.

Figure 1. Solar Irradiation Maps of Viet Nam – Annual Average of Daily GHI and DNI



Source: Polo/CENER (2015)

The mapping project in general confirmed previous estimates of Viet Nam's overall solar resources with an average of 4-5 kWh/m^2/day in most regions in Southern, Central and in certain parts even Northern Viet Nam (amounting to 1,460-1,825 kWh/m^2/year) and peak irradiation levels of up to 5.5 kWh/m^2/day on average in some southern regions (amounting to about 2,000 kWh/m^2/year).

Quite simply spoken, there is an abundance of solar resources in Viet Nam for all kinds of solar energy technologies and market applications.

The solar irradiation levels in Viet Nam mean that solar resources are comparable to most countries in the region, including the developed solar energy markets of China, Thailand or the Philippines.

It is remarkable that the solar resources show very limited spatial variation across the larger region. This can also be said for the average output of solar PV systems: The capacity factor[12] for fixed PV systems at the worst and best sites in Asia vary by 10% to 20%. For the majority of sites across the continent, the capacity factor lies within a few percentage points of 16%. No other energy resource is so equitably distributed (Ross, 2014). In comparison, the range of capacity factors for fixed PV systems in Germany is 10-12%.

Figure 2. shows this limited variation of solar irradiation in South and Southeast Asia:

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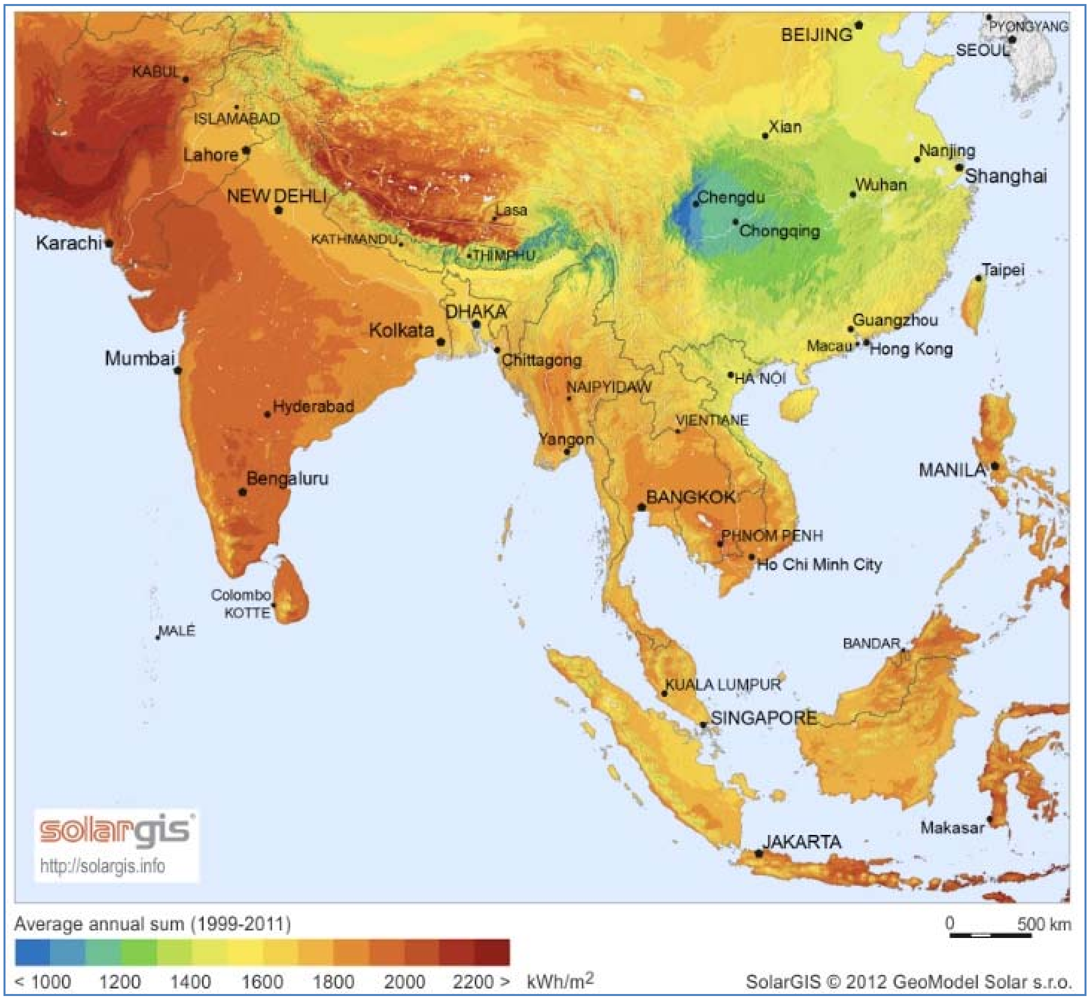
[12] The net capacity factor of a power plant is the ratio of its actual output over a period of time, to its potential output if it were possible for it to operate at nominal capacity continuously over the same period of time.

Figure 2. Global Horizontal Irradiation in South and Southeast Asia



Source: http://solargis.info

Capacity Potentials for Solar Energy in Viet Nam

So far, no thorough analysis of the overall expansion of Viet Nam's solar capacity has been conducted. Only a few rough estimations of MWp potentials in Viet Nam have been undertaken, either looking at the different parameters, such as utilizable roof or ground areas, or demand-oriented approaches that analyze the typical load curves of selected power consumers. However, these efforts do not provide a satisfactory level of accuracy and validity.

Table 1 displays the estimates calculated by a research project on the technically utilizable rooftop areas in cities, towns and provincial municipalities in Viet Nam, making rather conservative assumptions about suitable roofs within the respective categories (Nguyen, 2005).[13] Based on these assumptions, the estimated utilizable roof area in municipalities and

[13] For municipal areas it is asumed that 0.5% of all rooftop areas is suitable for solar energy utilization. For towns and cities the assumed share is 1%. See Nguyen (2005).

cities in Viet Nam amounts to a solar PV capacity of approximately 700 MWp.[14] 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 which is predicted to continue.[15] As a result, the long-term potentials for technically utilizable roof-area for residential and commercial PV applications should reach to at least **2-5 GWp** within the next two decades.

Table 1: Estimation of Technically Utilizable Rooftop Areas for PV and ST in Viet Nam

Market	Area (km^2)	Suitable Area for PV (km^2)	Suitable Area for ST (km^2)
Cities and Towns	1,869	9.32	9.32
Provincial Municipal Areas	1,812	4.53	4.53
Sum	3,681	13.85	13.85

Source: Nguyen (2005)

The same researcher studied PV capacity potentials using a demand-oriented approach for the hotel and office building sector in Ho Chi Minh City, resulting in an estimate of more than 110 MWp solar PV that could serve the day-time power demands of these two consumer sectors in the southern Vietnamese metropole (Nguyen, 2013).

In the context of another GIS-assisted research project, Nguyen looked at suitable areas for **ground-mounted PV capacities**, estimating an overall potential of **22,000 MW** for Viet Nam, with a focus on southern regions with high irradiation levels of 5 kWh/m^2/day or more (ibid.).

Regarding solar thermal applications, it is even more difficult to derive potentials from suitable roof-top areas since the technically and economically optimal system size (i.e. thermal collector size) for most applications not only depends on the available roof area but also on each building's demand for hot water, heat or cooling using system's thermal energy.

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.

Questions about Viet Nam's energy system and network, as well as energy market integration, are more important when assessing the potential capacities for solar energy deployment. Experiences from highly penetrated solar PV markets, such as Germany or Italy (6% and 8% share of solar energy in the national electricity mix, respectively, and even higher overall shares of variable renewable energy), show that the grid network integration of less than 15-20% variable renewable energy (wind and solar) into the electricity mix faces few limitations in terms of available solar irradiation and potential technical restrictions. Even

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[14] Here, the assumption is that most roofs in Vietnam are flat roofs and that the average area needed for 1 kWp PV capacity is around 20m^2.

[15] Data on the rate of urbanization in Vietnam varies between 2.5 and 3.4% per year between 2005 and 2010 (see World Bank 2012 and UNHABITAT).

penetration levels of up to 40% variable renewable power are manageable and realistic (see also Chapter 3.1).

Viet Nam therefore undoubtedly has the resource potential to become a major solar energy market with high shares of solar power and heat contributing to a green and economically sustainable energy system.

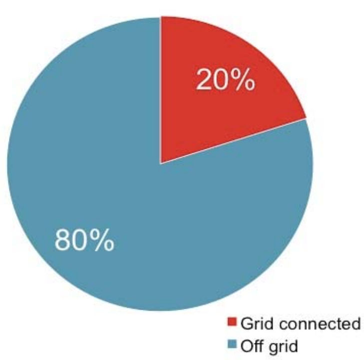
2.2 Current Status of Solar Energy Utilization

2.2.1 Utilization of Photovoltaic Power (PV)

The current solar PV market in Viet Nam is considered to be in the early "inception stage".[16] 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. As this study will point out (see Chapter 2.3.2), this very much applies to the situation of solar PV in Viet Nam.

At the end of 2014, approximately **4.5 MWp of solar PV capacity** was installed throughout the country.[17] Around 80% of that capacity was deployed off-grid and 20% is grid-connected (see Figure 3.).

Figure 3. Share of On-Grid/Off-Grid Installed PV Capacity in Viet Nam



Source: IoE (2014)

[16] According to diffusion theory, **different development stages** can be differentiated for RE. The theory proposes that markets typically grow slowly in the beginning, pick up speed over time and accelerate up to a certain point, after which the speed of growth starts to decrease again. Based on this, distinguish three main stages of RE market development can be identified: **The Inception stage** (limited market deployment of RE in fossil fuel dominated countries; RE mostly used for demonstration or in pilot projects; no effective policy framework for RE); the **Take-off stage** (growing RE deployment and awareness of RE as an alternative; initial implementation of policies and regulations promoting RE); and the **Consolidation stage** (RE technologies are cost competitive and account for substantial proportions of the energy mix; regulation and policies focus on keeping RE competitive and integrated into markets). See ACE (2013).

[17] Unfortunately, there is no official or publicly available commercial database on installed PV systems in Viet Nam. This is due to the absence of registration procedures or similar regulations that could document solar installations. Most figures on installed capacity or systems are based on private or scientific data collection, particularly those developed by former Director of the Solarlab-Institute in Ho Chi Minh City Mr. Dung (see Dung, 2015), or from publications issued by the Institute of Energy (see e.g. IoE, 2014 and IoE, 2015).

Based on existing data, roughly 60-70% of the off-grid installed capacity is dominated by smaller applications, such as Solar Home Systems (SHS), small base transceiver stations for telecommunications (BTS), solar public lighting systems and similar applications. Around 30-40% of the off-grid installations are bigger systems, such as local solar network stations and off-grid hybrid systems in remote areas or on islands.

The installed capacity connected to the grid is dominated by a rather small number of bigger rooftop systems, such as the installations owned by the Intel Corporation (220 kWp), Big C (200 kWp), the National Conference Hall in Ha Noi (154 kWp), the UNDP building in Ha Noi (119 kWp), the new National Assembly in Ha Noi (50 kWp) and the MoIT/GDE building (22 kWp).

All the existing larger PV 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 are currently no standardized regulations for the sale or feed-in of solar power, i.e. there are no viable business models that foster PV investments.

2.2.2 Utilization of Solar Thermal (ST) Domestic Hot Water, Industrial Heat and Cooling

The market for solar thermal applications in Viet Nam is in its early "Take-off stage".[18] Solar thermal energy is on the rise in Viet Nam, with a fairly developed domestic industry, some hundred retailers for domestic hot water systems (see Chapter 3.2.4) and viable business models in a subsidy-free market framework.

Small solar thermal domestic hot water systems are most commonly used in the residential market, mainly thermosyphon systems manufactured in Viet Nam or China. Furthermore, an increasing number of larger hot water systems have been installed on the rooftops of hotels, apartment complexes, tourist resorts and office buildings.

Reportedly, around 30,000 to 40,000 solar domestic hot water systems were installed annually in Ho Chi Minh City over the last 3-4 years.[19] This means more than 100,000 domestic hot water systems are currently in operation throughout the country. However, it has to be stated that there is no valid database for these systems, meaning that such figures have to be interpreted with caution.

Assuming that the yield of solar thermal systems in Viet Nam is comparable to those installed in Thailand (with comparable levels of solar irradiation and similar overall climatic conditions throughout the year), one can estimate that these approximately **100,000 solar hot water systems** correspond to an **installed capacity of 280 MW_{th}** with an **annual yield of 340 GWh_{th}**.[20]

Besides the domestic hot water segment, there is a very small but growing market for larger solar thermal industrial heat applications for a variety of production or manufacturing

[18] See Footnote 14.

[19] Most of these reports refer to a MoIT communication from 2011. The author could not verify this information but assumes that it is valid. See among others: http://www.saigon-gpdaily.com.vn/Science_Technology/2014/4/108874/

[20] For Thailand, the latest IEA Reports on solar thermal heat provide data on the average system size (for residential domestic hot water systems: 4m^2 per system), and the annual yield per m^2 (854 kWh/m^2) and per MW_{th} installed (1.2 GWh_{th}/MW_{th}). See IEA-SHP (2014).

processes with a heat demand of up to 120°C (see Chapter 3.2.3 for a more detailed examination of solar thermal industrial applications). Three large systems, covering a collection area of up to 1,000 m^2, have been realized in the Vietnamese textile and leather industry (see Chapter 4.2). These investments were realized without financial subsidies.

So far, no investments have been made in solar thermal cooling systems for commercial or industrial applications despite this technology being very promising, especially for combined cooling and hot water/heat applications (see Chapter 3.1.3).

2.3 National Energy Market and Regulatory Framework for Solar Energy

2.3.1 Overall Energy Market Structure and Developments

The rapid growth in demand for electricity is posing a huge challenge to Viet Nam'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 totalled 7.2%.[21]

According to Viet Nam's PDP VII, the average annual electricity demand is expected to grow by 14-16% in 2011-2015, and slow down to 11.15% in 2016-2020 and 7.4 – 8.4% in 2021-2030.

In response to this challenge, Viet Nam's reform agenda already includes energy market reform, fossil fuel fiscal policy reform and a transition to green growth.[22] 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. The Government has implemented a small environmental tax and has started to raise the electricity tariffs and prices for fossil fuels (such as the prices of coal and gas for power production) with a view to moving towards cost-reflective prices. While these are important steps, fossil fuel subsidies remain and fiscal policies still do not encourage improvements in energy efficiency and the generation of renewable, low carbon energy (UNDP, 2014).

With regard to renewable energies, the strategic targets of the **Green Growth Strategy**[23] are the most relevant. The strategy sets out the objectives of (i) reducing greenhouse gas (GHG) emission intensity and promoting the use of clean and renewable energy; (ii) moving towards greener production; and (iii) enhancing green lifestyles and sustainable consumption. The GGS, and subsequently the Green Growth Action Plan, commit to a roadmap for phasing out subsidies for fossil fuels; applying market instruments to assure principles of competitiveness, transparency and efficiency in the energy sector; and supporting renewable energy development (ibid.).

In addition, the government has committed to gradually re-orient 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. Decision 432/QĐ-TTg (12/4/2012) lays out the Strategic

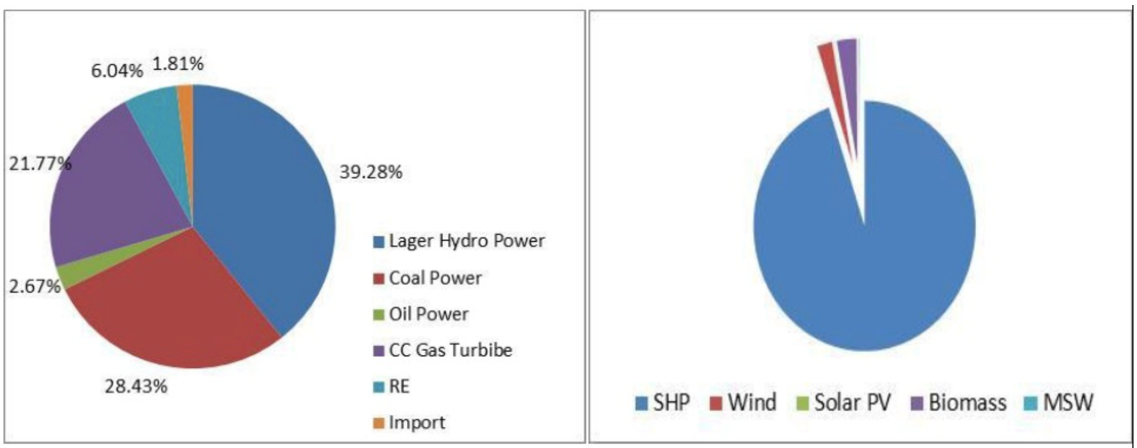
[21] See http://www.renewableenergy.org.vn
[22] For an overview of current reform processes see among others UNDP (2014).
[23] Decision 1393/QĐ-TTg, of 25/9/2012

Direction for Sustainable Development in Viet Nam for the period 2011-2020, including gradually liberalizing energy markets, and increasing the share of clean and renewable energy in Viet Nam's total energy use. These policies are recent and implementation has only just begun: The national Green Growth Action Plan for example was only approved in March 2014 (ibid.).

The **Power Development Plan VII** (PDP VII) sets out the detailed electricity development plans for Viet Nam until 2020, with a vision to 2030.[24]

Figure 4. shows Viet Nam's current power capacity mix as of late 2014. In total, a generation capacity of 33,964 MW has been installed, with 145.45 billion kWh of electricity being produced in 2014. Large-scale hydropower plants account for 39.3% of the capacity, with coal power and gas turbines accounting for 28.4% and 21.8%, respectively. Renewable energies make up 6% of the total capacity, with small-scale hydropower contributing most significantly with 94% of the RE capacity (IoE, 2015).

Figure 4. Viet Nam's Power Capacity Mix in late 2014

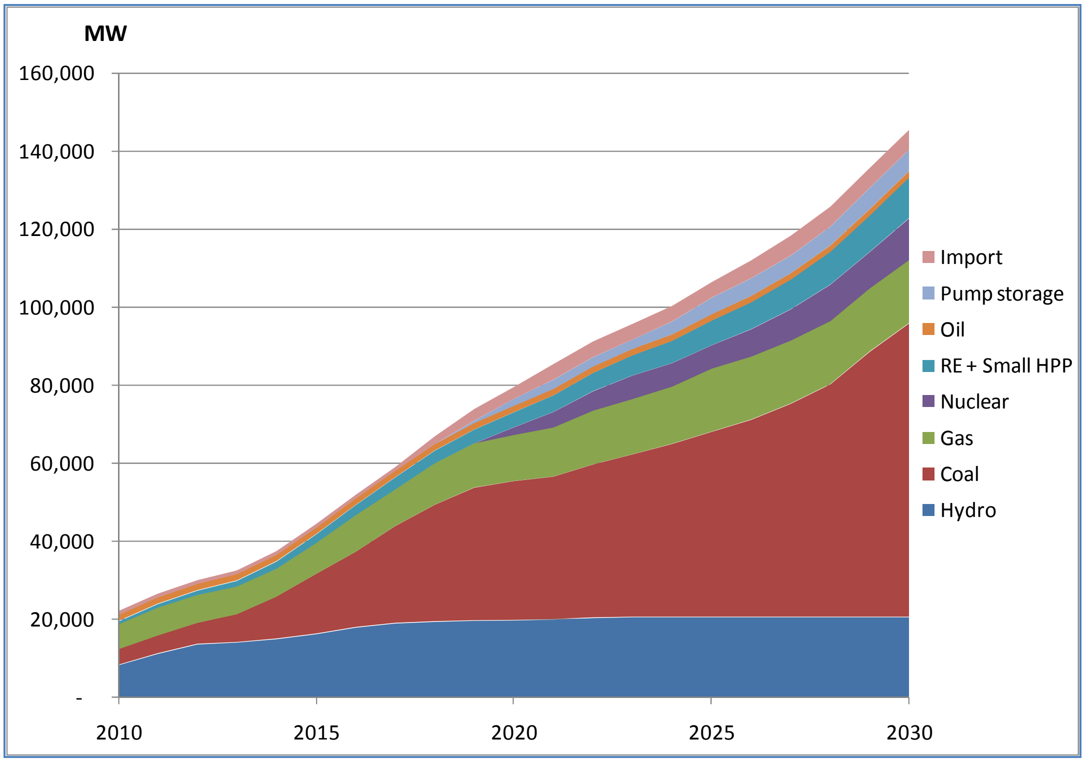


Source: IoE (2015)

Regarding the development of power generation, the PDP VII sets out targets for renewable energies. The current PDP VII aims to achieve a **share of 4.5% of renewable energy in the national energy mix by 2020** and **6% by 2030** based on the combination of wind energy, small-scale hydropower and bioenergy. A specific target for solar energy (PV) is not included. Figure 5. shows the development of the capacity mix by 2030 according to the PDP VII.

[24] Decision 1208/QĐ-TTg (21/7/2011)

Figure 5. Development of Power Generation until 2030 (PDP VII)



Source: PDP VII

Power Price Levels and Development in Viet Nam

The retail price level of electricity for the various end consumers is especially important for the competitiveness of solar energy - be it PV or solar thermal - since both are substitutes for conventional fossil fuel-based energy generation.

In recent years, Viet Nam has been substantially subsidizing the retail price of electricity for all consumer groups.[25] According to IEA figures, subsidies for fossil fuels in Viet Nam, imposed to keep power price levels low, varied from USD 1.2 - 4.49 billion annually in the period 2007-2012 (UNDP, 2014). As result, the energy price level in Viet Nam is low by international comparison. This has been a disincentive for investments in energy efficiency.

Regulatory mechanisms for electricity prices are in place in order to facilitate the adjustment of prices in line with production costs. Electricity prices are still regulated by the Government. Existing regulation[26] sets out a number tariff reforms: it specifies that from 2010 onwards electricity tariffs will be revised annually and need to reflect the evolving cost-chain elements. It also harmonized residential tariffs for customers served by power companies and local distribution utilities (LDUs) in rural areas. Cross-subsidies from the industrial sector to the residential sector will gradually be eliminated by increasing the tariffs for the former sector

[25] 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 (UNDP, 2014).
[26] Decision 21/QĐ-TTg (12/2/2009)

less rapidly than for the latter sector. However, cross-subsidization from large consumers to smaller consumers in the residential sector is expected to remain (UNDP, 2014).

Table 2 compares the average retail price levels in selected countries. However, these figures only show the average electricity prices, thus including all the subsidies to the energy markets, regardless of consumer differences. The price level for individual power consumers or consumer groups, for instance in the commercial or industrial sector, might look different (see Chapter 4.6 for an analysis of the power price levels and the PV power costs for potential commercial and industrial investors).

Table 2: Comparison of Retail Power Prices in Selected Countries

COUNTRY	ELECTRICITY PRICE (USD CENTS)	YEAR
Australia	22 – 46.56	2013
China	7.5 – 10.7	2013
Germany	31.41	2012
India	8.0 – 12.0	2012
Indonesia	8.75	2012
Japan	20 – 24	2012
Malaysia	7.09 – 14.76	2012
Philippines	30.46	2012
Viet Nam	7.6	2015

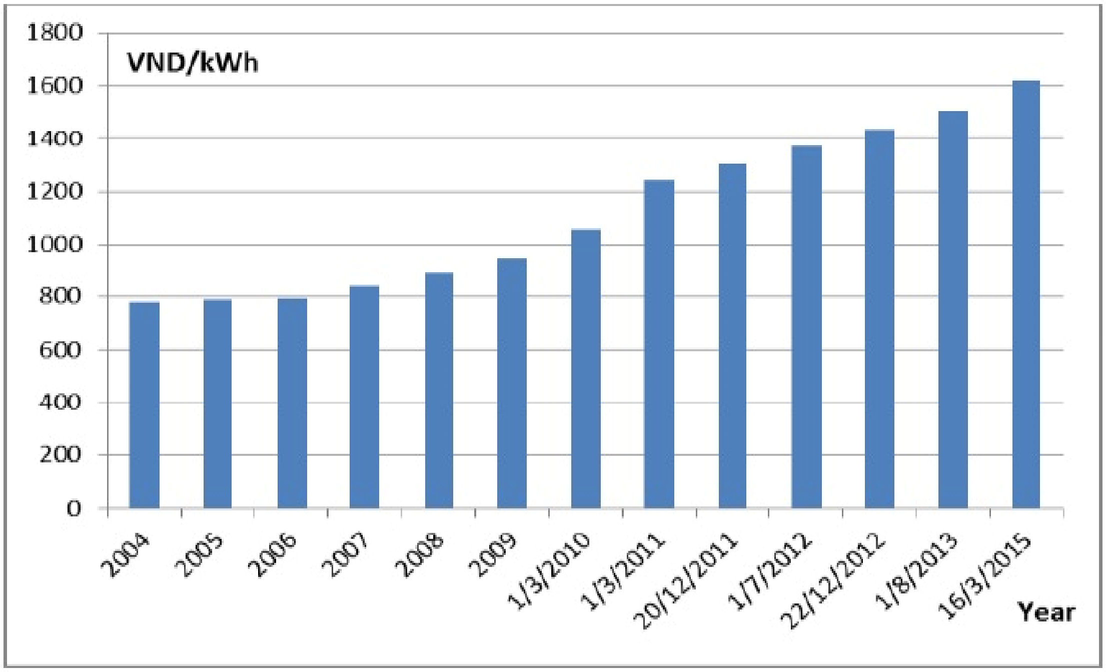
Source: UNDP (2014), IoE (2015)

The development over time has been affected by this subsidization policy and the political objective to keep power prices low for domestic consumers. In the course of the last decade, power prices largely increased in line with the overall inflation rate. Power prices even decreased slightly in terms of relative price development.[27]

Figure 6. shows the development of the average retail power tariff from 2004 until the most recent **price increase in March 2015**. Including this increase, the average tariff is now at **VND1,600.22/kWh**, which is **USD 7.6/kWh**.

[27] In VND_{2002} prices, the average retail power price decreased by 26% from VND 707/kWh in 2002 to VND 526/kWh in 2013. See UNDP 2014: http://www.vn.undp.org/content/dam/vietnam/docs/Publications/infographic%20revised%2014%20June_final.pdf

Figure 6. Development of the Average Retail Power Price 2004-2015



Source: IoE (2015)

Electricity markets in Viet Nam are dominated by **EVN**, from generation through to retail. While competition has in general been introduced into electricity generation, the extent of actual competition in generation markets is still limited: EVN controls close to 50% of the generation capacity and holds significant stakes in most other facilities (see UNDP, 2014). Furthermore, EVN owns the domestic transmission system (through a subsidiary), is a single-buyer and controls electricity retail in five regional subsidiaries that supply electricity to households and businesses below cost. Until June 2014, EVN offered a lifeline tariff (low tariff for basic needs power consumption) and provided cash to alleviate the burden on the poor. It also had an incremental block tariff scheme, which was reformed for the period after June 2014 (ibid.).

EVN is allowed to adjust electricity prices by up to 3-5% every 6 months without providing further notification as part of the new price framework issued by the Prime Minister. If changes in production input prices call for adjustments to the electricity price of more than 5%, EVN must consult with MoIT and the Ministry of Finance (MoF). On the supply side, the Government recognizes that in order to stimulate investments throughout the value chain and encourage competition, the prices at which EVN buys power from upstream plants will need to increase. However, no detailed mechanism or institutional arrangement has been put forward to achieve this (ibid.).

The **Electricity Law of 2005** started the process of partial liberalization of the power market, but it has not been fully implemented yet. The law states that the state monopoly in the sector should be limited to power transmission, national load dispatch and strategically important large-scale power plants, leaving power distribution and non-strategic power generation to potential private investors. In 2006, the Vietnamese Government approved a roadmap for the establishment of a competitive power market that envisages a phased approach to reforms. The first phase comprises the establishment of a competitive generation market. A single buyer, in this case EVN, buys electricity from the generating companies and sells it to distribution companies and large consumers at regulated prices. In the next phase, a competitive wholesale market will be developed in which sellers (power plants) and buyers (distributors and large consumers) interact competitively in a power pool. This phase was scheduled to commence in 2014 with a pilot wholesale market. The final stage, scheduled to start in 2022, will be a fully competitive retail market, in which retail consumers are allowed to choose their suppliers (CIEM, 2013).

The Electricity Regulatory Authority Viet Nam (ERAV) is the national electricity regulator. ERAV was set up to regulate Viet Nam's power markets, including supervising electricity pricing; monitoring supply and demand balances to promote energy security, efficiency and conservation; overseeing licensing; and resolving dispute resolution. However, it is managed by MoIT, which also manages EVN. Therefore, ERAV has not yet reached full independence (ibid.).

2.3.2 Policy Framework for Solar Energy

Taking a closer look at the policy framework for solar energy in general, it is striking that such little attention has been paid to that energy source. This applies in particular to **PV on-grid,** where applications have so far been connected in almost complete absence of any regulations and standards. **PV off-grid**, on the other hand, has been in focus for quite some time in the context of the country's rural electrification strategy. **Solar thermal** energy has not yet been included in the existing building or energy efficiency regulations. This, nevertheless, has not stopped domestic solar thermal hot water applications from becoming the most mature solar energy deployment in Viet Nam to date.[28]

Policy Framework for PV On-Grid Applications

The already mentioned PDP VII is currently under revision and expected to be finalized and published by mid-2015. The current PDP VII aims towards a **4.5% share** of renewable energy **until 2020** and **6% until 2030.** Observers reckon that these current development targets for renewable energy will be increased as part of the revision process. It is further expected that **solar PV** will be included in this revised draft with **a specific development target** for 2020 and 2030.

Apart from these general renewable energy targets, no specific regulations for solar PV have been implemented so far. This applies in particular to the following aspects of the regulatory energy framework:

[28] It has to be emphasized that, due to the limited timeframe for this preliminary market survey, it was not possible to conduct an in-depth analysis of primary legal sources covering all fields of solar energy-related legislation in Viet Nam. The regulatory landscape for energy reflected here thus needs to be seen as an overview based on secondary sources of information. Subsequent in-depth analyses of solar sector developments should include a survey of the primary legal and administrational sources.

* There are **no financial incentives** (such as Feed-in-Tariffs or net-metering schemes) to promote the deployment of solar PV. PV is not yet included in the existing FIT scheme for renewable energies.
* There is **no standardized interconnection code** (grid code) for PV systems. However, an ongoing project involving EVN, the energy authorities of Da Nang City and the International Copper Association Southeast Asia (ICA-SEA) has now made first steps in this direction and developed a proposal for an interconnection standard for PV as well as a general net-metering scheme.[29]
* There is **no effective regulation on the sale of excess solar electricity** generated by private or commercial PV systems. As interviews and consultations with private sector stakeholders have shown, this constitutes a significant barrier to investments in commercial PV applications (see Chapter 4.6).
* There are some **tax-related incentives** in place that can be applied to renewable energy investments and technologies in general, such as an import tax exemption, a corporate tax exemption and an environmental protection fee exemption (IoE, 2014). It is yet unclear whether these incentives can also be applied to solar energy applications or whether they have been applied in the context of the projects realized so far.
* Furthermore, there are **incentives for infrastructure and land use** regarding investments in major power stations that could also be applied to solar energy investments. In addition, the local People's Committees are responsible for providing available land to wind power projects (ibid.).

Policy Framework for Solar Thermal Applications

When looking at the possible regulatory constraints and barriers to solar thermal applications, the absence of public networks or grids to connect such systems to is a clear benefit. Most strikingly, solar thermal is not yet regarded as a means to achieving energy efficiency and is therefore not included in the existing energy efficiency strategies.

* There seem to be **no specific building regulations or standards** for domestic solar thermal hot water or process heat installations. For investments in commercial applications, the regular technical standards for commercial or industrial heat sources apply.
* **Energy efficiency strategies** and related legislation do not address renewable heat in general or solar thermal in particular.
* There is however one exception: A **grant program was implemented by EVN** in 2009 as part of the National Target Program on Energy Saving and Energy Efficiency to promote research on the technology itself as well as increasing production and imports of **solar water heating** equipment for use in households and other service sectors. The households who participated in the program received a subsidy of VND

[29] See ICA-SEA (2015). National Interconnection Standards and Net-metering for Rooftop Solar PV in Viet Nam. Consultation Workshop Report, 7 January 2015.

1 million. Electricity companies allover the country, solar equipment companies, and the Office of Energy Saving and Efficiency also participated in this initiative. During the first two years of the program, EVN built 900 pilot water heating systems using solar energy. The program has been continued, aiming to build an additional 1,000 water heating systems.[30]

Policy Framework for PV Off-Grid and Rural Electrification

The prospects for further PV off-grid development in Viet Nam are framed by the **national electrification strategy** and related political targets and measures. This strategy is based on the Power Development Plan (PDP), which prioritizes the development of rural power by 2020. The Government encouraged EVN to develop the national power grid in order to supply power to 100% of households by 2020. The main objectives of the 2011 PDP VII are (see USAID/Winrock/SVN, 2014*):*

- To further develop the national power system in order to supply sufficient electricity to meet the power demand for production and residential purposes in rural areas efficiently and with high quality. In case areas fail to meet the conditions for accessing the national power grid, the Government provides investment and support for the development of local power resources to ensure complete electrification of all households by 2020.
- To implement governmental support policies to help improve socio-economic conditions. This includes developing power supply systems for provinces and poor households in remote areas, especially for ethnic minorities, in order to strengthen solidarity, maintain defence security, ensure a standard of living as well as productive employment, and improve physical and mental health.
- To develop investment in supplying power to every hamlet and ethnic minority in Tay Nguyen.
- To upgrade the rural power grid to increase power supply capability and electricity quality, and reduce power losses in power lines.

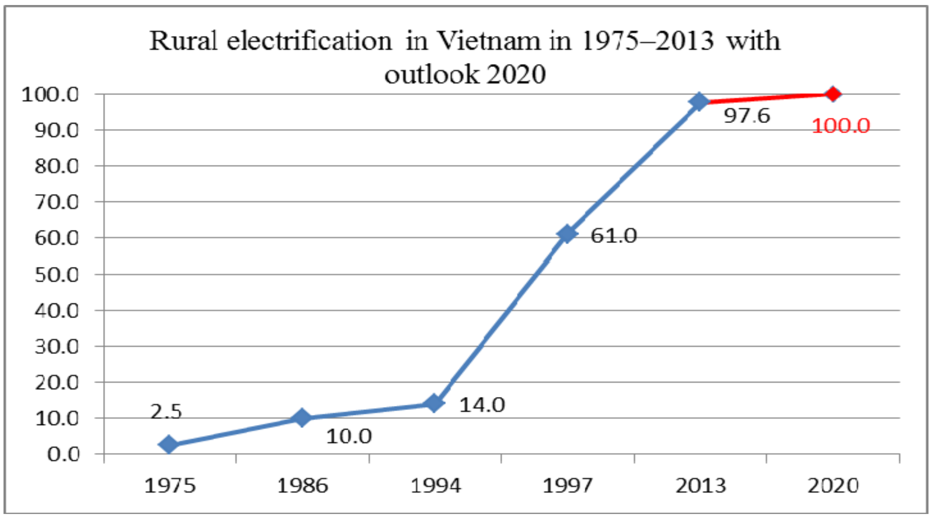
The second rural electrification project (REPII) is providing funds for this process. The objective of the REPII, which became effective in 2005, is to improve access to good, affordable electricity services for rural communities in an efficient and sustainable manner. Financed with a USD 200 million IDA credit and USD 5.25 million GEF grant, the project included a major upgrade and expansion of rural power networks in around 1,200 communes; the conversion of the existing ad hoc local electricity management systems to the local distribution utilities (LDUs) as legal entities recognized under Vietnamese law; the improved management of power distribution in rural areas; and capacity building measures for LDUs, provincial authorities, participating regional PCs, and national authorities involved in the planning and regulation of rural electrification. Additional financing for the Second Rural Electrification Project (USD 200 million IDA credit) was approved in May 2009 and is supposed to expand the project's outreach to 1.5 million households in 1,500 communes (ibid.)

[30] See http://www.renewableenergy.org.vn/index.php?page=solar-energy. More recent data on the program is not available.

The rural electrification project and previous efforts have been very successful. After the war in 1975, the electrification rate in Viet Nam was a mere 2.5%, increasing over the next 10 years to 10%. After introducing the economic changes of Dong Moi, it slowly increased to 14% by 1993. From then on, electrification was boosted by the implementation of the first North-South 500kV lines and the expansion of distribution grids. Within a few years, the electrification rate reached 60%.

In 2013, grid connections were expanded to most rural areas and were supplemented by micro-hydropower off-grid electrification in regions where grid connection was not feasible. As a result, the electrification rate reached 97.6% in 2013. Currently, Viet Nam is facing the "last smiles of electrification" (Dang, 2014), striving towards 100% electrification through expanding grid connection or supplying off-grid renewable energy.

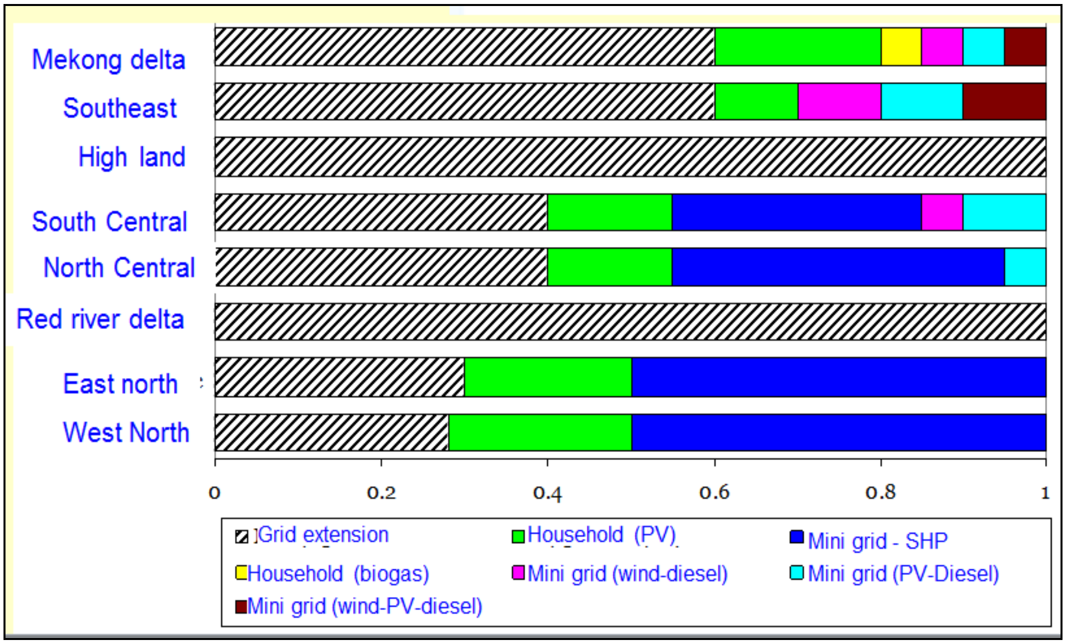
Figure 7. Rural Electrification in Viet Nam between 1975-2013 and Outlook until 2020



Source: Dang (2014) based on a MoIT communication from April 2014

Regarding the means of electrification and respective power sources, grid extension is clearly a priority in the Government of Viet Nam's planning. According to PDP VII, 37% of the remaining non-electrified households will be connected to the public power network, with the rest benefitting from renewable energy: 25% will be provided electricity through micro-hydropower, 17% will be equipped with Solar Home Systems (SHS), 13% will be powered by solar supported diesel or wind-diesel hybrid systems, 4% will benefit from wind diesel hybrid systems and 4% will be powered by biogas plants. The respective mix of these power sources is differentiated by region (see Figure 8.).

Figure 8. Planned Sources for Rural Electrification in the Main Regions of Viet Nam until 2020 (PDP VII)



Source: Dang (2014) based on PDP VII

Electricity tariffs for rural households are regulated by the State. In 2013, a new regulation was introduced for rural areas, highlands and islands that are not connected to the national grid. In these regions, the retail electricity prices for domestic consumption are approved by the provincial People's Committees, and cannot exceed defined ceiling and floor prices. In most cases, diesel generators provide power and the costs of supplying power are actually substantially higher than the politically fixed retail prices for rural households. The respective losses have to be covered by EVN or the State budget.[31]

After the most recent price increase in March 2015,[32] the general grid tariffs for households in rural areas vary from VND 1,230kWh (USD 0.057) to VND 2,088 (USD 0.094), depending on the amount of kWh consumed.

[31] One example is Ly Son Island, where a 3 MW diesel generator that is supposed to serve 3,000 consumers generates USD 25ct/kWh losses with each kilowatt-hour produced. As a result of this economic mismatch, the power plant was only in operation for a few hours per day and supplied electricity to only half of the consumers in shifts on every other day. The incentives to increase power production were low, since every kilowatt-hour produced would increase losses for EVN. Several consumers on the island then invested in their own individual diesel power generators (1-30 kW units) in order to access electricity on a 24-hour basis. Individual production was found to be even more inefficient, at an estimated cost of around VND10,000/kWh (0.5 USD/kWh). Such investments are of course not available for the poorest people (USAID/Winrock/SVN 2014).

[32] Decision 2256/QD-BCT dated 12 March 2015 and approved by the Ministry of Industry and Trade on regulating electricity tariffs.

3. Solar Energy for Viet Nam: Market Structures and Stakeholder Mapping

3.1 Solar Energy Applications: Existing Market Conditions and Possible Benefits for the Vietnamese Energy Sector

This section highlights the general international trends and market conditions regarding the development of the different solar energy applications and analyzes the basic Vietnamese market conditions for the application and deployment of these technologies. By doing so, it also points out the possible benefits the respective technologies have for the Vietnamese energy sector. Sub-section 3.1.1 focuses on grid-connected PV; Sub-section 3.1.2 on off-grid PV; Sub-section 3.1.3 on solar thermal hot water, process heat and cooling applications; and Sub-section 3.1.4 focuses on solar thermal power generation (CSP). A more specific and market segment-oriented view on both the Vietnamese market and international experiences is provided in Chapter 4 of this study.

3.1.1 The "Case for Solar" – Prospects of Grid-connected Solar PV for the Energy Sector

PV technology has undergone a tremendous and almost unprecedented development over the last decade, showing massive cost reductions due to a strong increase in production capacities worldwide and the large-scale deployment of PV power capacities in an ever growing number of energy markets, both in developed and developing countries.

With an increasing amount of solar markets reaching parity between solar power generation costs and the respective power retail price levels – so-called “grid parity” or “socket parity” of PV levelized costs of energy (LCOE) with end consumer power prices[33] – this development has led to an increasing number of global markets or market segments in which PV investments no longer rely upon financial support. Furthermore, current international research shows that PV technology is nearing cost levels for power generation – the so-called “generation parity” or “utility parity” of PV LCOE. However, many international markets still need support in order to foster technology deployment and industry development.

International Development Trends in Grid-Connected PV Technology

Figure 9. depicts the key international developments in the solar sector from 2010-2014. By the end of 2014, solar PV systems with a total capacity of 180 GW were in operation worldwide, with an annual market size of more than 40 GW in 2014. Within a few years, annual market growth increased by 150%. With decreasing technology costs and system price levels, the average (regionally weighted) LCOE for solar power has been cut in half between 2010 and 2014 - a trend which will continue.

[33] The term “grid parity” is most commonly used to describe the general competiveness of distributed RE technology (for an extensive discussion of the term and related aspects of PV competitiveness, see the reports of the EU Grid Parity Project, available under www.pvparity.eu). This is different than “socket parity”, used among others by the IEA, which refers to the price of producing energy compared to the costs charged by utility companies. Once socket parity is attained, customers save money by generating their own electricity rather than purchasing it from their utility provider (see among others IEA, 2014).

The average LCOE for residential PV applications in regions with high solar irradiation and low financing costs has reached levels of less than USD 0.15/kWh, making solar power cost competitive compared to retail power tariffs in an increasing amount of countries. The average LCOE for utility-scale PV power plants is even lower, sometimes less than USD 0.1/kWh in sites with optimal conditions. In late 2014, a USD 0.06/kWh power purchase agreement (PPA) was signed after a successful multi-MW auction in Dubai.[34] This, of course, is an uncommon example, but it indicates the future development of LCOE levels over the next few years.

Figure 9. PV Solar – Key Developments 2010-2014

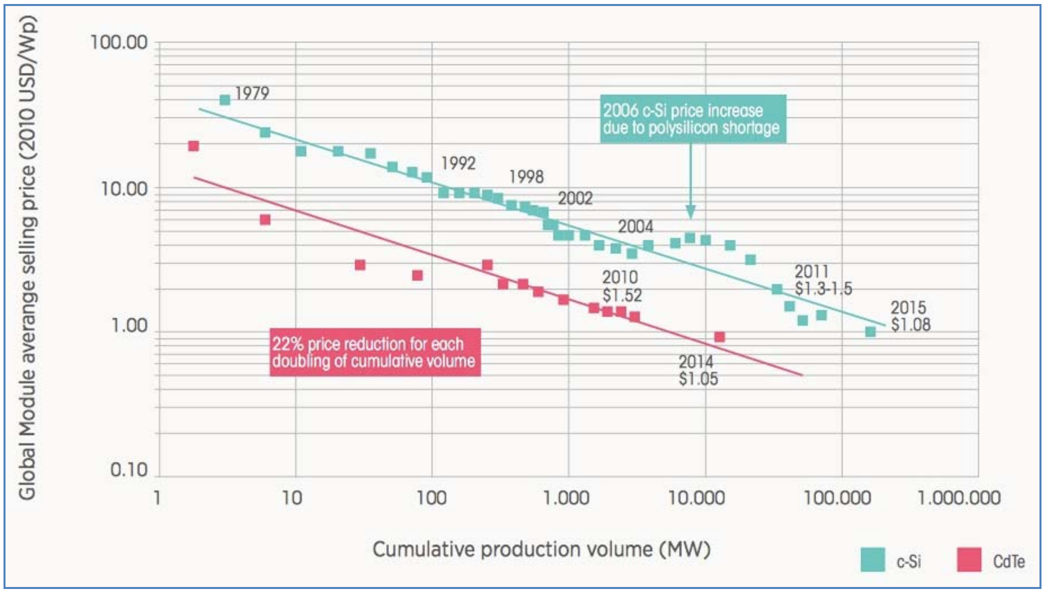
	2010	2013	2014	2010-2014 (% change)
New capacity additions (GW)	16	39	40+	150%+
Cumulative installed capacity (GW)	39	139	179+	360%+
Regional weighted average installed cost utility-scale (2014 USD/kW)	3 700- 7 060	1 690 – 4 250	1 570 – 4 340	-39% to -58%
Regional weighted average utility-scale LCOE (2014 USD/kWh	0.23 – 0.5	0.12 – 0.24	0.11 – 0.28	-44% to 52%
Residential LCOE in selected countries (2014 USD/kWh)	0.33 – 0.92	0.15 – 0.49	0.14 – 0.47	-49% to -58%

Source: IRENA (2015)

This rapid development of system prices and LCOE in recent years was mainly driven by the declining costs for key PV system components. The learning curve for PV modules shows that production costs decrease by more than 20% with each doubling of cumulated production capacity (see Figure 10.). Further cost reductions are being predicted due to the expected growth of the PV world market.

[34] http://www.pv-magazine.com/news/details/beitrag/six-cent-energy-is-not-the-new-normal_100017837/#axzz3W7Kdw59Z

Figure 10. PV Learning Curve – Development of Module Costs and Cumulative Module Production Capacity



Source: IRENA (2014b)

Possible contributions of Solar Energy to the Vietnamese Energy Market

In light of these developments, grid-connected solar PV has the potential to become an important pillar in Viet Nam's sustainable and cost competitive power supply, with substantial contributions to green growth targets, the transformation of the energy sector and industry development in general. The following political objectives and development targets could be tackled with solar PV in the coming years:

i. Developing a sustainable and cost competitive energy source for Viet Nam that contributes to reducing GHG-emissions as well as external environmental and health costs.

ii. Reducing fossil fuel import dependencies.

iii. Meeting peak power demand and reducing demand for high cost peak power generation capacities.

iv. Increasing the reliability and quality of energy supply to private and commercial power consumers.

v. Reducing grid transmission costs and distribution losses.

vi. Creating jobs and industry effects within the energy sector and related industries.

In the following sub-sections, these possible contributions to the Vietnamese energy market are discussed in more detail:

i. Developing a sustainable and cost competitive energy source for Viet Nam

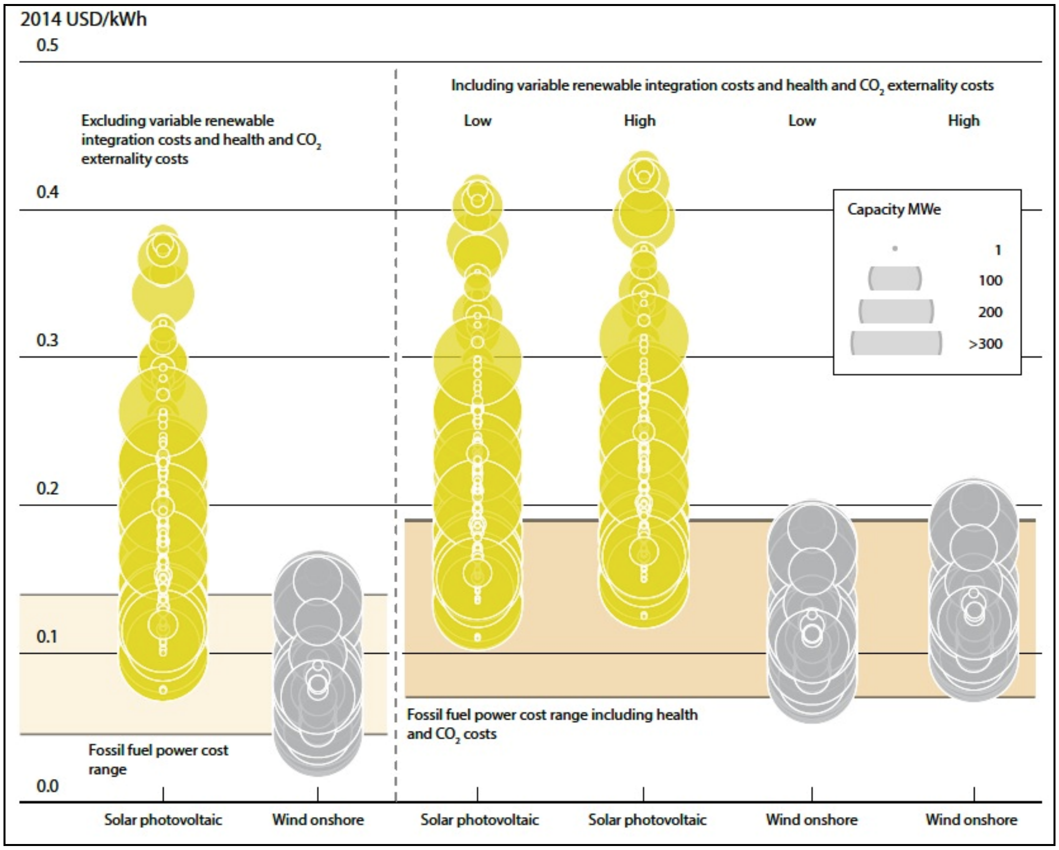
With the PV LCOE in decline and fossil fuel prices and related power generation costs on the rise, solar power is becoming an alternative long-term cost-efficient electricity source in Viet Nam.

Research on the costs of coal-fired power generation in Viet Nam indicates that the country is facing increasing costs for its predominantly coal-based power sector. Based on the preliminary results of the ongoing UNDP Fossil Fuel Fiscal Policy Reform Project, Viet Nam will become a **coal importer by 2017,** which will have substantial impacts on power generation costs. Power generation using **imported coal** will cost **at least USD 0.10/kWh** once CO_2-prices of USD 5-10/ton are included (see GreenID, 2015).

In comparison, the PV LCOE for utility-size power plants is estimated to reach this level within a rather short period of time. **Initial calculations** on the achievable **PV LCOE** conducted by the same UNDP project consortium **range from USD 0.11 to USD 0.17/kWh** for a 10 MW reference system in Southern Viet Nam (see IoE, 2015).

If external costs, such as environmental and health costs, are taken into account, solar PV is already cost competitive with fossil fuels in many regions of the world. If the economic costs of the harm caused to human health by fossil fuels, along with the **externalities associated with CO_2-emissions** (assuming USD 20 to USD 80/ton of CO_2), the cost of fossil fuel-fired power generation increases by USD 0.01 to USD 0.13/kWh, depending on the country and the technology used. According to an IRENA analysis of 26 countries, representing approximately three-quarters of global power consumers, **the cost of fossil fuel-fired electricity rises to between USD 0.07 and USD 0.19/kWh** if these health and environmental factors are taken into account (IRENA, 2015). Figure 11. shows a comparison of solar PV and Wind LCOEs with fossil fuel-fired power generation costs, including and excluding external costs for health and CO_2, as well as the variable renewable system integration costs (mainly for grid integration) for a 40% share of wind and solar in the overall electricity generation. The figures indicate that the PV LCOE already equals the costs of fossil power generation in many regions of the world if the true value of solar power for the environment and society is taken into account.

Figure 11. LCOE of Variable Renewables and Fossil Fuels, including Integration Costs and External Health and CO_2 Costs.



Source: IRENA 2015

International studies show that the general **environmental impact** of solar PV is **extremely low**. Since the operation of solar PV plants causes no emissions, the GHG-emissions released during manufacturing, which depends on the factory's energy supply, are the most serious concern. Estimates on the life cycle emissions of photovoltaic systems (post-2000) range from 10 grams to 217 grams of CO_2 equivalent/kWh with an average of around 60 grams. In comparison, the average operating emissions for electricity generation are 400 grams of CO_2 equivalent/kWh for natural gas and 900 grams for coal.

The energy required to manufacture a photovoltaic module can be generated by the module itself in as little as 1.5 years. Local impacts on land and vegetation, such as erosion, may be a concern for large-scale systems, particularly where the site is leveled to facilitate installation and vegetation is cut back or removed to eliminate shade. The impacts of PV roof-top installations are more benign. Most photovoltaic modules are made out of glass, processed silicon, aluminium, and a small amount of plastic. These components are relatively harmless for the environment (Ross/ADB, 2014).

ii. Reducing Fossil Fuel Import Dependencies

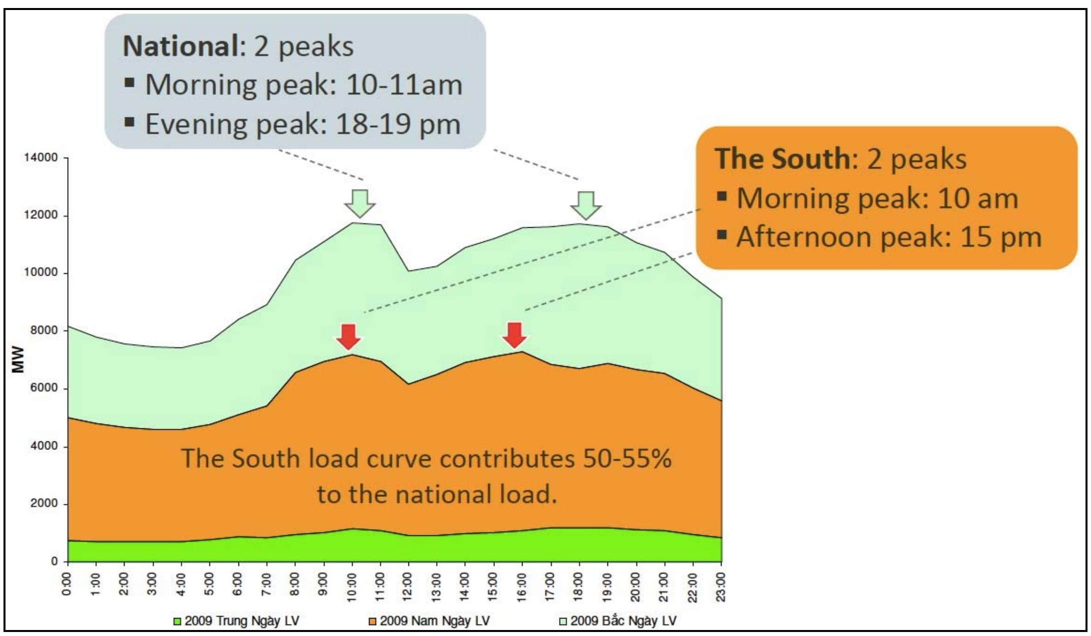
Solar PV's long-term stability of generation costs (current PV systems have a lifetime of 25-30 years with very low and stable operational costs throughout their entire life span) in addition to the general outlook on generation costs and rising coal prices, make PV an **economically viable energy source** that could reduce Viet Nam's import dependencies and increase resilience against rising fossil fuel prices in the future. Of course, solar PV will only have these significant benefits if the technology is deployed on a larger scale.

Germany, as a highly industrialized country currently transitioning towards 100% renewable energy, currently meets 10% of its primary energy demand with renewable energies, achieving substantial savings from reduced fossil fuel imports.

iii. Peak Power Demand – The Match for Solar

The main potential benefit of solar PV for the energy sector is based on an almost identical match between the average daily and annual solar generation and power demand (i.e. the load curve) throughout most parts of the country. Looking at the average daily load curve in different regions of Viet Nam, it appears that solar power production is able to contribute substantially to two demand peaks, one between 8.30am and 11.30am in the morning and another one between 2pm and 7pm in the afternoon/early evening (depending on the region). In the South of Viet Nam, with the afternoon peak at around 3pm, solar PV can supply power during all peak hours. In the North of Viet Nam, the afternoon peak is later, so solar production can at least supply energy during most peak hours, depending on the season (see Figure 12.).

Figure 12. Average Daily Load Curve in Different Regions of Viet Nam



Source: Nguyen (2013)

The power demand peaks shown in the load curves are largely reflected in the time-of-use retail tariffs for power consumers. Here, peak hours from 9.30 to 11.30 in the morning and from 5pm to 8pm in the afternoon have higher tariffs.

Being a “peak power energy source” to a large extent, solar PV has the potential to substitute cost intensive fossil fuel power generation in the future.

iv. Reliability and Quality of Energy Supply

Industrial electricity consumption is growing at a faster rate than GDP, reflecting Viet Nam's industrialization process. Residential electricity consumption has increased rapidly as well, due to an expanding customer base as a result of widened grid access, increasing owernership of electric appliances and growing urban populations with rising disposable incomes.

This development poses a challenge to electricity supply security. The power sector currently has to shift from connecting as many consumers as possible to ensuring good quality supply that can be relied upon 24-hours a day, all year round, through boosting investments, effectively operating existing infrastructure and promoting the efficient use of electricity. An ongoing World Bank project on improving the quality of the Vietnamese power grid indicates that power consumers are still affected by frequent power cuts or low quality power supply in many regions, especially in Southern and Central Viet Nam.[35]

One main indicator for the **quality of power supply** is the **SAIDI-Index**, the System Average Interruption Duration Index that measures the average annual power outage duration for each customer, usually expressed in minutes per year. These power outages do not include interruptions in power supply due to normal grid maintenance measures. According to the World Bank Power Distribution Project, the average SAIDI-value in the southern network (SPC) was 6,958 minutes at the end of 2011. The respective figure for the northern distribution network (NPC) was 5,145 and 3,631 for the central distribution network (CPC). In comparison: In Thailand the average SAIDI between 1992 and 2002 was around 1,500, in the Philippines it was 1,200, 800 in Indonesia and 182 in Australia.[36] The average SAIDI for Germany over the last five years was around 2.5 minutes in the low voltage networks and around 15 minutes in the medium voltage networks, making it one of the top 3 countries in the world in terms of the quality of power supply.

For many commercial enterprises and manufacturing businesses in Viet Nam, these power outages cause productivity losses and costly inefficiencies for their respective business processes. To counter these risks of power cuts, businesses invest in diesel generators or other back up power capacities. For some, **solar PV** could be an **alternative that increases power supply reliability as well as quality** through a PV system that at the same time covers their respective manufacturing or commercial processes substantial shares of costly peak power demand for their respective manufacturing or commercial processes.

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[35] See the intermediary reports oft he World Bank „Distribution Efficiency Project“ (World Bank 2014).

[36] See http://earlywarn.blogspot.com/2013/05/international-power-outage-comparisons.html

v. Reducing grid transmission costs and distribution losses

According to the assessments undertaken by the World Bank Distribution Efficiency project of Viet Nam's power supply and grid quality, **grid distribution losses** in the Vietnamese power networks ranged from 10% to nearly 25% in different grid areas in late 2011. In addition to these quality related power distribution losses that could be reduced with further investments in the grid infrastructure, there will be an increasing need for power transmission from Northern Viet Nam to Southern Viet Nam due to the fast growing industrial sector in the South and the unequal distribution of generation capacities throughout the country.

A larger-scale deployment of distributed solar PV, in particular in Southern and South Central Viet Nam, could substantially reduce the need for further expanding grid capacities to supply the South. With decentralized solar power generation in regions with high solar yields and an additional capacity demand, solar PV could reduce distribution losses and grid transmission in the future.

Regarding the possible **costs** of the large-scale **deployment** and **grid integration of distributed PV** or grid integration, international experience and cost estimates may be indicative: There are no insurmountable technical hurdles to the integration of the variable technologies of solar PV, and the additional system costs that could exceed the LCOE are modest. Cost implications for transmission and distribution systems are typically minimal. However, the additional spinning reserve required to meet voltage fluctuations in order to allow for intermittency and provide the capacity to ride out longer periods of low sunshine (or wind), can add to the overall system costs.

Estimates of these costs depend on a range of factors, including: the specific electricity-system configuration, existing generation assets, the share of variable renewable penetration, the distribution of renewable resources and their covariance, and existing market structures. However, estimates range from USD 0.035 to USD 0.05/kWh with a variable renewable penetration of around 40% (IRENA, 2014). While these figures must be treated with caution and are not a substitute for detailed system modeling, they give an idea of the order of magnitude to be expected. Studies from countries with an already high rate of penetration of solar PV, such as Germany, indicate that additional grid costs for the integration of solar PV are within the range of maintenance expenses and other necessary investments in grid modernization, if available smart technologies and grid management mechanisms are implemented.[37]

vi. Job and Industry Effects

International experience clearly shows that the development of a domestic PV market, i.e. the deployment of distributed solar PV in different market segments, can trigger positive industry and employment effects. Detailed asessment studies on the impact of PV market deployment on the job market have not been conducted in many countries yet. But estimates based on the industry developments in Europe and Japan during the 2000s indicate that job creation is substantial due to the often small-scale and localized nature of investments.

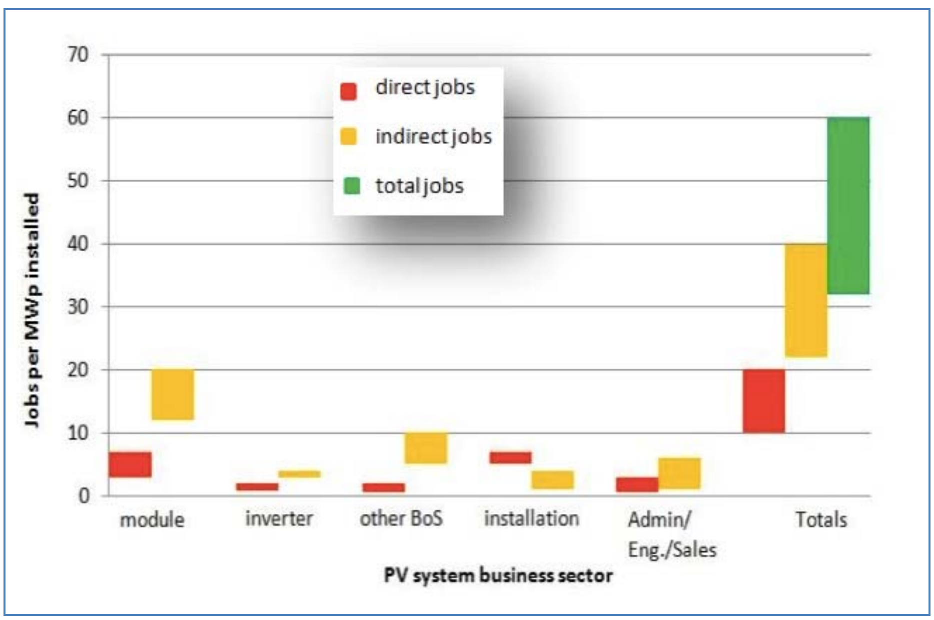
[37] For an overview see Fh-IWES, 2012. Presentation held by Jan Appen at the „Solar Energy Conference“ in Kristiansand, 5 September 2012.

The value chain for the PV industry comprises two categories of jobs: **Direct and indirect jobs. Direct jobs** are provided by companies or individuals who are fully dedicated to the PV chain, such as PV production sites, inverter manufacturers, on roof or on ground installers and recycling companies. In PV companies, such jobs include a range of positions and levels, from construction and manufacturing workers, engineers and administrative assistants, to senior executives and CEOs. **Indirect jobs** support the PV industry by providing more generic components or services, such as raw material suppliers (glass, dopant gases, silver paste, steel bars etc), electricity, production equipment, electrical devices (e.g. wires, fuses) and public officers for administration and taxes. In late 2012, the global PV industry **directly employed** more than **435,000 people**, as well as **one million indirect employees** (EPIA, 2012).

EPIA, the European Photovoltaic Industry Association calculated that work in wholesale, retail, installation and maintenance services provide **30 new jobs per MW of installed PV capacity** (see Figure 13.).

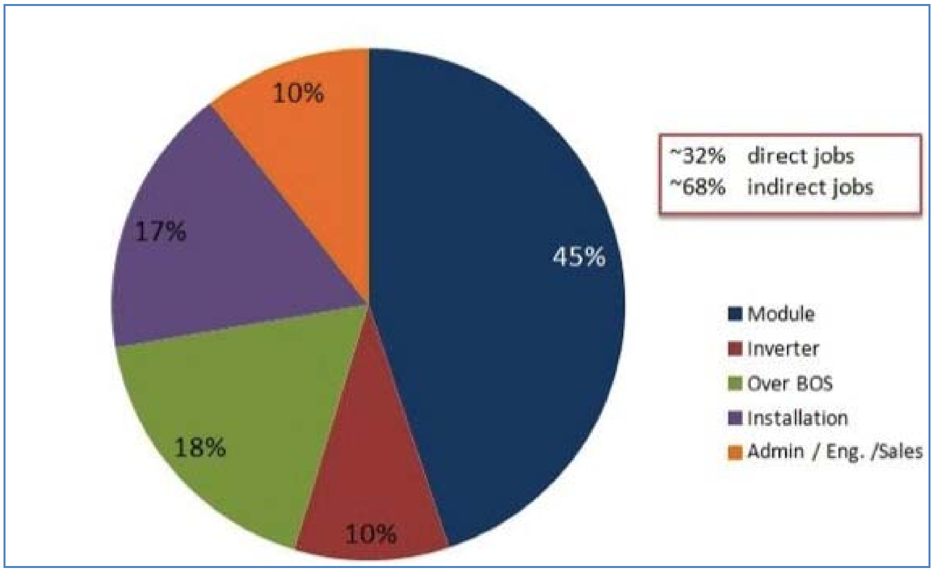
The first investments in PV manufacturing have already been realized in Viet Nam (see Chapter 3.2.4). With a growing domestic PV market, further investments of this kind can be expected. PV module manufacturing creates 3-7 direct jobs in production zones and 12-20 indirect jobs per MWp produced, depending on the technology. All other jobs are localized throughout the site of the system or close to the customer. These jobs relate to the installation of the PV system: local roofers, electricians, civil workers and all the supportive jobs (engineering, administration, catering, public jobs, etc). Half of the direct and indirect jobs are linked to the production phases of the PV chain and the other half is linked to installation efforts.

Figure 13. Jobs created in the PV Value chain (Per MW_p installed)



Source: EPIA (2012).

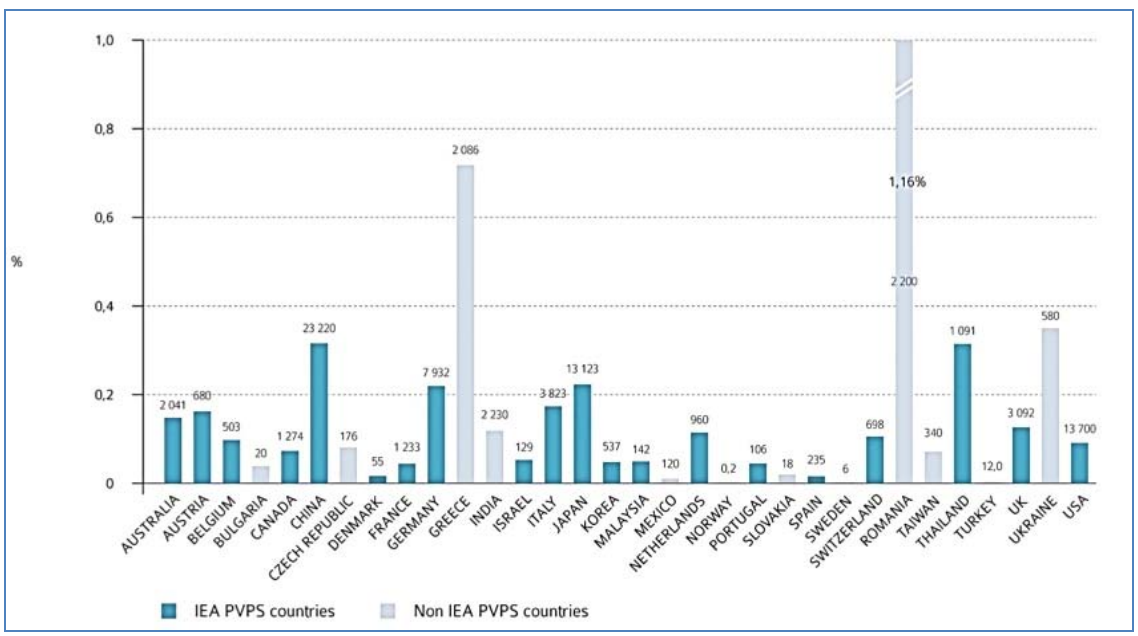
Figure 14. Distribution of Jobs in the Global Photovoltaic Industry Value Chain



Source: EPIA (2012)

Estimates by the International Energy Agency (IEA) highlight the **business value of national PV markets** in absolute figures as well as in comparison to the respective national gross domestic product (GDP). Following these IEA statistics, the PV market in Thailand already reached a business value of more than USD 1 billion in 2013, accounting for 0.3% of GDP. Regarding the relative business value, this was comparable to the Chinese PV market at the time (see Figure 15.).

Figure 15. Business Value of Selected PV Markets Compared to GDP in % and in USD million



Source: IEA (2014b)

In conclusion, a PV market with an annual installed capacity of 300 to 500 MW and **a solar power sector with 15,000 to 25,000 green jobs could be created** (including jobs related to export manufacturing). The calculations of MW-job factors so far have been based on market developments in developed economies with high ratios of automization. In a developing country context it can be assumed that the number of jobs created by solar energy market development will be at least 50% higher per MW deployment due to a lower automation rate (and lower labor costs). It is therefore assumed that **50 new jobs can be created per MW installed PV capacity in Viet Nam**.

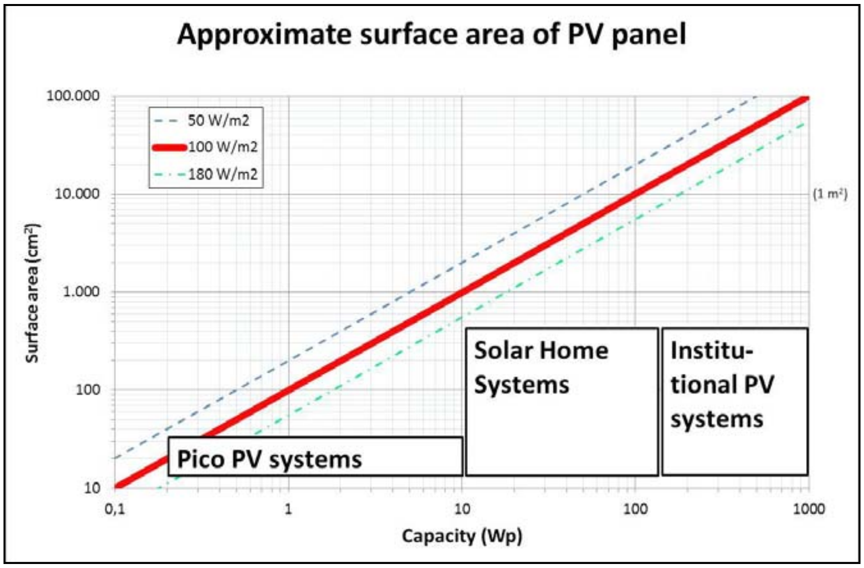
3.1.2 Off-Grid Solar Power Supply for Rural Areas and Islands

The term off-grid is generally used to refer to areas that are not connected to the national grid. Affected households and communes are typically located in rural, mountainous areas or islands. This includes communities that have decentralized diesel (or other sources) electricity generation. Furthermore, there are areas that are connected to the national power grid but still need additional "off-grid" power support from diesel generators or other power sources due to poor grid electricity supply. Off-grid areas are generally small and dispersed communities with low-income households, and thus unattractive to private sector energy providers or even government electrification programmes. This also applies to Viet Nam (USAID/Winrock/SVN, 2014).

PV now represents a competitive alternative to providing electricity in such areas where traditional grids have not yet been deployed. In the same way as mobile phones are connecting people without the traditional network lines, PV is perceived as a way to provide electricity without first having to build complex and costly grids. The challenge of providing electricity for lighting and communication, including access to the Internet, makes PV one of the most reliable and promising sources of electricity in developing countries in years to come (IEA-PVPS, 2014b).

PV off-grid applications can be divided into two main categories: **small-scale applications** for domestic (lighting, home appliances etc.) or non-domestic (telecommunication, BTU etc.) use and **larger PV off-grid systems** that either include additional infrastructure for local power distribution or management (mini-grids) or additional sources of power, such as diesel generators or wind turbines (hybrid systems). The former can be subdivided into Pico PV applications, such as solar lanterns or solar battery chargers, Solar Home Systems (SHS) for domestic appliances primarily and larger stand-alone PV systems for institutional uses, such as community or medical centers. The power capacities of these systems range from less than 1 Wp for Pico PV applications to 1 kWp and more for larger stand-alone systems.

Figure 16. Segmentation of Small Off-Grid PV Applications



Source: Lysen (2013)

Latest developments in lighting and other home appliance technologies are opening up new opportunities for Pico PV applications: Combining LED technology and highly efficient end use equipment, a new generation of Pico PV systems are now entering the market, offering the tremendous advantage of modularity. Rather than having to find a way to finance the full cost of a SHS with a 50 Wp panel plus appliances – either by way of cash or through a financing mechanism – it is now possible to use extremely efficient end use appliances, thus decreasing power usage to 30% or 50% of what was previously required. By selling the panel, central system and basic appliance to start with, customers can then progressively buy additional appliances and add panels and batteries in series, to a service level approaching that of a SHS. These very recent technical developments offer a new realm of opportunities in terms of services, including lighting, audio-visual, telephone charging, radio and TV (IEA-PVPS, 2014b).

Larger-scale off-grid applications, such as hybrid systems and PV mini-grids, are used in a number of countries' remote areas or islands without grid access. In these regions, diesel power generators (or other fuels) are the dominating source of energy supply. With an LCOE of USD 0.20 to USD 0.40 and more for diesel, the PV “hybridization” of these diesel gensets is often a means to reduce costs and environmental harm related to fossil fuel combustion. Solar PV becomes particularly attractive in remote areas, since grid connection is very costly in these cases, with the transport of diesel making this source of power even more expensive. In Indonesia, for instance, more than 1,600 MW of diesel power capacity out of a total of 4,000 MW is generated more than 100km away from the power grid (Blechinger 2015).

Market Conditions in Viet Nam and Possible Benefits of Off-Grid PV for the Energy Sector

The framework conditions for PV off-grid development in Viet Nam are mainly shaped by the national electrification strategy and related political targets and measures (see Chapter 2.3.2).

Heaving already reached an electrification rate of 98%, the potential for further PV off-grid development in Viet Nam is limited in general and mostly relates to remote mountainous areas and islands. Here, diesel power generation costs are typically high and energy supply from solar power or hybrid applications can be cost competitive. Grid connection is often a costly alternative as well. In mountainous areas grid expansion can easily cost as much as USD 5,000 per km (USAID/Winrock/SVN, 2014).

Thus, PV off-grid applications in general have the potential to provide a cost competitive and energy efficient source of power in remote areas, granting access to energy for the poor and marginalized residents of Viet Nam's mountain regions as well as island communities that are not (yet) connected to the national power network. For EVN, PV hybrid systems on islands can be a particularly attractive investment, since power supply with diesel generators is creating losses for the national utility company due to politically fixed low electricity tariffs for the respective households and consumers.

3.1.3 Solar Thermal Domestic Water Heating, Process Heating and Cooling

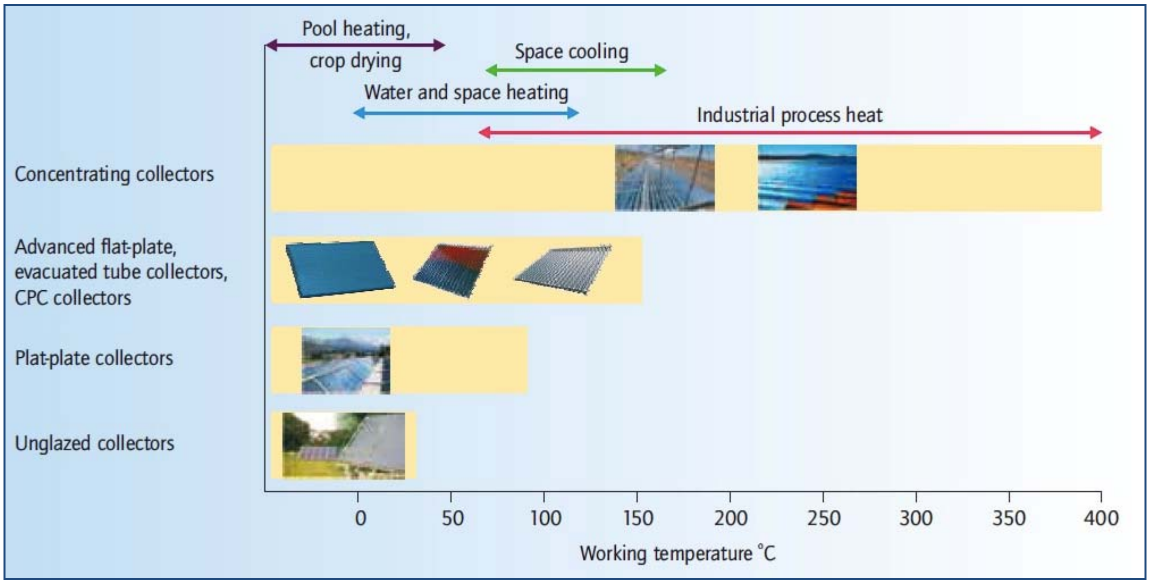
Solar thermal heating and cooling covers a wide range of technologies, from mature domestic hot water heaters to applications just entering the early market development phase, such as solar thermal cooling. Figure 17. gives an overview of the existing technologies and the application of solar thermal energy. Solar thermal heating and cooling technologies based on flat-plate or vacuum tube collectors are relatively simple (mainly using basic raw materials such as metal), offering opportunities for local manufacturing and economic development, in developing as well as developed economies.

Solar thermal technologies have the potential to contribute significantly to the global demand for heat energy. In 2009, the IEA reported that the global energy demand for heat represented 47% of the final energy use, higher than for electricity (17%) and transport (27%) combined. Thus, solar heating and cooling technologies can have an important role to play in realising energy security and economic development targets, and in mitigating climate change (IEA, 2012).

Solar heating and cooling technologies have specific benefits. They are compatible with nearly all sources of back-up heat and are almost universally applicable due to their ability to deliver hot water, hot air and cold air. Furthermore, solar heating and cooling technologies, just like all solar technologies, can increase resilience against rising energy prices, since most costs are incurred at the moment of investment (upfront costs). Operating costs are minimal and there is almost no exposure to the volatility of oil, gas or electricity prices.

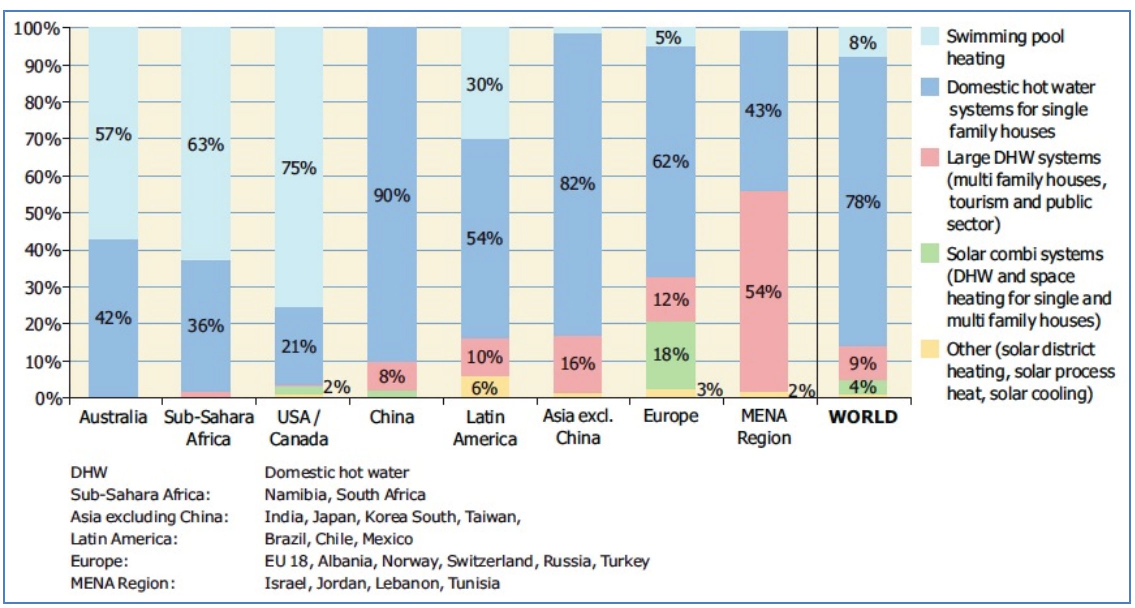
Maximum solar irradiation usually coincides with the peak cooling demand in residential or commercial buildings. Solar cooling therefore does not require additional electricity generation and transmission capacity like other sources of energy that are affected by the higher average peak loads caused by the rapidly increasing cooling demand in many parts of the world. It can also allow for a more optimal use of solar energy applications for domestic hot water and heating purposes.

Figure 17. Solar Collectors and Working Temperatures for Different Applications



Source: IEA (2012)

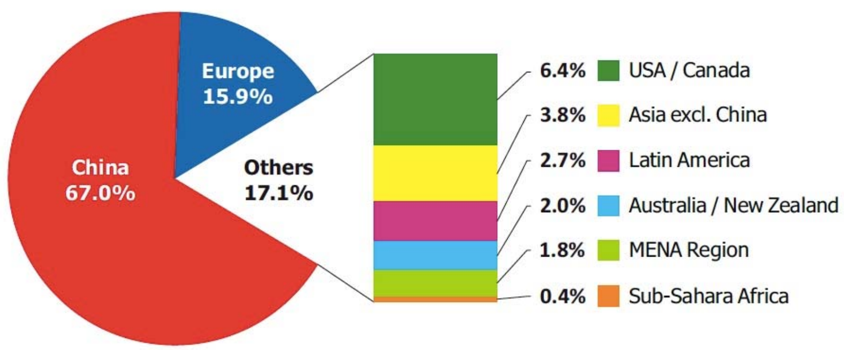
Figure 18. Distribution of Solar Thermal Systems by Application for Different World Regions by End of 2012



Source: IEA-SHP (2014)

The market for solar heating technologies has recorded substantial growth rates over the past decade, especially in Europe and China. At the end of 2012, the vast majority of the total capacity in operation was installed in China (180.4 GW_{th}) and Europe (42.8 GW_{th}), accounting for 83% of the total installed capacity (IEA-SHP 2014). The remaining installed capacity was shared between the United States and Canada (17.2 GW_{th}), Asia (excluding China, 10.3 GW_{th}), Latin America (7.4 GW_{th}), Australia and New Zealand (5.4 GW_{th}), the MENA2 countries Israel, Jordan, Lebanon, Morocco and Tunisia (4.9 GW_{th}), and the Sub-Sahara African countries Mozambique, Namibia, South Africa and Zimbabwe (1.0 GW_{th}).

Figure 19. Share of total installed Solar Thermal Capacity in Operation by Economic Region at the End of 2012



Sub-Sahara Africa:	Mozambique, Namibia, South Africa, Zimbabwe
Asia excluding China:	India, Japan, Korea South, Taiwan, Thailand
Latin America:	Brazil, Chile, Mexico, Uruguay
Europe:	EU 28, Albania, Macedonia, Norway, Switzerland, Russia, Turkey
MENA Region:	Israel, Jordan, Lebanon, Morocco, Tunisia

Source: IEA-SHP (2014)

In China, by far the biggest market in the world, the use of solar domestic hot water heaters is continuing to grow rapidly. They are increasingly popular due to their cost-effectiveness compared to electric and gas heaters: the average annual cost (calculated for the heater's lifetime) for an electric water heater is USD 95 and USD 82 for a gas water heater, whereas a solar water heater only costs USD 27 per year on average (cost estimate for 2010, IEA, 2012).

Regarding the deployment of different collector types, in late 2012 the cumulated capacity in operation can be broken down into 64.6% for evacuated tube collectors, 26.4% for glazed flat-plate collectors, 8.4% for unglazed water collectors, and 0.6% for glazed and unglazed air collectors (IEA-SHP, 2014).

Vietnamese Market Conditions for Solar Thermal Heat and Cooling

Looking at the Vietnamese energy market, there generally is a high demand for solar water heating in residential housing but also in many commercial and manufacturing processes. The growing tourism sector with its increasing amount of hotels and resorts in many parts of Central and South Viet Nam, as well as a number of commercial and manufacturing sectors, such as the textile, food & beverage, fishery and paper industries, have a growing demand for hot water, process heat and cooling. These processes generally require heat temperatures of 30 to 120°C, which most conventional flat-plate or evacuated tube collectors can deliver. Temperatures of more than 120°C, which are necessary for a number of processes, for instance in the Vietnamese chemical and plastic industry, can be reached through different concentrated solar thermal technologies, such as parabolic concentrators.

Since maximum solar irradiation in South and Central Viet Nam widely coincides with peak cooling demand in residential or commercial buildings, solar cooling could help reduce electrical network peaks associated with conventional (electric powered) cooling.

The following sections will briefly highlight the general international and national market setting for the main solar thermal applications and their potential benefits for the Vietnamese energy sector.

Solar Thermal Heat for Domestic Hot Water

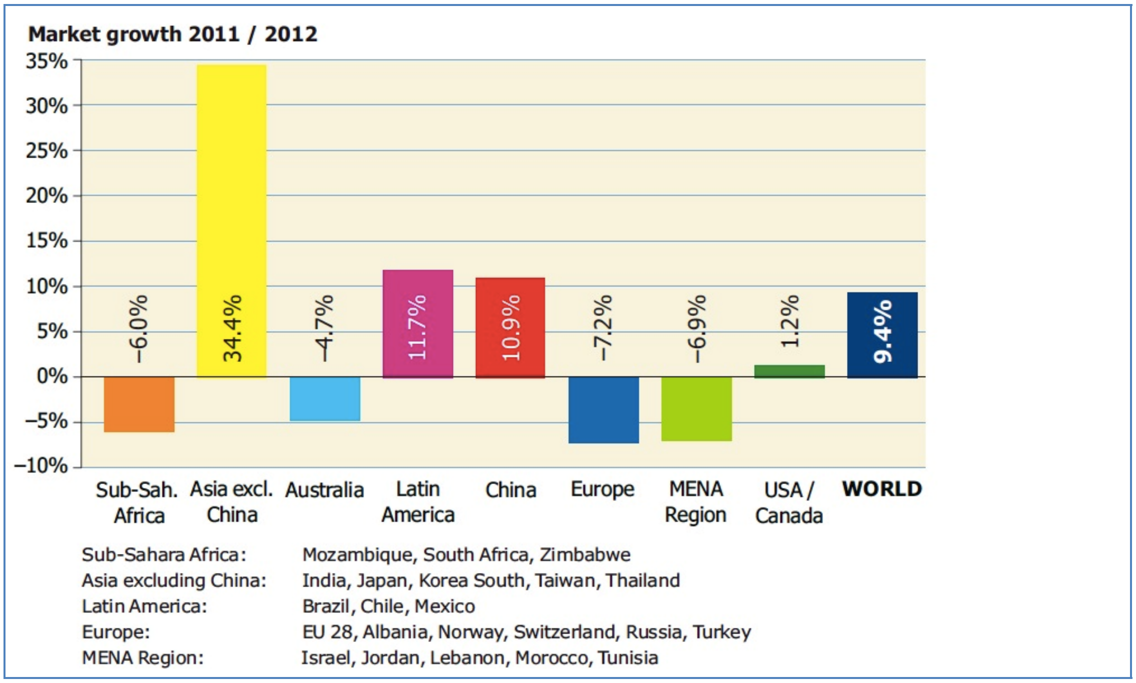
The most mature solar thermal technology, the solar domestic hot water system, has a long history, but was first deployed on a large scale in the 1960s in Australia, Japan and Israel (IEA, 2011).

Since then, some markets have shown a strong increase in deployment, either as a result of the introduction of long-term subsidy schemes or solar building requirements (e.g. subsidies in Austria and Germany, and renewable obligations for new or substantially renovated buildings in Germany and Israel), or as a result of solar hot water systems' competitive advantage over alternative technologies. Over the past 15 years, China's economic development has spurred the market for solar water heating, both in terms of system component manufacture and end-use demand.

Individual domestic hot water systems are generally relatively small systems with a collector size of between $3m^2$ and $6m^2$, with storage for 150-300 litres. Solar domestic hot water systems can be designed to cover between 30% (in combination with a back-up system) to nearly 100% of domestic hot water demand, depending on the collector area, storage size and climate. These systems can comprise thermosiphon (natural circulation) or pumped (forced circulation) systems (IEA, 2012).

The development of the global market shows that solar domestic water heating has experienced substantial growth in recent years, especially in non-Chinese Asian markets, such as Thailand, with an increase of installed collector capacity of almost 20% and more than 20,000 solar thermal systems in operation by the end of 2012 (IEA-SHP 2014).

Figure 20. Market Growth of Newly Installed Solar Thermal Capacity between 2011 and 2012 by Region



Source: IEA-SHP (2014)

Viet Nam shows an increasing demand for domestic hot water, predominantly in residential housing and the fast growing tourism sector. The market for these applications is already fairly established (see also Chapter 4.1 and 4.2), with some 300 small retailers for small residential thermosyphon systems and economically viable larger scale solutions deployed in tourism and other sectors without substantial subsidies.

Solar Thermal Heat for Industrial Processes

A variety of industrial processes demand vast amounts of thermal energy, which makes the industrial sector in general a promising market for solar thermal applications. Depending on the temperature of the heat needed, different types of solar thermal collectors are used - air collectors, flat-plate and evacuated tube collectors for temperatures of 120°C or less, and concentrated solar thermal collectors, such as parabolic troughs, Fresnel collectors or Scheffler dishes, for temperatures up to 400°C. For medium and high-temperature applications, concentrated solar technology is limited to areas with good DNI. Currently, India is the biggest market for concentrated solar thermal commercial and industrial heat applications.

At present, solar heat for industrial processes is still a niche market, but a number of promising projects have been realized in the last couple of years, ranging from small-scale demonstration plants to very large systems, such as the world's largest solar thermal plant in Chile, which delivers heat for the electro-extraction of copper. Currently, 124 large-scale applications are in operation all over the world, with a cumulated installed capacity of more than 93 MW_{th} (133,200 m^2). 18 of these systems are larger than 1,000 m^2 and another 25 systems cover between 500 and 1,000 m^2 (IEA-SHP 2014).[38]

Based on a global assessment of process heating requirements, IRENA estimated a total global future potential for solar thermal of 15 Exajoule out of the 160 Exajoule total process energy demand in 2030 (IEA-ESTAP/IRENA, 2015). Considering fossil fuel prices and technology learning curves for solar process heat, IRENA estimates that out of this potential, approximately 3.3 Exajoule (~180 GWth) of the installed capacity can be deployed cost-effectively if technology costs for solar process heating technologies continue to decline, but only 0.5 EJ (~30 GWth) if prices remain at current levels. This equates to 3-20% of the low- and medium-heat temperature demand from additional plants built between 2010 and 2030 (IRENA, 2014).

The cost of solar heat for industrial process heat strongly depends on the process temperature, demand consistency, project size and the level of solar radiation at the site. For conventional flat-plate and evacuated tube collectors, investment system costs range from EUR 250–1000/kW (USD 265-1,060/kW) in Europe, and around EUR 200–300/kW (USD 210-320/kW) in India, Turkey, South Africa and Mexico. The energy costs for feasible solar thermal systems range from Eurocents 2.5 to 8/kWh (USD ct2.6-8.5/kWh). A European roadmap is aiming towards solar heat costs of Eurocents 3–6/kWh (USD ct3.2-6.4/kWh). For concentrated systems, heating costs range from Eurocents 6-9/kWh with a target price of Eurocents 4-7/kWh (USD ct4.2-7.4/kWh) for concentrated systems by 2020 (ESTIF, 2014).

Regarding market conditions in Viet Nam, a number of domestic industrial sectors use process heat at temperatures <120°C and are therefore likely to have a significant potential for the application of solar thermal to meet their process heat needs. Examples of these sectors are machinery, mining and quarrying, food and beverage, pulp and paper, and textiles and leather. Processes involved in these sectors include washing and leaching (mining industry); cooking, pasteurizing and sterilizing (food and beverage); drying, preheating of boiler feedwater, bleaching (paper and textile); and heating industrial buildings in some regions.

Solar Thermal Cooling

Solar thermal cooling applications convert solar energy into cooling energy by driving a thermal cooling machine with thermal energy generated by solar thermal collectors. Solar thermal cooling has a number of attractive features compared to alternative technologies, e.g. electric cooling (air conditioning).

Since maximum solar irradiation usually coincides with peak cooling demand in residential or commercial buildings, solar cooling can help reduce electrical network peaks associated with conventional cooling. If deployed widely, solar cooling can reduce the need for expensive additional electricity network resources associated with electric cooling.

[38] For a database on global solar process heating projects, see http://ship-plants.info. The database currently comprises three large-scale solar process heat projects deployed in Viet Nam (all three in the textile industry, see Chapter 4.2).

Moreover, solar thermal cooling can also be utilized overnight if thermal storage is used (heat generated during the day can be stored and used for cooling with a heat exchanger during the night). Furthermore, in colder periods of the year, solar cooling systems can be used for heating purposes, such as domestic hot water generation or space heating. Some types of cooling systems can also manage humidity levels as well as space cooling. In addition, industrial refrigeration, for instance in the food processing sector, is also a possible application for solar thermal air-conditioning technology.

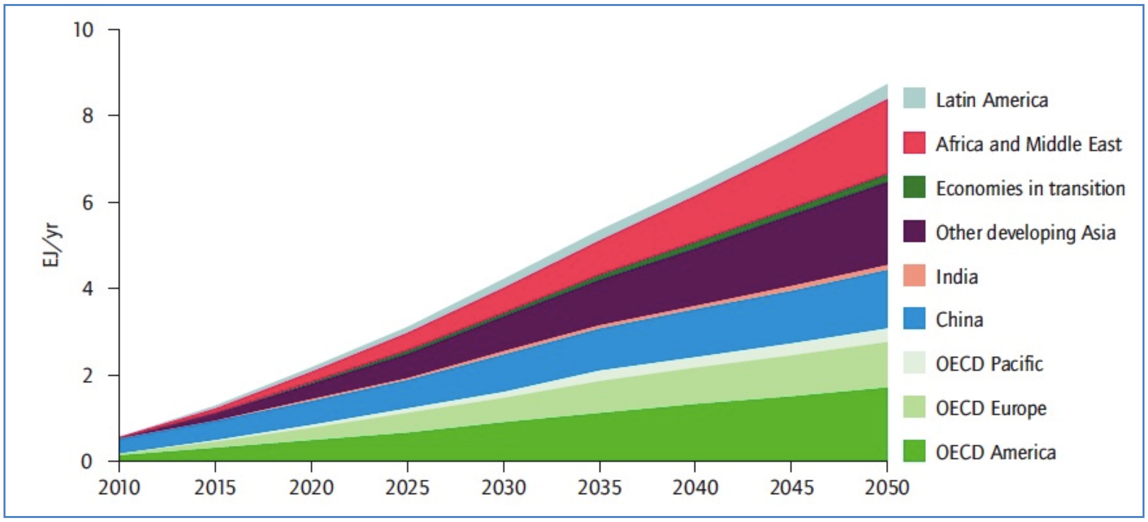
Solar thermal cooling, just as any other absorption chiller, does not use refrigerants (CFCs and HCFCs, used in electric compression chillers), which are harmful greenhouse gases (IEA, 2012b).

International market figures however show that solar thermal cooling is still is a niche market application. By the end of 2013, an estimated 1,050 solar cooling systems were installed worldwide. The market showed a positive trend between 2004 and 2013, with slightly decreasing growth rates in the last few years (Jakob, 2013). Since 2007, a cost reduction of around 50% has been realized as a result of the further standardization of solar cooling kits (Jakob, 2014). This trend is expected to continue in the near future.

Approximately 80% of the global solar cooling installations are installed in Europe, mainly in Spain, Germany and Italy. The majority of these systems is equipped with flat-plate or evacuated tube collectors. However, there are also some examples of thermal cooling machines driven by concentrated solar thermal energy (with concentrated solar thermal collectors such as parabolic troughs or Fresnel collectors) in India, Australia and Turkey (IEA-SHP, 2014).

Looking at future developments, the international technology roadmap describes how solar cooling can deliver considerable contributions to overall cooling needs, especially after 2030 when the costs of solar cooling technology are expected to decline rapidly while electricity costs are expected to increase continuously. China and other emerging Asian markets will meet around 30% of their cooling energy needs with solar power by 2050 (IEA, 2012b). The international experience in particular shows that the utilization of solar thermal cooling systems for cooling and heating, as well as hot water purposes, is a key prerequisite for substantially improving cost effectiveness.

Figure 21. IEA Roadmap Vision for Solar Cooling (Exajoule/yr)

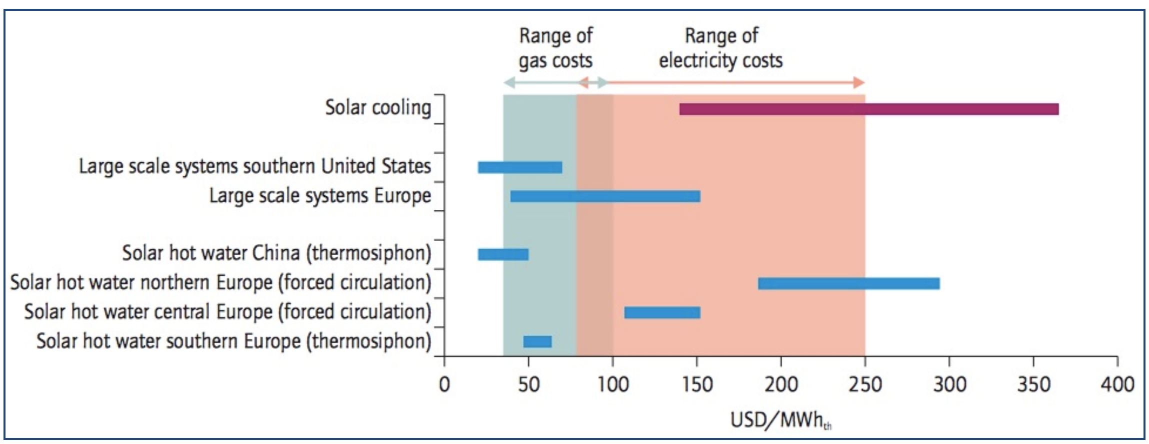


Source: IEA (2012b)

The overview of the possible market applications for Viet Nam shows that the growing food and fishery industry with its vast cooling and refrigeration demand could benefit significantly from the application of solar thermal cooling technologies. Furthermore, space cooling in a number of public and commercial sectors could be a suitable application for solar thermal cooling as an alternative to electric cooling and air conditioning.

The general assessment of the current state of the technology however shows that solar cooling is still in the early stages of market development. Costs are still high compared to conventional technologies (see Figure 22.) and need to be reduced through further development and increased deployment (IEA-SHP, 2014).

Figure 22. Costs of Solar Heating and Cooling (USD /MWh$_{th}$)



Source: IEA (2012)

Job and Industry Effects

Regarding international data on the job impact of solar energy, it appears that most of the existing studies focus on solar PV (see Section 3.1.1). In the Vietnamese context, it can be assumed that solar thermal energy would have a similar value chain and high rate of domestic employment as solar PV if deployed at a comparable scale. The manufacturing of solar thermal component manufacturing is even less high-tech and automatable than PV component manufacturing. Looking at the prevailing industry structures in Viet Nam, this assumption is therefore valid. A number of jobs are already available in the retail sector for solar thermal hot water systems (approximately 300 retail companies) due to the relatively developed market for these applications.

When applying the existing international data and experience to solar thermal potentials in Viet Nam (see Section 4.1.2 with estimates on the current Vietnamese solar thermal market), it becomes apparent that doubling or tripling the current market of approximately 30.000 domestic hot water systems per year (corresponding to 85 MW_{th}) to 170-255 MW_{th} per year could create **a solar thermal sector with 9,000 to 13,000 green jobs** (including jobs in export manufacturing). This calculation assumes a job factor of 50 new jobs per MW_{th} installed capacity per year.

Overview of Potential Benefits of Solar Domestic Hot Water, Heat and Cooling

With regard to international market developments and the general Vietnamese market conditions, the following key potential benefits of solar domestic hot water, process heat and cooling can be identified for Viet Nam:

- Solar thermal technologies are **compatible with nearly all sources of back-up heat** and are almost **universally applicable** due to their ability to deliver hot water, hot air and cold air.
- Solar thermal heating and cooling technologies can **decrease import dependencies** related to fossil fuels, especially coal imports, and can **increase resilience against rising energy prices**.
- All solar thermal technologies can **help reduce electrical network peaks** associated with conventional (electric) heating or cooling.
- Solar thermal heating and cooling applications can significantly **contribute to the reduction of GHG-emissions as well as environmental and health costs** if deployed on a larger scale.
- Due to its low-tech nature and reliance on localized demand, the development and enforced deployment of solar thermal technologies will most likely **create local jobs** in construction, procurement, BOS-component manufacturing, and operation and maintenance, as well as further **strengthening industry development** in Viet Nam (this will be discussed further in Chapter 3.2.4).
- **Cost competitive investments** in residential and commercial domestic hot water applications are already possible in Viet Nam (subsidy-free) and can therefore contribute to a cost efficient, secure and green energy supply in the heat sector if scaled up further.

3.1.4 Solar Thermal Power Generation (CSP)

Solar thermal power generation utilizes different concentrated solar power technologies (Concentrated Solar Power, CSP), usually including the use of mirrors to concentrate the direct solar irradiation (Direct Normal Irradiation, DNI) to drive traditional steam turbines or engines that generate electricity. Since thermal heat is produced and transformed into electrical power, CSP plants can incorporate heat storage and are therefore principally able to generate power on a 24-hour basis. This is a possible advantage over solar PV technologies, depending on energy market needs and local power demand. With the possibility to store energy for a few hours, CSP plants can serve peak, intermediate and, in certain circumstances, base-load demands.

The key prerequisite for CSP technologies is therefore a high overall rate of direct, non-diffused sunlight, i.e. strong sun and clear skies. According to IEA surveys, CSP developers typically set a bottom threshold for DNI of 1,900 kWh/m^2/year to 2,100 kWh/m^2/year (IEA, 2010: p.9ff). Below that threshold, other solar power technologies that can take advantage of direct and diffuse irradiation, notably solar PV, have a competitive advantage.

As a result, CSP technologies are almost solely installed in deserts or desert-like regions. The most favorable areas for CSP applications are therefore found in North Africa, Southern Africa, the Middle East, Northwestern India, the Southwestern United States of America, Mexico, Peru, Chile, Western China and Australia. Other areas that may be suitable include South Europe and Turkey, Southern US locations, Central Asian countries, Brazil and Argentina, and other parts of China (ibid.).

With a DNI range of 800 to 1900 kWh/m^2/year (see Chapter 2), even the regions in Viet Nam with the highest direct solar irradiation barely meet the minimum requirements for economically viable CSP investments. In addition, most regions in Viet Nam show a high methodological variability, in particular a large number of days of partial cloud coverage and very high relative humidity, which results in a high variability of DNI.

Additionally, international trends show that solar PV is on the rise compared to CSP technologies, even in many solar markets with high DNI, due to significant recent cost reductions and an expected further cost decline in the future. This trend resulted in the near-collapse of the Desertec Industrial Initiative (DII) in 2013, which originally based its visionary EU-MENA solar plan solely on CSP technologies.[39]

This study therefore does not focus on solar thermal power generation and CSP technologies as a key potential renewable power application for Viet Nam.

3.2 Stakeholder Mapping of the Vietnamese Solar Energy Sector

This chapter maps the main stakeholders of the Vietnamese power sector and solar energy industry. It highlights these institutions and enterprises that are relevant for the further development of solar energy with a brief summary of their key tasks and objectives.

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[39] Reportedly, one of the main reasons for the withdrawal of major investors and shareholders in the DII was the lack of faith in CSP technologies in light of the ongoing global cost reductions and continuous development of solar PV technology (see among others: http://www.rtcc.org/2013/07/05/desertecs-collapse-unlikely-to-affect-eu-energy-plans/)

3.2.1 Government Agencies and the Public Power Sector

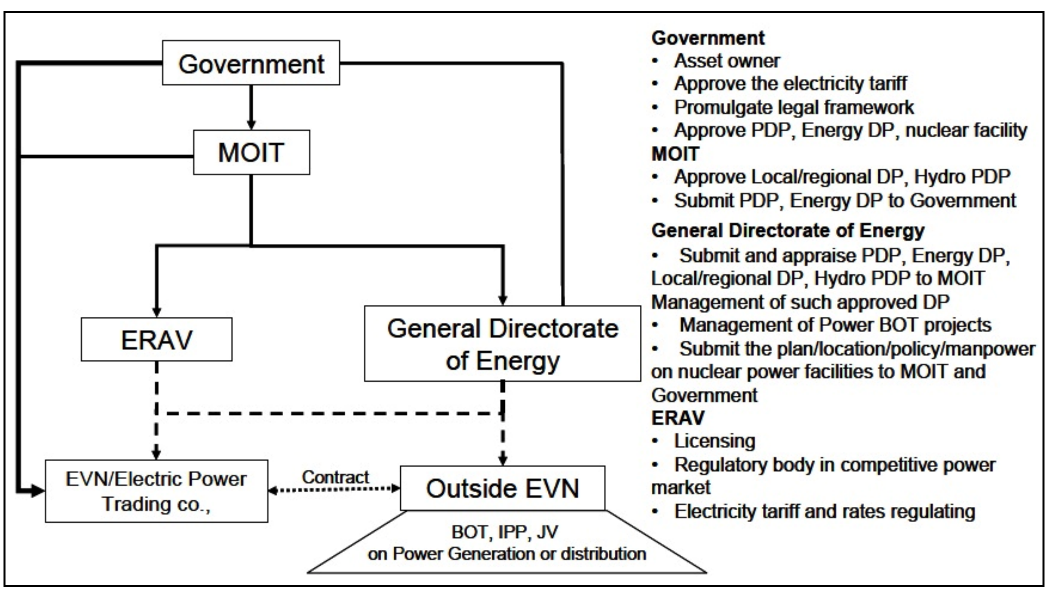
In general, the key organizations in Viet Nam's public power sector are GDE (General Directorate of Energy, under MoIT), ERAV (Electricity Regulatory Authority of Viet Nam) and EVN. GDE is responsible for overall energy planning and policy. ERAV is the country's regulatory agency, responsible for establishing and supervising the power market, power planning and development, tariff regulation, and licensing. EVN is the state-owned and, despite initial steps to liberalize the energy market, monopolistic utility provider, which is responsible for the whole chain of electricity production, transmission and distribution.

The Government

Within the Government structure, different line ministries related to the energy sector are assigned by law to formulate general energy sector policies (i.e. energy sector development strategies, the Master Plan for Power Development, the Master Plan for Oil and Gas Sector Development, policies on energy market regulation, etc.) and submit them to the Prime Minister's office for approval. So far, almost all important decisions or decrees related to the energy sector have been formulated by MoIT and then signed by the Prime Minister on behalf of the Government.[40]

The Government also has ownership over the SOEs. It Government authorizes the Prime Minister, line ministries, the Provincial People's Committees or the management board to execute ownership responsibilities. For large SOEs, such as EVN, the Prime Minister signs the decisions related to their establishment, operations and development strategies. The Government also play the role of energy investor, producer and distributor through its ownership of energy SOEs.

Figure 23. Main Government Institutions in the Vietnamese Power Sector



Source: Nguyen Anh Tuan/IoE (2012)

[40] For a more detailed analysis of Government structures and main policy processes in the energy sector, see CIEM (2013).

GDE/MoIT

The **General Directorate of Energy** (**GDE**) under MoIT is responsible for strategy and policy formulation regarding national development and planning for each of the country's energy sub-sectors and the formulation of legal documents within the energy industry. GDE monitors the implementation of such documents and provides guidance on handling violations of State management regulations in the energy industry. GDE instructs and inspects the implementation of legal mechanisms and policies after their approval. Lastly, GDE presides over the appraisal of investment projects within its authority and submits them to the Minister for approval.

GDE strives to ensure a rational economic structure in manufacturing, trading, investment, import and export, and business joint ventures and associations in the energy sector. Therefore, it implements industry strategies and development plans. Regarding the development of the electricity sector**,** GDE organizes the appraisal of the PDP and related sub-sector plans, such as hydropower plans for rivers, plans for small-sized hydropower projects and plans for new and renewable energies (IHR, 2012).

With regard to renewable energy development in Viet Nam GDE is the key Government institution, with a designated renewable energy unit: The **Science, Technology and Energy Conservation Department.** This department under **GDE** is responsible for energy efficiency, product and manufacturing standards, as well as technical and economical standards for electric power operation. This makes it relevant for solar power and solar thermal applications.

Other State Ministries and Departments

The **Ministry of Science and Technology (MoST)** appraises the draft Master Plan for Energy Sector Development prepared by MoIT before submitting it to the Government for approval. It furthermore coordinates the implementation of the Green Growth Strategy, including the measures on energy fiscal reform. It also formulates draft regulations on SOE management reform, including for the energy sector. Apart from that, MoST manages all the scientific and technological development strategies and efforts, and is also responsible for nuclear energy and nuclear safety issues.

The **Ministry of National Resources and Environment (MoNRE),** among other tasks, organizes the monitoring and assessment of the impacts of climate change on natural, human and socio-economic conditions. It coordinates with concerned ministries, branches and localities to initiate and submit appropriate response measures to competent authorities for approval, which also includes measures in the energy sector.

Other ministries also have responsibilities in energy-related fields, such as the **Ministry of Planning and Investment (MPI)** and the **Ministry of Finance (MoF)**.

EVN

Despite initial steps in energy market liberalization (see Chapter 2.3.2), **EVN** as the main SOE in the power sector still dominates the electricity market. EVN alone holds shares of 46% in the electricity generation market. In the wholesale market, it has a monopoly as a single-buyer through its subsidiary National Power Transmission Corporation, and distributes more than 90% of electricity in the retail market; the remainder is distributed by local utility providers (CIEM, 2013).

EVN is organized as a corporation with a series of wholly owned subsidiaries. EVN owns and operates all state-owned power plants built to date, and holds shares in a number of independent power plants (IPPs). Key subsidiaries include the seven regional Power Companies (PCs), which are in charge of power transmission and distribution from 110 kV downwards. Other key entities under the EVN umbrella include four Power Transmission Companies, four Power Engineering Consulting Companies, the National Load Dispatch Center, and a number of equipment manufacturing companies.

EVN's generation and network development plans, and all major investment projects must be approved by the Government. MoIT is currently responsible for executing bidding and contracting procedures for large IPPs. The retail electricity tariff is also tightly regulated by the Government, with adjustments recommended by MoIT requiring the approval of the Prime Minister. EVN is the single-buyer of electricity from power plants and holds a monopoly on electricity transmission and distribution (ibid.).

ERAV

ERAV is the national electricity regulator. It was established to regulate the power markets, including supervising electricity pricing; monitoring supply and demand balances to promote energy security, efficiency and conservation; overseeing licensing; and resolving disputes. However, it is managed by MoIT, who also manages EVN. Therefore, ERAV has not yet achieved fully functional independence.

3.2.2 Main Scientific Research and Training Organizations

A number of research and training institutions are relevant with regard to solar energy technologies and policy. Some of them are closely linked to Government institutions, sometimes even being integral branches. Others are more academic institutions, such as departments of major universities in Ha Noi, Da Nang and Ho Chi Minh City.

Institiute of Energy (IoE)

The **Institute of Energy (IoE)** was established in 1989 by the former Ministry of Energy (now MoIT) as a merger of the Energy and Electrification Institute and the Electric Power Research Institute (Dung, 2013). With almost 25 years of experience in energy research, the IoE is now the leading national research institution that provides scientific input into most of the national energy strategies. The institute has carried out research on a variety of technology and policy related issues, often as part of international cooperation projects.

In order to conduct technological research, the institute has its own laboratories, including a renewable energy laboratory with a testing site for wind and solar energy, and testing facilities for biogas and residential cooking applications.

With regard to energy policy related issues, the IoE is involved in the National Energy Strategy and planning processes in various sectors. It prepares and monitors the National Energy Development Master Plan, the PDP, rural electrification planning as well as other strategies on energy or energy efficiency for MoIT. It also prepares power development plans for territories, provinces, cities, industrial zones and residential areas throughout the country.

IoE has been involved in recent research and international cooperation projects on energy sector reform and renewable energies, such as the UNDP Fossil Fuel Fiscal Policy Reform project (see IoE, 2014 and 2015).

Viet Nam Academy of Science and Technology (VAST)

The **Viet Nam Academy of Science and Technology (VAST)**, a governmental agency, evolved from the previous Viet Nam Academy of Science, which was set up as early as 1975 by the Council of the Government (now the State Government).

VAST is one of Viet Nam's key scientific and technological agencies, playing a leading role in the national scientific and technological framework. It conducts basic research on natural sciences and comprehensive high-quality research on technological development. In 2008, the Government implemented new regulations on the functions, tasks, powers and organization of the Academy. Today, VAST's basic functions are to study the natural sciences and develop technologies based on the State's key objectives in order to provide a scientific basis for scientific and technological management; the development of policies, strategies and plans related to socio-economic development; and training qualified scientific and technological human resources for the country. VAST also hosts a number of scientific institutions relevant for the solar energy sector, most prominently the Solar Laboratory of the Institute of Physics, Solarlab.

Solarlab

Solarlab, the Solar Laboratory of the Institute of Physics in Ho Chi Minh City under the Vietnamese Academy of Science and Technology (VAST), is one of the leading technical solar research institutions in Viet Nam. Substantial research efforts on solar energy technologies date as far back as 1975, when solar PV became the focus of initial studies at the former Center of Physics under the Viet Nam Academy of Science in Ho Chi Minh City.[41] The first solar cell was made in 1976 out of monocrystalline silicon, measuring 5cm in diameter. In 20 years of research, different types of solar cells – such as thin film solar cells, mono- and polycrystalline silicon and amorphous silicon solar cells, were developed at Solarlab. In 2000, the first prototype solar module was developed to international quality standards (Dung, 2005).

Another one of Solarlab's technical fields of expertise is hybrid systems - solar PV combined with hydropower, diesel or grid-connected power sources. This research culminated in Solarlab's own Hybrid Technology of Renewable Energy Sources (Madicub). Solarlab has already begun exporting to neighboring countries. Its successor, the Madicub Intelligent Energy Power, is an integrated solar local grid managing system. This model is being developed further for rural electrification as a "mini solar power plant". Madicub is available

[41] A good overview of early solar research activities can be found in the publications of Solarlab and its former Director Trinh Qung Dung (see Dung, 2009 among others).

from 1 kVA to 10 kVA for systems with a variable power range between 500 Wp and 10 kWp (USAID/Winrock/SVN, 2014).

Institute for Hydropower and Renewable Energy (IHR)

The **Institute for Hydropower and Renewable energy (IHR)** is an independent scientific and technological research institute based in Ha Noi. IHR is acitve in scientific research, technology transfer, postgraduate educational training, international cooperation and consultancy. Its main focus lies on hydropower plants and other renewable energies. Solar energy is an additional research and development focus.

Renewable Energy Research Center (RERC)

The **Renewable Energy Research Centre (RERC)** of the Ha Noi University of Technology has its main research focus on solar thermal applications, as well as smale-scale hydropower, wind energy, energy supply in rural areas and renewable energy economics.

Renewable and New Energy Center (RNEC)

The **Renewable and New Energy Center** is another institute under the Viet Nam Academy of Science and Technology (VAST), focussing on research and technology development in different areas of renewable energy. Regarding solar energy, the institute has experience with on- and off-grid PV applications and the development of hybrid systems.

Other Relevant Research Institutions

Further relevant research institutions include the **University of Technology in HCMC** (focus on research and technical development of solar hot water systems); the **University of Technical Education in HCMC** (focus on solar thermal hot water systems) and the **Institute of Energy Science (IES)** under the Viet Nam Academy of Science and Technology (focus on solar energy as well as other renewables and off-grid technologies).

Furthermore, the **Ha Noi University of Science and Technology (HUST)**, the **HCMC University of Technology (HCMUT), the Danang Electrical University** and the **University of Science and Technology in Ha Noi (USTH)** have a more general focus on energy related engineering training as well as technological and managerial capacity building.

3.2.3 International Donor and Financing Organizations

A key stakeholder group within the renewable energy sector in Viet Nam is represented by international donor and financing organizations. This section gives a brief overview of relevant stakeholders in the sector. A more profound and detailed overview of the support provided by international development partners to the Vietnamese energy sector can be found in the ongoing mapping project of the Delegation of the European Union to Viet Nam.

The preliminary results of this energy sector review have been incorporated into this report and the following section in particular.[42]

ODA funding and technical assistance projects have made a substantial contribution to the development of the Vietnamese energy sector and especially to the improvement of access to energy for the rural population over the last years. The total budget allocated to the sector, including programs with newly planned projects up to the 2020s, amounts to EUR 5.2 billion (Nguyen, 2015).

Development cooperation efforts in the energy sector are characterized by multilateral or bilateral mechanisms with a long-term commitment and funding from international donors and development banks.

Most of these activities and development strategies are generally linked to important national development strategies, such as the Green Green Growth Strategy or the Power Development Plan. A major part of financial aid is directly disbursed to the energy sector, while other funds are directed as part of the context of climate change initiatives.

Although the majority of ODA funding in the energy sector is spent on selected large infrastructure investments - often including fossil fuel power generation in addition to electricity transmission and distribution networks, renewable energy and energy efficiency are now attracting more funding as some donors, such as Germany, are shifting their strategic focus towards renewable energies. This is generally in line with the Government's recent commitment to a more sustainable and greener economy.

Spanish Development Cooperation in the field of solar energy started in 2012 with the project **"Support to the development of solar energy in Viet Nam"**, based on Spain's experience in developing its own solar energy market. The project included a grant of EUR 1 million for GDE/MoIT to assess the potential for solar energy in Viet Nam (see CIEMAT et al., 2015) and provide insights into the necessary economic framework for decision-making through the completion of a Baseline Study and a financial feasibility study to evaluate power generation, storage, distribution costs and a potential feed-in-tariff.

Technical assistance is also being provided to GDE/MoIT. Furthermore, the Spanish Agency for International Development Cooperation (AECID) has also supported **two solar PV pilot projects**: 1) A solar PV system on top of the GDE building and 2) a PV-diesel hybrid system on Con Dao Island commissioned on 31 January 2015. The solar resource mapping of the Spanish research consortium in particular has provided a fundamental basis for the future development of solar energy in Viet Nam.

German Development Cooperation in the field of energy started in 2009 and has been the focal area of German DC in Viet Nam since 2013**.** The guiding strategic priority for German DC is to support Viet Nam in implementing its Green Growth Strategy and National Power Development Plan with a focus on **renewable energy and energy efficiency.** Currently**,** support is provided by two implementing agencies of the German Government: GIZ, focusing on technical cooperation (supporting the improvement of framework conditions and the regulatory environment, providing capacity development and technological cooperation) and

[42] See the Draft Final Report by Nguyen Nam Hoai to the EU Delegation to Vietnam from March 4th, 2015 (Nguyen 2015).

KfW, focussing on financial cooperation (financing investments, accompanying technical assistance).

KfW's total financial support to Viet Nam from 2012 to 2020 is estimated at EUR 362 million spread over the two major components renewable energy and energy efficiency. The first priority is to finance larger projects (such as grid rehabilitation, power generation, transmission, smart grid) in order to address short-term needs in the energy sector and enable large-scale effects. A second priority is to invest in smaller innovative pilot projects (e.g. renewable energy) that are important for the sector in the medium and long term.

GIZ has successfully provided technical assistance to MoIT on the promotion of support mechanisms for renewable energies, such as small hydropower plants (avoided cost, selling price, 2008), wind power (feed in tariff, 2011), and biomass and solid waste to energy (2014). A revised feed-in tariff scheme for wind energy was submitted to MoIT and the Government in 2014. In the upcoming period 2015–2020, GIZ is extending cooperation to energy efficiency as well as the grid integration of variable renewable energy sources (smart grid).

The upcoming **GIZ Renewable Energy and Energy Efficiency (4E) program**, commissioned by the German Ministry for Economic Cooperation and Development (BMZ), will have a technological focus on renewable energy, including solar energy and energy efficiency. The program aims to generate and shape the necessary legal and regulatory preconditions for investments in renewable energy and energy efficiency, and provide the required technical and economic foundation for political decision-making and priority-setting in Viet Nam.

UNDP's activities in the energy sector are located under the umbrella of its climate change program. UNDP is implementing projects in partnership with Government-embedded projects, ranging from technical assistance for studies and supporting policies on green growth and energy subsidies, to project implementation in the field of solar energy, NAMAs and energy efficiency in SMEs, such as the brick industry or construction. UNDP has also implemented projects on rural energy, but is now considering incorporating rural energy into the GEF-funded activities on renewable energy by providing energy for the poor. These projects are closely related to the policy framework of Sustainable Energy for All, GGS, PDP7, and the Energy Efficiency Law.

UNDP's Green Growth and Fossil Fuel Fiscal Policies Project (Phase III, 2014-2015) focuses on fiscal policy reform and reducing long-term investments in coal-fired power plants, as well as improving the efficiency of such plants. This also includes enhanced investments in and use of **solar PV** and other renewable energies (see IoE, 2014 and 2015). Further project concepts related to solar PV are being formulated and will attract funding from the GEF and the EU.

The United States Agency for International Development (USAID) is the coordinating development agency for US efforts in Viet Nam. USAID's Country Development Cooperation Strategy for the period 2014-2018 focuses on climate change, low emission energy systems and increased energy efficiency in the construction sector. USAID also supports the development of sustainable building materials and building standards. The Viet Nam Clean Energy Program is under Winrock's management (a development project implementer), who were also responsible for the study on off-grid opportunities and challenges in Viet Nam which also covered **solar PV in off-grid applications** (USAID/Wincrock/SVN, 2014).

A number of additional international development cooperation programs implement acitivities in the energy sector, with a more general focus on sustainable energy use and renewable sources rather than solar energy, such as the French Government (AFD) or the Dutch Government (SNV) (see Nguyen, 2015).

With regard to financing institutions, the **World Bank** implements various energy projects in Viet Nam. The main focus areas in the energy sector include promoting energy efficiency on the supply and the demand side, energy sector reform and the promotion of renewable energies, including **solar energy**.

In this context, the **Renewable Energy Resource Mapping** of the Energy Sector Management Assistance Program (ESMAP) aims to develop high-resolution maps and geospatial plans for wind, solar, biomass and small hydropower energy to promote the development of renewable energies and establish a one-stop-shop for public and private investors. With regard to solar energy, the World Bank has been cooperating with the Spanish solar mapping project.

The energy sector is also a priority area for the **Asian Development Bank (ADB)**. ADB's country partnership strategy for 2012–2015 for Viet Nam and related loan program focuses on reforms in order to meet energy demands by creating a reliable and environmentally sustainable supply; investments in energy efficiency and renewable energies; and the expansion of the power transmission network. Ongoing projects are currently financing generation, transmission, distribution and renewable energy (small hydropower) infrastructure, while technical assistance is being provided to build the capacities of power utilities and support the reform process.

The European Investment Bank (EIB) has prioritized activities in the energy sector, with a focus on the use of renewable energy sources and energy efficiency measures. This is a component under the Viet Nam Climate Change Global Loan that finances climate change mitigation projects. The loan fosters environmental sustainability and makes long-term financing available for investments that contribute to climate change mitigation through avoiding, reducing or sequestering greenhouse gas emissions.

As shown above, solar energy has not been a central focus of energy-related donor activities in the past, but it is starting to receive increasing attention with an emerging number of major ODA stakeholders in Viet Nam.

3.2.4 The „Solar Value Chain“ - Private Sector and Business Associations

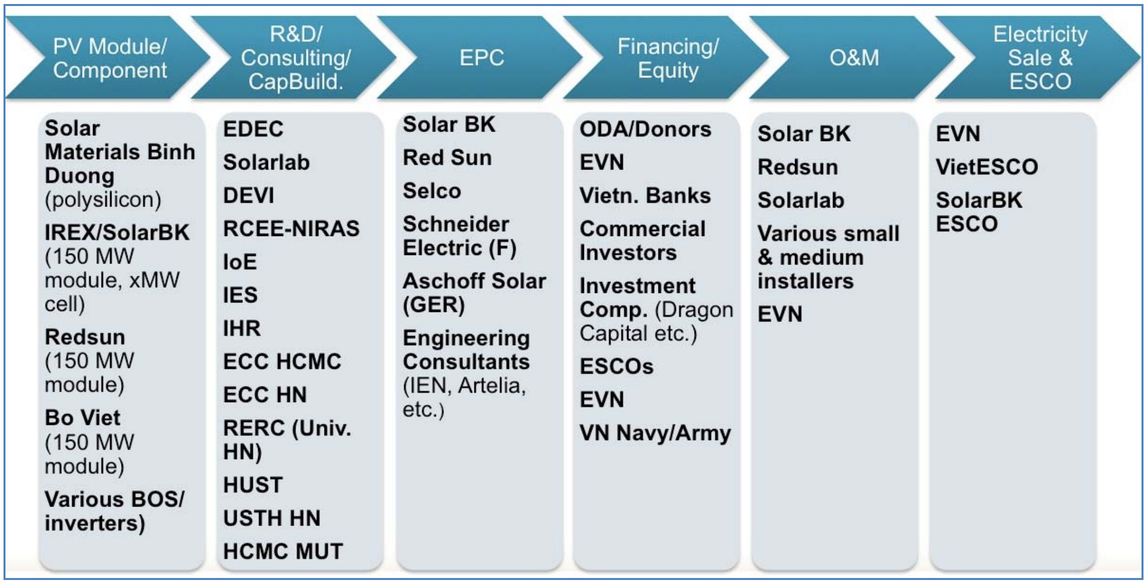
In Viet Nam, the domestic solar industry is still small and developing, but it already covers the most relevant parts of the value chain, from component manufacturing to the supply of solar electricity or hot water/heat to customers.

A few companies manufacture the key components of solar PV and solar thermal systems, i.e. solar cells, modules and inverters, or thermal collectors and water storage, respectively. Most of them are of domestic Vietnamese companies or spin-offs from national technical universities. In addition, there are a few manufacturers of balance-of-system (BOS) components, such as mounting systems, cables and pumps and other structural and electrical BOS. On the other end of the value chain, the first new solar business models are emerging, such as energy service companies (ESCOs) that sell solar kilowatt-hours or litres of solar heated water. Some of the key stakeholders in the solar value chain are active in both fields of solar energy, solar PV and solar thermal. This applies to stakeholders in manufacturing and engineering, procurement and construction (EPC), such as Solar BK, as well as consulting and research and development (R&D).

Interestingly, EVN as the dominant SOE power utility is also taking part in both solar PV and solar thermal activities, including ESCO partnerships with solar companies that promote the use of solar thermal systems to private households and commercial customers.

Figure 24. gives an overview of the key private and public sector stakeholders in Viet Nam's PV value chain.

Figure 24. Viet Nam's Solar PV Value Chain



Source: own compilation

Solar PV Component Manufacturing

A number of domestic manufacturers produce components, such as modules or inverters, for export to other solar markets. Foreign direct investment and international enterprises are active in the manufacturing sector, e.g. Chinese module manufacturing company Bo Viet, and in the EPC sector, e.g. German Aschoff Solar or French Schneider Electric.

Solar BK is one of the most prominent domestic solar companies in the PV value chain, from manufacturing to EPC and system leasing. The company is a spin-off of the HCMC Bach Khoa University and still has a strong R&D focus. Founded in 2006, it has installed more than 50 PV off-grid island systems and one of the few larger PV rooftop systems on top of the UN building. In 2012, the company founded the **IREX** module manufacturing plant in Vung Tau province (planned final capacity of 100 MW), producing fully internationally licenced PV modules of different sizes, mainly for export purposes. In 2015, it plans to build a PV cell manufacturing plant near the existing module production site.

Another domestic PV module manufacturer is **Redsun Energy Joint Stock Company.** The company was established in 2007 by two major shareholders: New Era Technology Co. Ltd Viet Nam and the Energy Conservation Center of Ho Chi Minh City (ECC HCMC). Redsun focuses on the development of solar PV modules from 25Wp to 175Wp, mostly for export markets (planned final capacity of 150 MW).

Other module or key component manufacturers include **Bo Viet Solar Technology**, Co. Ltd, a Chinese investment module manufacturer (planned final capacity of 150 MW) and **Viet Linh**, a producer of the AST-branded solar PV inverters which was established in 1986.

Regarding PV component manufacturing, a number of investments are planned but have been put on hold due to limited market demand, financing constraints and technological issues (USAID/Winrock/SVN, 2014).

One of these plans includes **Indochina Energy's** 120 MW/year module production factory in Chu Lai Economic Zone, Quang Nam Province, which commenced construction on 14 May 2011. **First Solar,** a US based thin-film module manufacturer and one of the largest EPC companies worldwide, recently postponed its plans for a thin-film module manufacturing plant in Ho Chi Minh City, with a planned investment of USD 300 million. Construction on another solar module production facility began in January 2013 in Phong Dien Industrial Zone, Thua-Thien Hue Province. **World Tech Transfer Investment** and **Global Sphere** planned total investments of USD 300 million.

Most recently, a number of new foreign investments in module production have been announced, such as the 20 MW module manufacturing site near Ha Noi, which hosts **US Spire Corporation** production facilities.[43]

Furthermore, a number of other domestic component and BOS-manufacturers are active in this field:

Solarlab is a prominent manufacturer of off-grid components with a strong R&D focus. It is also responsible for the construction of a number of PV on-grid systems in Ho Chi Minh City. **Vu Phong Cor. Ltd**, established in 2009, designs and supplies PV off-grid and on-grid systems under the trademark "SolarV". **Selco Viet Nam Co. Ltd,** established in 1997, is a subsidiary of SELCO-Inc., based in the USA, which is specialized in the design, assembly and installation of Solar Home Systems (SHS). Selco Viet Nam has installed around 100 PV off-grid systems in 30 national parks and natural conservation zones throughout the country as well as PV systems with a capacity of up to 1,000 Wp for more than 50 army border stations and islands. **Tan Viet Joint stock company,** established in 1997, provides equipment and services for solar power and other renewable energies. Tan Viet has implemented a number of solar power projects in disadvantaged and remote communes in Ca Mau, Quang Binh and Bac Lieu Provinces and subcontracted NAPS SYSTEMS to implement solar power solutions for 300 disandvantaged communities in mountainous areas as part of a Finnish-funded program.

Solar Thermal Component Manufacturing

There is also a small solar thermal domestic manufacturing sector, although most of the domestic hot water systems are imported from China.

Solar BK has a manufacturing line for flat-plate collectors, evacuated tube collectors and

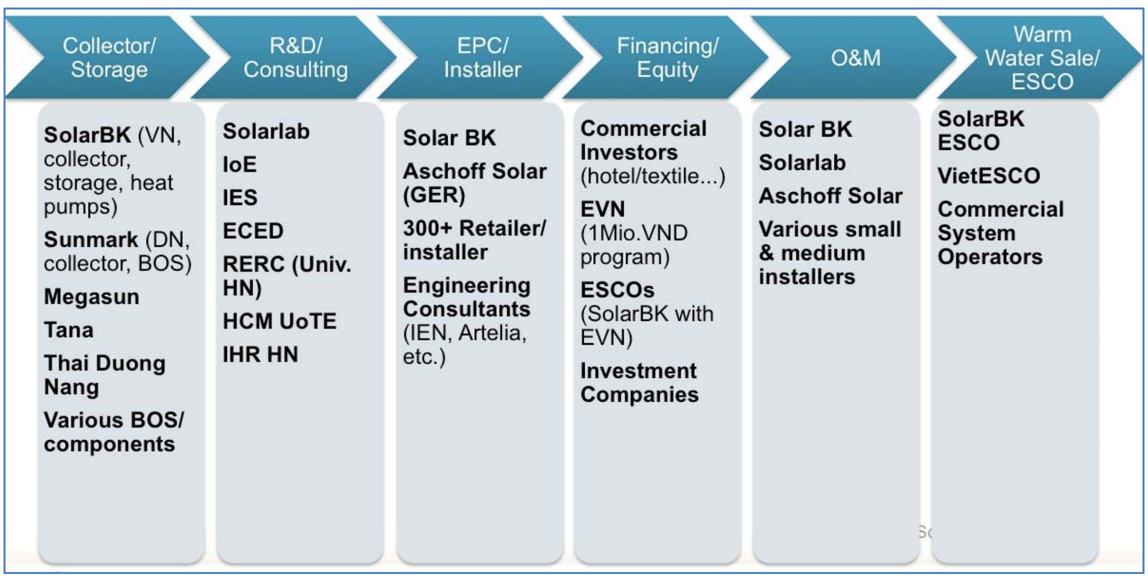
[43] See http://www.solarserver.com/solar-magazine/solar-news/current/2015/kw10/spire-supplies-20-mw-turnkey-pv-module-production-line-to-vietnam.html

solar thermal system technology, as well as heat pumps, in Ho Chi Minh City. With a strong R&D background, Solar BK has developed its own technological solutions, especially for large-scale applications with daily hot water demands of 10,000-20,000 liters and more. In addition to its manufacturing activities, Solar BK is also one of the biggest project developers for commercial solar thermal applications using ESCO business models.

Gia Nam Corporation in Dong Nai Province produces **MEGASUN** solar water heater components for different solar thermal applications, but generally focuses on large-scale commercial applications.

Viet Nam has also benefited from the first foreign direct investment by Danish solar thermal specialist **Sunmark** corporation.[44] Sunmark is a leading company in solar energy, both as a producer of solar thermal collectors and a provider of individual turnkey solutions. In 2003, Sunmark commenced production in Viet Nam and tripled its manufacturing capacity in 2009 with the launch of a new factory in Binh Duong Province, close to Ho Chi Minh City. Sunmark specializes in large-scale solar thermal applications.

Figure 25. The Solar Thermal Value Chain in Viet Nam



Source: own compilation

EPC, Installation and Distribution

With regard to project development, construction and distribution of **solar PV** systems, a small number of domestic and international EPC companies are active on the market. **Solar BK** and **Redsun**, both manufactures of PV modules, also have EPC 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.

[44] In early 2015, the company merged with Danish solar thermal specialist Arcon. It now operates as Arcon-Sunmark. See http://www.sunwindenergy.com/solar-thermal/arcon-sunmark-merge.

Aschoff Solar and **Schneider Electric** have both implemented PV rooftop systems, such as the system on top of the new National Assembly in Ha Noi (Aschoff Solar) or the commercial systems of Big C and XP Power (Schneider Electric). Schneider Electric's Corporate Sustainable Responsibility program focuses on small-scale rural off-grid solutions to enhance access to energy for disadvantaged and marginalized communities in Viet Nam.

The developed residential sector for domestic hot water heaters has resulted in the emergence of more than **300 retailers** for thermosyphon systems throughout the country. In addition to these rather small retail and O&M workshops, a few bigger retailers, such as **Tana**, **Hot King** or **Thai Duong Nang**, are operating on the market.

Aschoff Solar's representative TERRAMAR in Ho Chi Minh City and **Grammer Solar** from Germany have implemented three larger **industrial process heat** application projects in Viet Nam so far.[45]

Investors and Financing

In addition to the international donor organizations and development banks mentioned above (see Chapter 3.2.3), a number of private investment companies are focusing on green energy investments in Viet Nam.

Dragon Capital's Mekong Brahmaputra Clean Development Fund L.P. (MBCDF) was launched in July 2010 with a focus on on clean technology in the Mekong River region and the Brahmaputra River region.[46] The fund comprises USD 100 million in total, but aims to fund energy projects worth USD 1–5 million per investment. The expected IRR is >15%, with a timeline of 10 years maximum. The fund makes investments that meet the "Triple Bottom Line" principles of "People, Planet and Profit".

Indochina Capital Corporation (Indochina Capital, a Viet Nam-focused fund management group) launched the Mekong Renewable Resources Fund (MRRF) in June 2011.[47] The USD 50 million fund from the US Overseas Private Investment Corporation (OPIC) invests in renewable resources opportunities in the Lower Mekong region. MRRF focuses on environmental services and infrastructure investments, including waste-to-energy, recycling, solid waste management, sustainable forestry projects, wastewater treatment and clean water initiatives. Its renewable energy investments include wind, small-scale hydropower, biogas and biomass, and solar energy, while energy efficiency investments can entail renovations of existing power plants, agricultural processing and industrial facilities. The MRRF is current raising an additional USD 100 million from institutional investors.

Viet Nam is one of the target countries of the **Armstrong S.E. Asia Clean Energy Fund**, a USD 160 million private equity fund that invests in small-scale renewable energy (wind, solar, hydropower, biomass, waste-to-energy) and resource efficiency (clean water supply, waste management and recycling, energy efficiency) in Southeast Asia.[48]

Apart from these professional investment companies, a large number of potential

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[45] See: http://ship-plants.info/solar-thermal-plants?country=Viet+Nam

[46] See http://www.dragoncapital.com/dragon-capital-funds/mekong-brahmaputra-clean-development-fund-lp.

[47] See http://indochinacapital.com/infrastructure.

[48] See http://www.armstrongam.com/investment.php.

commercial investors from various **industrial and commercial sectors** are predestined to invest in solar energy applications. Investments have so far been made in the tourism, textile, and wholesale and retail sectors.

Solar Energy Sales and Services

Due to its dominant position within the power and energy sector, **EVN** is a key stakeholder at the downstream end of the solar value chain, especially regarding solar PV. As a single-buyer of electricity, the utility is involved in many off-grid projects, in particular on islands, where it functions as energy investor and off-taker.

The emergence of **energy service companies (ESCOs)** and corresponding business models, such as leasing of systems or solar energy supply with power purchase agreements (PPAs), is a remarkable development. ESCOs, such as **SolarESCO** (a branch of Solar BK) or **VietESCO,** have started to successfully deploy commercial solar water heater systems via leasing contracts in the hotel sector in Ho Chi Minh City, Da Nang and Ha Noi, partly with additional investments from EVN. These ESCO models can potentially overcome some of the main barriers to investments in solar energy, i.e. high upfront investment costs in a difficult financing environment and a lack of knowledge on this rather new technology in Viet Nam (see the following section). As interviews with investment companies and private sector stakeholders showed, a number of initiatives and ESCO projects aimed at commercial investors in solar PV are currently being developed.

Business Associations

Stakeholders' interests and concerns regarding energy issues in general and renewable or solar energy in particular are often addressed through business associations and chambers of commerce, of which most private enterprises are members. Among these, the **European Chamber of Commerce (EuroCham)** with its Green Growth Sector Committee has addressed renewable energy issues in particular, suggesting the promotion of policies for solar energy, such as tax credits for solar PV or solar thermal investments (see EuroCham, 2014).

Furthermore, the **International Copper Association Southeast Asia (ICA-SEA)** has recently addressed solar energy issues in Viet Nam. In a cooperation project with EVN and other stakeholders, ICA-SEA proposed a standardized interconnection code for solar PV systems and a net-metering scheme to foster investments in distributed solar PV applications.[49]

Domestic business and energy sector associations, including the **Vietnamese Energy Association (VEA),** focus on energy fiscal reforms, energy policies and measures on energy sector development and the development of energy sector strategies, such as the PDP. Other energy-related domestic associations include the **Viet Nam Electricity and Energy Association (VEEA)**.

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[49] See ICA-SEA (2015). National Interconnection Standards and Net-metering for Rooftop Solar PV in Vietnam. Consultation Workshop Report, 7 January 2015.

In addition, a number of associations are related to different energy consumer groups in Viet Nam such as the **Viet Nam Chamber of Commerce and Industry (VCCI)** or the **Viet Nam Textile Association (VITAS).**

Project and Business Consulting

Apart from the research and training institutions with a broader focus on renewable energy and solar energy applications in particular (see Section 3.2.2), a number of specialized consultancies focus on technical development, project development or business development.

DEVI Renewable Energy, founded in 2011, is one of the youngest organizations involved in the renewable energy market in Viet Nam, aiming to contribute to research, education, training and the commercialization of energy products produced in Viet Nam. DEVI is specialized in solar PV and solar thermal energy, as well as related policy issues. It focuses on training and advising entrepreneurs, researchers and teachers, as well as university students.

The **Energy Development Center (ECED)** was established in 2011 by Mrs Duong Thi Thanh Luong, a former teacher at the HCMC University of Technology and a pioneer in wind and solar thermal energy in Viet Nam. EDEC's mission is to raise awareness amongst Viet Nam's population and Government on renewable energy issues. ECED works on the technological development of solar water heater applications in close cooperation with domestic manufacturers, as well as on renewable energy sources for rural electrification, including solar PV, wind turbines and hybrid systems.

The **New Energy Research Center** was established in 1986 by the Ministry of Education and Training. The center operates under the Ha Noi University of Science and Technology and focuses on new and renewable energies, such as solar energy, wind energy, applications for rural electrification and hydropower. Its work is based on renewable technology research and training.

In addition to these institutions, a variety of **national and international consultancies** with a track record in project- or business-related advisory services are active in Viet Nam's solar energy sector. These include the **Viet Nam Energy and Environment Consultancy JSC (VEEC)**, the **New Energy and Environmental Engineering Center** at Can Tho University, the Danish-Vietnamese **RCEE-NIRAS JSC, Artelia Group**, **IEN Consultants** and **Futuretech,** as well as sector-specific consultancies, such as **HTM-Tourism,** and specialized law-firms, such as **Duane Morris Viet Nam LLM**.

The **Energy Conservation Centers (ECC)** in some of the larger provinces and cities play a substantial role in the provision of advisory services, including the **Energy Conservation Center in Ho Chi Minh City (ECC HCMC)**, which operates under the public Department of Science and Technology in Ho Chi Minh City or the **Energy Conservation Center in Ha Noi (ECC HN)**. These centers conduct hundreds of energy audits of the industry and commerce sectors every year and advise the private sector as well as public sector stakeholders on energy efficiency and renewable energy issues.

4. Potential Market Segments and Main Solar Energy Applications

This chapter examines the different market segments and applications of solar energy according to their respective potentials on the one hand and the existing market or regulatory framework conditions on the other hand. Furthermore, there is a brief examination of international experience and best practices for each market segment, which provides an outlook for the further development of these market segments. This analysis builds up on the general findings of the current utilization of solar energy in Viet Nam, the potential benefits and the regulatory framework conditions, as well as the stakeholder landscape analyzed in the previous chapters.

Chapter 5 then assesses the different segments and prospects in a comparative approach and draws conclusions for further in-depth analysis and the development of solar energy in Viet Nam in general (see also Annex II summarizing this comparative assessment).

4.1 Solar Thermal Residential/Commercial Hot Water

4.1.1 Status Quo

As already discussed in Chapter 2.2.2, the market for solar domestic water heater systems is the most mature and developed solar sector in Viet Nam and is thus considered in a “take off stage”. It features the following **key characteristics**:

- **The main application** is the **domestic hot water supply for residential housing** using small thermosyphon systems.
- A **growing number** of larger **systems for commercial domestic hot water** applications are in operation, for instance on the top of hotels, apartment complexes, tourist resorts or office buildings. They are often combined with heat pumps to cover the entire hot water demand of the respective buildings.
- Reportedly, **around 30,000 to 40,000 solar domestic hot water systems** were installed **annually** in Ho Chi Minh City alone in recent years. In total, the author assumes that by the end of 2014 there **more than 100,000 systems were installed nationwide**.[50]
- A **viable business model** (power savings for residential hot water demand) drives investments without substantial subsidies.
- The market builds upon a **fairly developed domestic industry** that includes the manufacturing of key components as well as the distribution and O&M of the systems. Most domestic manufacturing is Vietnamese-owned, except a few foreign direct investment projects, such as the Danish Sunmark manufacturing.

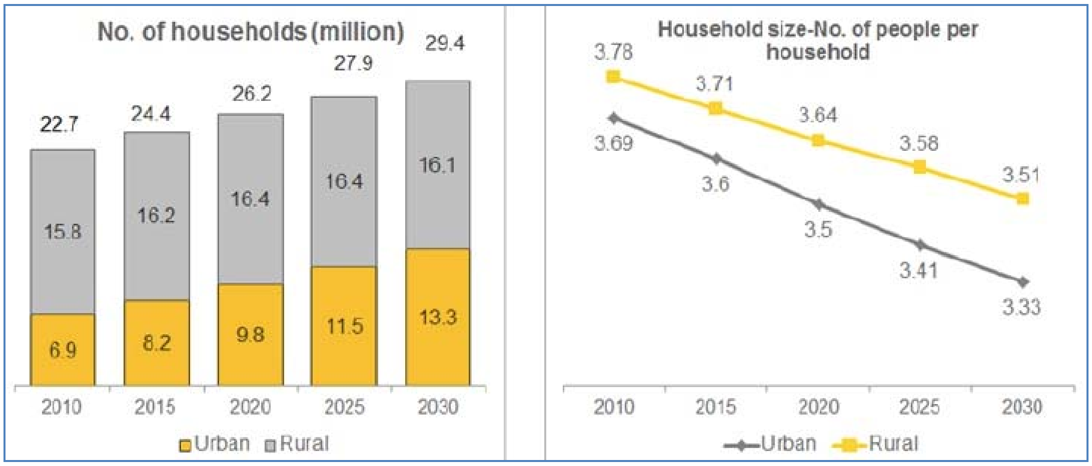
4.1.2 Energy Market and Industry Potentials

There is only limited data available on housing or building types and the respective hot water demand in the residential and commercial sector, which makes it difficult to estimate the

[50] See footnote 14.

exact market potentials and possible contributions of solar heat to the overall heat demands. The ADB estimates that there are around 24 million households in Viet Nam, with 16 million located in rural areas and 8 million in urban areas, with an average household size of 3.7 and 3.6 persons, respectively.

Figure 26. Number of Households (in mio.) and Household Size (Person p. Household) in Viet Nam



Source: World Bank-ESMAP (2015), based on ADB estimates

In some emerging markets in Asia and other regions of the world, solar thermal hot water applications already contribute substantially to energy savings and CO_2 emission reductions in the heat sector. In this international comparison, Viet Nam is still a small but emerging solar thermal market with estimated annual (fossil) energy savings of 37,000 tons (oil equivalent) and an annual CO_2 reduction of 120,000 tons (see Table 3).

Table 3: Overview of installed Capacity, Energy Savings and CO_2-Reductions of Solar Thermal Installations in Viet Nam (late 2014) and Selected Countries (late 2012)

	Total capacity (MW_{th})	Total annual yield (GWh_{th})	Number of systems	Energy savings (t_{oe}/a)	CO_2 reduction (t_{oe}/a)
China	180,390	149,837	58,742,715	16,104,526	52,061,101
Germany	11,788	6,939	1,841,364	745,807	2,410,971
Brazil	5,783	5,785	1,329,864	621,816	2,010,145
India	4,516	5,423	1,224,561	582,826	1,884,103
S. Korea	1,179	854	242,952	91,753	296,611
Taiwan	1,004	880	293,158	94,586	305,769
Thailand	84	103	30,090	11,043	35,697
Viet Nam*	**285**	**342**	**100,000**	**37,000**	**121,000**

Source: IEA-SHP (2014) and author's own calculations

** All figures are estimates based on the assumed number of domestic hot water systems installed in Viet Nam by the end of 2014. They are calculated on the basis of key technical parameters that were applied to Thailand, assuming that conditions in both countries are generally comparable.*[51]

The overall prospects for solar thermal hot water and heat applications are generally very promising. The IEA roadmap for solar thermal energy predicts that solar thermal collectors for hot water and space heating in buildings could reach an installed capacity of nearly 3,500,000 MW_{th} worldwide, satisfying around 8.9 Exajoule of the annual demand for hot water and space heating in the building sector by 2050. Solar hot water and space heating would then account for 14% of space and water heating energy use in buildings (IEA-SHP, 2014). In line with projections, solar hot water and space heating in buildings will increase by 7.1% annually between 2010 and 2050 on average, while the total energy used for water and space heating will only increase by 1.3% (or 0.8 EJ). By 2050, solar hot water will account for 25% of water heating energy use, while 7% of the energy used for space heating will be solar. The greatest potential for solar heat in buildings will thus consist of solar domestic hot water heating, where the potential for 2050 is almost 2.5 times higher than the solar space heating potential (ibid.).

In Viet Nam, solar thermal has the potential to become a strong pillar in supplying sustainable energy to the heat sector in coming years. Considering that the market development so far was possible without substantial subsidies and additional financial support, it can be assumed that scaling up investments is manageable and will not require strong financial support measures to close the competitiveness gap.

Possible benefits of a developed solar thermal domestic hot water market for Viet Nam would be:

- Due to the generally high level of irradiation throughout most parts of the country and the possibility of comparably inexpensive thermal storage, solar hot water applications have the potential to make **high contributions to daily and annual hot water demands** in private households, office buildings and a number of commercial sectors, such as hotels.
- With these potential contributions to meeting the hot water demand, this segment has a **high overall potential** to increase the **renewable energy supply** and reduce GHG-emissions and fossil fuel import dependencies.
- In addition, solar domestic hot water could substantially **reduce peak power network demands** that usually occur at times of high solar production. The fact that there has been a public grant program for private investments in solar thermal hot water systems (see the following section) shows the important link between the solar hot water segment and the power system: Peak loads can be reduced by using solar energy instead of electricity.
- Regarding **industry effects,** the further expansion of the solar hot water market will bring job and **industry opportunities for manufacturing** key components of solar thermal systems, either in domestic enterprises or in form of further foreign direct investments,

[51] The following parameters taken from IEA-SHP (2014) have been used for calculating the Vietnam figures: average system size (for residential domestic hot water systems: $4m^2$ per system), annual yield per m^2 (854 kWh/m^2) and per MW_{th} installed (1.2 GWh_{th}/MW_{th}), energy savings (130 t_{oe}/MW_{th}) and CO^2 reduction (425t/MW_{th}).

since a growing domestic market will attract close-to-the-market manufacturing. The Sunmark investment for example is a promising sign of this future trend. This potential will be limited however, since neighboring China has large manufacturing capacities and is currently the region's leading component and system exporter. An even **bigger industry potential** can be expected for **installation, O&M** and **energy serving businesses (ESCO),** since these value chain links and business models are already implemented by various enterprises throghout the country.

4.1.3 Framework Conditions and Existing Restrictions

In general, the regulatory framework conditions for solar thermal applications in Viet Nam are good, since there are no basic restrictions or barriers to investments and installations. Although there have been some Government efforts to promote solar thermal energy in Viet Nam, this does not seem to be embedded in an overall heat energy sector strategy with distinctive targets for RE heat development or solar thermal energy in particular. Solar heat is also not included in the national Energy Efficiency Strategy and related programs.

However, the general analysis of the regulatory framework has not identified any substantial barriers and restrictions for the further market development. Measures taken in the past to promote solar thermal energy include: To promote the use of solar water heating as part of the National Target Program on Energy Saving and Energy Efficiency, EVN designed a program on solar water heating systems in 2009. The program promoted research, production and imports of solar water heating equipment for use in households and other service sectors such as commercial centers, hospitals, schools and governmental offices. The households who participated in the program received a subsidy of VND 1 million. During the first two years of the program, EVN built 900 pilot water heating systems using solar energy. The program was continued with a plan to build an additional 1,000 water heating systems.[52]

The domestic solar thermal industry is small but developing well, with a limited component manufacturing sector and a stronger focus on distribution, installation/EPC (especially for smaller residential applications) and O&M. For larger applications, the existing EPC capacities are still limited (see Chapter 3.2.4 for a more detailed view on the domestic solar thermal value chain).

To **summarize the framework conditions** for solar thermal hot water applications:

- **No political target** or overall **energy strategy** on renewable hot water and heat sources has been defined.
- **No substantial subsidies** have been introduced so far, except a VND 1 million per system grant program for solar water heater systems for different applications.
- **No substantial market or regulatory barriers** have been identified that could restrict or hamper further market development.
- There is a **small but developing domestic industry** (installation, EPC, O&M).

[52] See http://www.renewableenergy.org.vn/index.php?page=solar-energy. More recent figures on this program are not available.

4.1.4 Lessons from International Experience

Renewable heat policies for end use sectors (mainly construction and industry) often have more in common with energy efficiency policies than with renewable energy. In fact, in many countries, renewable heat policies are seen as “competing” with energy efficiency policies (and related public budgets). A closer look at best practices shows quite the opposite: effective renewable heat policies are thoroughly integrated into energy efficiency strategies and synchronized with respective energy efficiency instruments. As a matter of fact, most renewable heat technologies are more cost effective if they are combined with energy saving measures in buildings or industrial processes.

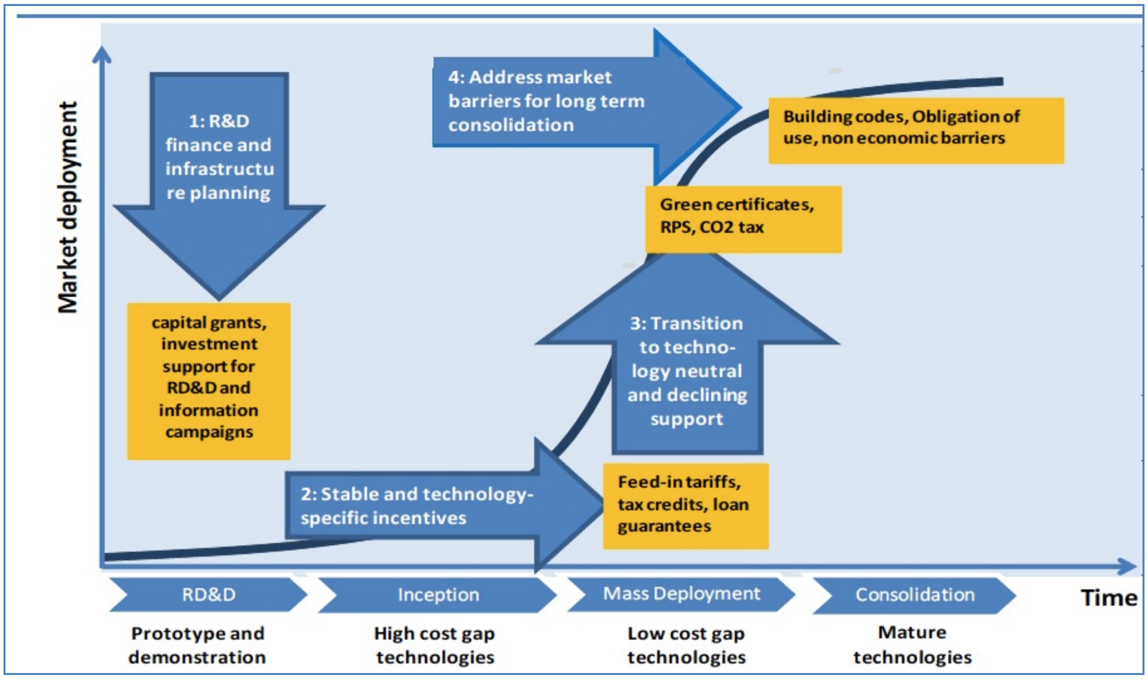
Revisiting the market development phases and related best practice policy measures, it becomes clear that Viet Nam’s domestic hot water market is currently transitioning from the inception to the take off stage. At this point, it is important to provide stable and technology-specific incentives, such as investment grants and tax incentives. Additionally, these measures need to go hand in hand with technology-neutral measures, such as energy efficiency standards, carbon taxing or the removal of non-economic barriers to investments.

As the technologies mature, the building codes and solar regulations will come into focus. The challenge in this phase will be to develop policies that secure predictable and reliable investment conditions for a variety of investors. In particular, a “stop-and-go” investment climate due to changing and unpredictable state budget subsidies should be avoided. Furthermore, market growth needs to be maintained, whilst at the same time keeping the overall policy costs manageable.

Furthermore, capacity building and technical training for “gatekeepers”, such as installers and architects, as well as support for efficient market infrastructures in manufacturing and other parts of the supply chain are important during the take off stage.

Figure 27. gives an overview of the best practice support measures and policy instruments during the main phases of the market deployment of solar thermal applications.

Figure 27. Best Practice: Policy Instruments for Renewable Heat Over Time and Market Development Phases



Source: IEA (2012)

Bests practice also shows that in addition to specific investment incentives, financing issues have to be addressed, especially in the construction sector, as well as the "split-incentive" problem in the construction and industrial sector.[53]

Eventually, during the consolidation phase, renewable heat technologies will face fewer challenges than other renewable energy sectors, such as renewable electricity. The visual environmental impact of solar thermal technologies is low, and the localized production and demand for heat encourages public acceptance. Moreover, renewable heat creates fewer integration challenges for the large-scale deployment than renewable electricity (IEA, 2012).

In **South Africa**, where there is almost no demand for space heating – just like in Viet Nam, the domestic hot water demand is increasingly leading to peaks in the electricity demand. To avoid power shortages at peak hours due to the overwhelming reliance on electrical water heaters (4.2 million in 2010), the South African Government launched the Solar Water Heating Program in 2008, which aimed to install 1 million solar heaters by 2013. The Solar Water Heating Program is a rebate program for solar water heater purchasers supported by the national power utility ESKOM and funded by a tariff levied on consumer electricity bills fixed by NERSA (National Energy Regulator of South Africa). By mid-2014, the program initiated more than 400,000 investments in solar hot water systems. In the first three years of implementation, the number of system suppliers increased from a mere 20 companies to more than 400. After analyzing the program and identifying lessons learned, the South

[53] The "split-incentive" problem or "investor-tenant-dilemma" refers to the fact that it is usually building owners who pay for retrofits and efficiency or renewable energy investments, but they cannot recover the savings from reduced energy use that the tenant accrues. This creates problems for encouraging energy efficiency and RE investments. Different policy measures exist to address this problem (see e.g. EC-JRC, 2014).

African Department of Energy took over the responsibility from ESKOM in early 2015 and relaunched the program to strengthen market development and investments.[54]

The **Tunisian** PROSOL program has been particularly successful in encouraging the solar water heater market through a combination of policies and private sector involvement from the early stages onwards.[55] The evolution of the solar thermal support framework since 1985 demonstrates the importance of an integrated policy approach. The Tunisian solar water heater program was primarily based on VAT exemptions for producers and a state monopoly on installation activities. The main policy instruments and features of the program where:

- A loan mechanism that enabled domestic customers to purchase solar water heater systems and repay them through their electricity bills (discounted interest rates on loans were progressively phased out).
- A Government capital cost subsidy of up to 100 Dinars (EUR 57)/m^2.
- By identifying new lending opportunities, banks started to develop dedicated loan portfolios, helping to shift the solar water heater market from a cash-based to a credit-based market.
- The program included other important measures, such as supply promotion, system quality control, an awareness-raising campaign and a capacity building program.

Germany is a good example of a mix of different policy instruments. In 2000, the Government introduced investment grants for solar thermal applications (per m^2 installed collector area), funded by an annually approved and adjusted State budget fund (Market Incentive Program Renewable Energy, MAP).[56] For larger applications (>40m^2), it provided soft loans from the German development bank KfW. The program was continuously developed and now it includes a variety of different renewable heat technologies and applications, such as solar thermal systems for domestic hot water and space heating, as well as process heat and cooling. From the very beginning, despite its overall success in fostering investments in solar thermal hot water and space heating systems (currently there are more than 2,000,000 ST systems in operation), the German program suffered from a "stop-and-go" market development landscape due to annually changing and unstable State budgets. Very recently, the program was widened to an optional heat generation-related incentive (per kWh_{th}) instead of the capacity-related (per m^2 installed) investment incentive with the aim to foster system quality. Due to the "stop-and-go" issue, many political and business stakeholders demanded a change in funding from the State budget to a fund based on small levies on fossil fuel consumption.

During the 1980's and early 1990's the German Government successfully introduced an accelerated tax depreciation for solar thermal installations that attracted investments in this market segment. Currently, this instrument is in the political focus again and supposed to be introduced for all renewable heating technologies until 2017.

In 2008, Germany, as one of the first countries in Europe after Spain, then implemented a

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[54] For an overview, see the South African Alternative Energy Association: http://www.saaea.org/news/category/solar%20water%20heating%20swh6206859afc.

[55] For an overview, see IEA (2012).

[56] For an overview of the current MAP regulation, see: http://www.res-legal.eu/search-by-country/germany/tools-list/c/germany/s/res-hc/t/promotion/sum/136/lpid/135/.

renewable heat obligation for new buildings, introducing the German Act on the Promotion of Renewable Energies in the Heat Sector. In 2011, the obligation was extended to all existing public buildings used for legislative or executive purposes. It is currently under discussion whether to expand the obligation to use renewable heat sources to all major renovations on existing buildings. This public procurement program is meant to pave the way for the obligation to become a standard for all of Germany's buildings.[57]

Both instruments, the investment grant and the building obligation, were accompanied by a soft loan program for investments in building efficiency.

Pricing policies are still rare in the heating sector. While many electricity feed-in tariffs (FIT) include a premium for combined heat and power to remunerate useful heat output, only a few countries have tariff policies dedicated to renewable heat generation. The **United Kingdom** for example has a FIT for renewable heat. Launched in March 2011, the Renewable Heat Incentive (RHI) seeks to increase the share of renewable heat from 1% to 12% by 2020, including private and commercial applications.[58]

To **summarize the international experience** that can be applied to Vietnamese framework conditions:

- In the early take off stage, a mix of **stable and reliable investment incentives** (investment grants, soft loans, tax credits) embedded into an **overall energy efficiency and decarbonization strategy** can attract investments from private and commercial customers. As soon as the market has developed further, **solar building obligations** can be considered.
- **R&D programs, financial support (corporate financing)** and **capacity building for the domestic industry** (manufacturing, EPC, O&M) help set up infrastructure, improve product and system quality, and reduce overall system costs.
- **Public awareness-raising** helps educate customers and investors, and raise the technology's attractiveness**. Pilot and demonstration projects** can increase awareness of and confidence in the technology (larger commercial applications).
- **Quality control** should be addressed from the very beginning.

4.2 Solar Thermal Industrial Heat and Cooling

4.2.1 Status Quo

In addition to the dominating domestic hot water segment, there is a very small but growing market for larger solar thermal industrial heat applications for a variety of production or manufacturing processes up to 120°C heat demand (see Chapter 3.2.3 for a more detailed examination of solar thermal industrial applications). Three large systems on collector areas

[57] For a comprehensive discussion of best practice in solar obligations policies, see ESTIF (2007).
[58] For an overview of the initial program setting, see: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48237/1393-rhi-faqs.pdf.

of up to 1,000 m^2 have already been realized in the Vietnamese textile and leather industry.[59] These investments were made without any additional subsidies.

So far, Viet Nam has not received any investments in solar thermal cooling systems for commercial or industrial applications.

To summarize the **key features of this market segment** in Viet Nam:

- The market is in its early **"inception stage"**.
- Only a **few systems** are in operation (process heat only, no solar cooling project so far).
- Investments have been made by **first mover** private enterprises based on a viable **business model** (energy savings, ROI 3-5years) and no substantial subsidies.
- **Industry capacities** (EPC, system integrators) are **very limited.** All systems have been implemented by international solar companies.

4.2.2 Energy Market and Industry Potentials

Although the long-term potentials for solar thermal industrial heat are very promising at the global and regional level (IRENA estimates that 2-20% of the additional industrial heat plants built between 2010 and 2030 worldwide will be solar thermal), the short- and medium-term perspective for Viet Nam is a slowly developing niche market (see Chapter 3.1.3).

However, a number of domestic industrial sectors use a significant proportion of their process heat at temperatures <120°C and are therefore likely to have a potential use for solar thermal energy to meet their process heat needs (textile, mining, food and beverage, paper etc.). In these sectors and processes, solar thermal generated process heat, in combination with other energy efficiency measures, could contribute to substantial energy savings (two systems in operation in the textile industry allow for annual savings of 50,000-120,000 liters of fuel oil).

Solar process heat applications appear to be particularly attractive for small- and medium-size enterprises (SMEs). Firstly, SMEs often rely on expensive fossil fuels for heat production. Solar thermal systems could reduce their dependence on fossil fuels and contribute to the reduction of operating costs. Secondly, the heat demands per plant are relatively small compared to energy-intensive industries, which makes the integration of solar heating systems easier. Thirdly, the large number of SMEs could result in declining costs due to learning-by-doing and more effective installations (IEA-ETSAP/IRENA, 2015).

However, in absence of aggregated data on the size and growth perspectives of the respective sectors, it is difficult to estimate precise potentials for solar thermal industrial heat in Viet Nam. It seems that these potentials will be limited in the short term, but improve in the medium and long term.

With regard to solar thermal cooling, the situation is comparable to solar industrial heat. IEA projects that solar thermal energy could account for 17% of the global cooling energy use by

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[59] One air collector system (480m^2) in Central Viet Nam, installed by Grammer Solar in 2012; one ETC system (1,000m^2) at a tannery in HCMC, installed by Aschoff Solar in 2009; and another ETC system (420m^2) at a textile manufacturing site in HCMC, installed by Aschoff Solar in 2012. See: http://ship-plants.info/solar-thermal-plants?country=Viet+Nam.

2050, corresponding to a cooling capacity of 1,000 GW_{th}. In China and other emerging Asian markets, solar energy could account for around 30% of total cooling energy needs by 2050 (IEA, 2012). However, this technology has only left the R&D phase and entered into the early inception stage with only 1,000 systems in operation worldwide. This solar market segment is a short- and medium-term niche market compared to the far more mature domestic hot water applications. It is even less promising than solar process heat applications due to the higher system costs.

To summarize the **market potentials and possible benefits** for the Vietnamese energy system:

- There is a rather **limited potential** in the **short term** and a **medium potential** in the **medium and long term** for increasing the **renewable energy** supply in the heat sector and reducing GHG emissions and fossil fuel import dependencies.
- However, due to their **cost competitiveness** (3-5-year ROI), these applications could be an attractive means to realize **substantial energy savings** through renewable heat. This potential **could be achieved** through **"low-cost" support measures**, mainly capacity building and awareness-raising.
- There is a **limited potential for industry development** in the manufacturing and EPC sector due to the technology being highly specialized and market leaders being located outside of Viet Nam.

4.2.3 Framework Conditions and Existing Restrictions

In general, there are no specific regulations or support measures regarding solar process heat. Renewable heat for industrial processes is not part of the overall energy or energy efficiency strategy. Thus, there are neither specific subsidies nor regulatory restrictions for investments or system installations.

All solar process heat systems involve high initial investments in advance of a practically cost-free harvesting period. However, proper maintenance is required to ensure that the systems operate optimally throughout their full lifetime expectancy. The up-front costs hamper deployment in small- and medium-size enterprises, where financing is not available. The ESCO business models that are implemented in commercial domestic hot water applications, e.g. in the Vietnamese hotel sector, show that this type of business model could also be applied in industry in the future.

Interviews with the companies that have already implemented solar process heat systems in the textile industry reveal that, despite solar heat's cost competitiveness with other sources of heat generation, the ROI of these investments is still not attractive enough for many potential investors, i.e. the 3-5-year ROI is still too long. A strong competitor for solar process heat applications is found in the Mekong delta, where customers can source steam from nearby domestic suppliers, paying around USD 12-16/ton.

In addition, the industrial sector is also facing a "split-incentive" problem: In many cases, manufacturing companies rent their production space or factory building, thus making it difficult to gain ownership of the solar systems. To implement a viable business model mean including the facility owner as a third party, making investments more complex and difficult.

Apart from these economic issues, it appears that decision-makers in industry, politics and administration lack awareness and information on the practical and economic advantages, which is a key barrier to the technology's wider adoption and acceptance. Consequently, businesses often prefer conventional systems that are more familiar. This also seems to apply to the public consulting institutions and Energy Conservation Centers in many Vietnamese provinces. Their focus has only recently shifted towards solar energy for domestic hot water applications, such as in tourism.[60]

Regarding the domestic solar industry and R&D landscape, only a few professional organizations and research institutes have adequate experience in solar industrial heat technologies. The need for capacity building and the dissemination of existing experience and concepts is evident.

To **summarize the framework conditions** for solar thermal industrial heat and cooling applications in Viet Nam:

- **No political target** or overall **energy strategy** for RE heat in the industry sector has been defined.
- Solar thermal heat or cooling applications for the industry sector are **not included** in efforts and **strategies on increasing energy efficiency**.
- **No** substantial **subsidies or support measures have been implemented so far**.
- **No substantial market or regulatory barriers** have been identified that could restrict or hamper the further market development.
- **Awareness** and knowledge of the technology, its potentials and benefits is low (even more so for solar thermal cooling). Domestic industry capacities (EPC, system design, O&M and business models) are generally very limited.
- **The lack of financing options** and **high upfront costs** are a barrier to investment.
- **In addition, ambitious ROI expectations** (<3yr) often make investments in solar process heat unattractive.

4.2.4 Lessons from International Experience

Despite its technical potential, as well as the potential economic and environmental benefits of using solar heat and cooling in industry, the actual international deployment levels remain quite low. This is also reflected in international policy. Almost no specific policies on the promotion of renewable process heat in general or solar heat in particular have been implemented so far.

In 2013, **India** was the leading market for solar process heat applications, with 61% of its solar thermal capacity used for industrial process heat (including community cooking). As the largest milk producer in the world, India's dairy sector is also one of the most attractive application areas, where up to 13% of process heat is supplied by solar thermal energy. An important driver for the deployment of solar thermal systems in India is the capital subsidy (of

[60] One example is the ECC Ho Chi Minh City with its affiliation VietESCO. Another example for a fully private enterprise is Solar BK with its subsidiary SolarESCO.

up to 60%) provided by the Indian Government and a UNDP-GEF project (IEA-ETSAP/IRENA, 2015).

In 2012, **Germany** introduced an investment grant for up to 50% of eligible investment costs for solar industrial heat systems. The program triggered around 200 investments in solar process heat systems in the first two years. However, the program's impact has failed to meet initial expectations. Due to conditions specific to Germany, solar process heat faces strong competition from the subsidized combined heat and power systems (CHP).

The case of **Italy** shows that energy efficiency policies also affect the deployoment of renewable heat in industry. Implemented in 2004, the Italian White Certificate system obliges electricity and gas system operators to meet a fixed energy efficiency and/or energy saving target each year. In some cases, savings are fixed on the basis of the installed unit. For instance, the replacement of an electric boiler with a solar thermal installation saves 0.154 tons of oil equivalent/m^2 of installed glazed solar thermal panel. Higher coefficients apply to fuel switching from conventional to renewable energy (IEA 2012).

In general, the limited international experience suggest the following **policy options** for fostering market growth for solar industrial heat applications:

- **Increase awareness of the benefits** of solar process heating, especially in industrial clusters of small- and medium-size enterprises, for instance by supporting pilot and demonstration projects.
- Provide **financing mechanisms to cover upfront costs,** such as soft loans or investment grants.
- **Reduce fossil fuel price subsidies** to national industries and consider supporting solar thermal energy as an alternative.
- An **integrated policy strategy** that aims to **reduce fossil fuel subsidies** and decarbonize the economy, such as **carbon taxes** and **energy efficiency measures for industry,** would help solar thermal applications for industrial processes become competitive.
- Furthermore, solar process heat technologies can be supported by **strengthening domestic manufacturing and industry,** for instance by implementing **R&D programs** and **capacity building measures.**

4.3 PV Off-Grid Small (Pico PV/SHS)

4.3.1 Status Quo

By the end of 2014, roughly **15,000 small scale PV off-grid applications** with a **total capacity of 3,600 kWp**, the vast majority being <200 Wp in size and only a few with more than 1kWp, were installed in Viet Nam (Dung, 2015).

These applications included 5,000 solar home systems (SHS) with a size of 20-200Wp, 2,100 telecommunication and BTS systems (300-4,000 Wp), and more than 1,000 small-scale PV systems deployed in rural and mountainous areas or on islands for public use, such as community centers, schools or medical centers (up to 3,000 Wp). Furthermore, approximately 5,000 solar signal lights (20-100 Wp) and 2,000 public lighting systems (50-

250 Wp) were installed on roads and highways throughout the country.[61]

Table 4: Small-Scale PV Off-Grid Applications in Viet Nam 1989-2014

Year	PV Application	Size (Wp)	Number	Total Capacity (kWp)
1989-2012	Solar Home System (SHS)	22-200	5,000	800
1989-2012	Public Use/Community/Medical etc.	75-3,000	~800	~1,000
1990-2012	BTS/Telecommunication	300-4,000	2,100	400
1989-2012	Forrest Stations/National Parks	100-1,000	102	87
2000-2013	Solar Civil/Fishing Boats	100-640	30	10
1990-2012	Solar Farm/Sea Farm	100-1,000	20	10
1990-2012	Solar Signal Lights	20-100	5,000	300
2004-2012	Solar Public Lighting	50-250	2,000	500
1989-2014	Other (PV Lanterns, Ambulance etc.)	1-500	~100	~1
Total			**~15,000**	**~3,600**

Source: Dung (2015) and author's own calculations

Most of these PV power projects were funded by the Government or international organizations and donors through different support mechanisms. However, current surveys and case studies revealed that only few are currently operating at full capacities mainly because of technical failures and lack of proper maintenance (USAID/Winrock/SVN, 2014).

To summarize the **key features of this market segment** in Viet Nam:

- The small-scale PV off-grid segment is **mainly driven by Government and international funding**. These investments were realized in the overall context of the Governmental **rural electrification strategy** and national and international efforts to provide **access to energy** for poor and marginalized communities.
- In addition, a number of **corporate social responsibility (CSR)** projects are involved in the deployment of technology and capacity building (i.e. vocal training) in rural areas. The main stakeholder is the French energy company Schneider Electric.
- Viable **consumer business models** have **not been rolled out** on a broader basis yet.

[61] All figures were taken from Dung (2015).

4.3.2 Energy Market and Industry Potentials

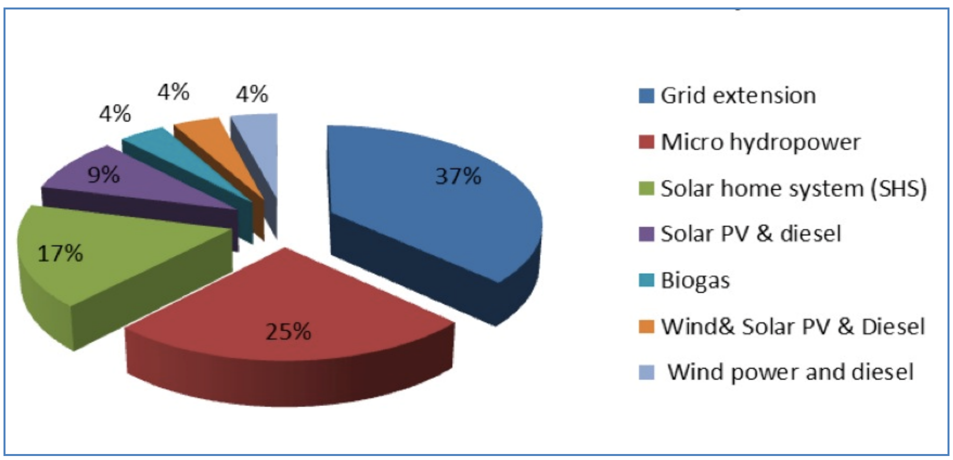
The overall potential for small-scale PV applications in Viet Nam is limited due to the high rate of electrification. Furthermore, the large-scale deployment of substantial solar capacities is unlikely due to the small size of systems and applications and the difficult framework conditions for investments (see also the following section).

A substantial market based on off-grid solar energy service business models cannot be expected: Previous surveys have shown that the ability to pay for such services is very low in most of the remaining non-electrified areas and local stakeholders have limited technical expertise (USAID/Winrock/SVN, 2014).

However, in light of the very difficult conditions that these poor and marginalized communities face, access to affordable energy remains a main political priority for the Vietnamese Government. Solar home systems or community systems for different public uses are often a cost effective alternative to grid expansion, in particular in mountainous areas with difficult terrain or on islands (Dang, 2014). Nevertheless, Government plans aim to enforce grid expansion and connect most of the remaining communities to the national grid by 2020.

In this respect, current government planning according to PDP VII envisages only 17% of rural electrification to be provided by solar home systems, with another 13% provided by solar-supported mini-grids and hybrid systems (see the following section on larger off-grid applications). Almost 40% of households are supposed to be connected to the national power network.

Figure 28. Rural Electrification in Viet Nam by Means of Grid Expansion and Renewable Energy until 2020



Source: Dang (2014), based on PDP VII figures

Regarding the industry potentials, the segment can build upon a small domestic industry with a small number of component manufacturers, such as Solarlab, Solar BK, Viet Linh and others. These domestic manufacturers and system providers focus on small- scale (SHS), medium- and large-scale off-grid applications, such as hybrid systems and mini-grids. Solarlab's Madicub system, an integrated solar local grid managing system, is available for

PV arrays between 500 Wp and 10 kWp (USAID/Winrock/SVN, 2014). However, international technology and imported systems have been used for solar electrification projects in the past. Due to the limited scope for future solar electrification, a strong impact on domestic industry development is not to be expected.

To summarize **market potentials and possible benefits** of the further development of small-scale PV off-grid applications:

- Due to the **high rat of rural electrification** already achieved in Viet Nam, combined with the expected **dominance of grid expansion** in increasing rural electrification, the overall **potential for small-scale PV applications is limited**.
- However, **access to affordable energy** remains a main political task for the Vietnamese Government and international donor organizations. Small PV off-grid solutions will be able to contribute substantially to the increased access to energy in remote and rural areas.
- Within this limited sector, there is **some business potential** for the development of domestic technology solutions **for local manufacturers**.

4.3.3 Framework Conditions and Existing Restrictions

The policy framework shaped the development and implementation of the off-grid rural electrification program (see Chapter 3.1.2). The Power Development Plan VII from 2011, as the main strategy to develop rural electrification, sets out the target of supplying 100% of Vietnamese households with power by 2020. The policy is stimulating EVN to expand its national power grids to areas that are not yet electrified.

Communities and households that do not the requirements for grid access have access to Government investment and support policies for the development of local power resources to ensure that the target of total electrification is met by 2020. These Government funds are complemented by various financing instruments and multilateral funds dedicated to rural electrification.[62]

As recent surveys revealed, off-grid electrification projects in Viet Nam face a number of problems and barriers. Many projects, such as the World Bank-supported Remote Area Rural Electrification (RARE) project, the Muong Te scheme (new off-grid electrification combined with the rehabilitation of existing hydropower schemes), the low-cost village-level electrification project by the Japanese Development Agency JICA and the Viet Nam Sweden Renewable Energy Project (VSRE), suffered serious delays and difficulties (USAID/Winrock/SVN, 2014).

In general, the higher upfront investment costs compared to traditional energy forms, such as kerosene lamps or diesel generators, are the main financial barrier for solar energy projects in rural areas. In Viet Nam this barrier has been lowered thanks to the involvement of donors and/or the Government. So far, most off-grid RE power projects in Viet Nam have been funded by the Government or international organizations.

[62] For an overview, see USAID/Winrock/SVN (2014) and the scoping for international donor activities of the EU Delegation to Vietnam by Nguyen Nam Hoai (2015).

Furthermore, the involvement of Government funds, donor funds and/or EVN investments directly competes with potential private sector investment. Investments are often not encouraged and local stakeholders wait for public funding at lower costs rather than taking any investment risks. Therefore, investments in capital-intensive renewable energy solutions need to come from local Government and/or EVN. Local governments receive State budget allocations each year that need to be disbursed in line Government priorities and local needs. Since EVN indicated that it would extend the grid (100% by 2020), the willingness to allocate funds to renewable energy investments is very limited. At the same time, renewable energy solutions often require larger investments than conventional solutions, thus making it a lower priority in these predominantly poor areas (ibid.).

Last but not least, system quality and limited technical and business capacities – as seen in many other PV off-grid regions of the world[63] – have lead to project failures in Viet Nam. Almost every survey done on rural electrification in Viet Nam (IE, 2009 and World Bank, 2011) or in general indicates that there is a large need for appropriate training and knowledge transfers. The main short-comings usually are: uncoordinated R&D efforts, limited skills in business plan development, and limited local information and knowledge on the available technologies and opportunities of solar energy on behalf of enterprises and local Government.

To **summarize the framework conditions** for small-scale PV off-grid applications:

- The government **target of 100% electrification by 2020** and the rural electrification program are the main framework regulations for PV off-grid applications.
- The politically-driven **grid expansion is "competing" with renewable energy investments** in rural areas.
- Strong financial **Government and donor support** is partly **discouraging private investments.**
- **No viable business models** for commercial small-scale PV applications are being implemented so far.
- A number of **corporate CSR programs** (e.g. Schneider Electric) are being implemented.
- The projects implemented so far show a **lack of local capacity**, **skills and information** regarding solar energy technology and opportunities, system O&M and business development.

4.3.4 Lessons from International Experience

Over the last 20-30 years, millions of Solar Home Systems (SHS) have been installed in remote areas throughout developing countries. Most of these programs were supported financially by donor agencies and multi-lateral financing organizations. These programs developed different business models, including specific financing models, such as commercially-led approaches, in which suppliers and dealers develop the market (typically relying on cash sales); programs managed by a variety of stakeholders (typically relying on

[63] For an overview, see IOREC 2012.

consumer credit); utility models (mostly with fee-for-service payments); or grant-based models (typically used for highly managed and structured institutions).[64]

One of the most successful SHS programs has been implemented in **Bangladesh**, where approximately one million SHS systems were installed by 2012. This was achieved as a result of strong Government support via the Infrastructure Development Company (IDCOL) and financial support from donor agencies, such as the World Bank, KfW, GIZ, and ADB. Here, micro-finance institutions, so called Partner Organizations (PO), provide loans, install and maintain the solar systems, and collect fees (IEA-PVPS, 2013).

Laos and **Cambodia**, with support from the World Bank GEF program, have also engaged in large-scale programs (more than 15,000 SHS), providing individual SHS of 20 Wp to 50 Wp to remote rural households. An upfront subsidy is provided by the national governments who then offer customers the option of paying back a loan over a period of four to ten years, incurring monthly payments of USD 1-5, or a leasing scheme, with the household owning the system at the end of the period, simply needing to replace the battery. Though the conditions for success sound good on paper, reality has proven more difficult: many customers could not afford to pay cash for the battery replacement. Furthermore, the costs of servicing the systems and collecting payments became too high due to the scattered locations of the participating households (IEA-PVPS, 2013).

To **summarize the international experience** with small-scale PV off-grid applications:

- Small-scale domestic and non-domestic off-grid PV programs for rural electrification are mostly **dominated by ODA-/public funding** models.
- Some **commercial business models have been implemented** with financial support (e.g. SHS-leasing).
- **System quality and capacity building for local stakeholders** (municipal Government, communities, SME enterprises etc.) and **investors/ commercial sectors** are the **main prerequisites** for successful and sustainable solar electrification programs.

4.4 PV Off-Grid Large (PV Hybrid/Mini-Grid)

4.4.1 Status Quo

The market for PV hybrid and mini-grid systems in Viet Nam is still rather small, with limited potential for further growth due to the overall high electrification rate (see Section 4.4.2). Most of these projects, often implemented on islands and involving PV and wind energy, have been funded by the Government, EVN or the Vietnamese navy, as well as international organizations and donors.

A larger project is located in Bai Huong village[65] on Cu Lao Cham island (28 kWp PV plus 20 kW diesel generator) and in Mang Yang in the Central Highland Province of Gia Lai with 100 kWp PV combined with a 24 kWp mini-hydropower plant. Further projects are being developed by Golden Bridge Co. Ltd for a number of islands, including PV-wind hybrid

[64] For an overview of business models for Pico-PV and SHS, see IEA-PVPS (2013), IEA-PVPS (2014) and IFC (2012).
[65] For a brief project summary, see USAID/Winrock/SVN, 2014, p.21).

systems.

The Vietnamese company Solar BK, specialized in PV-wind hybrid systems, has already implemented more than 50 PV hybrid projects, mainly on islands and naval outposts. All of these projects were realized together with EVN and the Vietnamese Navy as the main investors and energy consumers. Solar BK is currently preparing an ESCO model for these PV hybrid systems together with these two main investors.[66]

Solarlab has also already implemented PV hybrid projects in mountainous areas or on islands, using its Madicub hybrid technology.

To summarize the **key features of this market segment** in Viet Nam:

- The market segment is still in the **"inception stage".** It is widely dominated by Government and EVN funding.
- A **few larger mini-grid and PV hybrid** (diesel, battery, wind) **systems** have been implemented, mainly on islands. A larger number of small- and medium-size systems have been built on islands and naval outposts.
- First commercial **ESCO business models** with public or SOE-partners (EVN/ Vietnamese navy) are under development.

4.4.2 Energy Market and Industry Potentials

As stated above, the market and industry potentials for larger scale PV hybrid and mini-grid systems are fairly limited in general due to the high rate of electrification. Viet Nam is therefore not ranked among the top 20 countries with a high potential for PV hybrid or PV mini-grids (see Breyer et. al./RLI, 2013, for the most systematic international analysis of market potentials).

However, due to the number of sparsely populated islands that EVN has to deliver power services to, at comparably high costs of USD 0.40 to USD 0.60 per kWh, PV-supported hybrid systems can be an economically viable solution, at least until these islands and rural areas are connected to the public power network. However, the bigger island communities, such as Phu Quoc, Ly Son and Cu Lao Cham, have already been connected to the grid or will be connected in the very near future.

Regarding industry potential, records of domestic specialist companies and institutions, such as Solar BK or Solarlab, show that there are a number of business opportunities for local industry in this limited market segment.

To summarize **market potentials and possible benefits** of the further development of larger-scale PV off-grid applications:

- Due to the **high level of rural electrification** and the low amount of islands **that will not be connected to the national power network**, the overall **potential for PV hybrid and mini-grid applications is limited**.

[66] For an overview of these projects, see http://en.solarbk.vn/dao-noi_-truong-sa/558.

- The expected **contributions** to an **increase in RE supply**, **GHG-reductions** and the **reduction of fossil fuel import dependencies** are therefore limited.
- However, **access to affordable energy** remains a **main political task** for the Vietnamese Government and international donor organizations. Large-scale PV off-grid solutions can contribute substantially to increased access to energy, especially on sparsely populated islands with high power generation costs (diesel generators or mini-grids).
- There is a **limited potential** for the further **development of local/domestic manufacturing, EPC and O&M** of such complex hybrid and mini-grid systems.

4.4.3 Framework Conditions and Existing Restrictions

Most of the framework conditions and general barriers for investment identified for small-scale PV off-grid systems under 4.3.3. also apply to larger PV hybrid and mini-grid applications.

Additional barriers are evoked by the more complex nature of hybrid and mini-grid applications with regard to technical/adequate system sizing. Furthermore, questions on project implementation and sustainable operation create additional potential barriers compared to small-scale Solar Home Systems or Pico PV applications.

To **summarize the framework conditions** for larger-scale PV off-grid applications:

- The government **target of 100% electrification by 2020** and the rural electrification program are the main framework regulations for PV off-grid applications.
- The politically-driven **grid expansion is "competing" with renewable energy investments** in rural areas and on islands (e.g. Phu Quoc and Ly Son).
- Strong financial support from the **Government/navy, SOE (EVN) and donors** is partly **discouraging private investments.**
- **High costs of alternative power** generation (off-grid diesel generators or mini-grids) are creating business oportunities for targeted business models.
- **Local capacities and skills** regarding solar energy opportunities and technology, O&M and business development are very limited. A **small number of specialized domestic companies and institutions** are involved in the sector.

4.4.4 Lessons from International Experience

International experience shows that PV-supported electricity mini-grids can power households and local businesses in a cost effective manner, especially in areas where grid expansion is too costly, not feasible due to rural isolation, or unlikely to be accomplished in the mid-term.[67]

[67] For an overview of international experience with PV hybrid and mini-grid systems, see ARE (2014), among others.

Diesel is expensive and difficult to distribute to rural areas. A 100% diesel mini-grid is not only more expensive than hybrid ones, but also less autonomous since fuel availability can often not be assured. Hybrid mini-grids utilize the available local resources, making power shortages less likely.

In fact, LCOE cost models for mini-grids show that in regions with good solar irradiation, such as Viet Nam, PV-wind hybrid mini-grids are cost competitive with pure diesel generators, even at low diesel price levels of USD 0.70/liter[68] (see ARE, 2014). In March 2015, the pump diesel price in Viet Nam was USD 0.76/liter. The installation of PV hybrid mini-grids becomes even more attractive in light of the high costs of transporting diesel to rural areas and subsidizing electricity for customers in these areas.

Financial and operational issues are critical to the long-term sustainability of mini-grids. Addressing operations and maintenance; the role of the private sector, tariffs and subsidies; and capacity building and training is essential when developing rural electrification programs. This is particularly true with the use of hybrid mini-grids.

The lack of financial, institutional and technical capacities is one of the main reasons for unattractive programs and misunderstandings between the public and the private sector, including the financial sector.

Hybrid business models tend to be highly site specific and can thus be quite diverse in terms of ownership structures, O&M contracts and other variables. The business model most commonly used for PV hybrid and mini-grid projects is the **community-based model,** with its success varying depending on the involvement of the community and the pricing policy. The community needs to be involved as early and as much as possible through financial or in-kind participation and through the establishment of a social structure that supervises the implementation and the O&M of the projects. Tariffs are often determined in advance, but flat-fees with categories adapted to different users are usually a good option, since consumption is generally low. Tariffs always have to be high enough to cover O&M as well as replacement costs. Some community-run mini-grids have proved to be successful, with a number of positive impacts on the community itself in terms of self-governance and local buy-in into the electrification system. However, this approach also requires a long preparation period and a lot of technical and social capacity building in order to compensate for the lack of skills and mitigate potential social conflicts. Therefore, the introduction of another partner – either private or public – to take over some aspects of system management is preferable (ibid.).

Another business approach for mini-grid rural electrification is based on a **private operator**, whose participation is only realistic if a project is profitable and therefore attractive. Output–based aid and long-term concessions, when well designed, can be attractive schemes to increase the participation of the private sector. However, in order to be developed in rural areas, this model requires significant training, both on technical and business issues. This approach also requires community involvement and a proactive private sector development component to build demand for electricity services. Projects implemented in the mining sectors in Chile and South Africa show that PV hybrid systems with private sector operators

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[68] See http://www.globalpetrolprices.com/Vietnam/diesel_prices/. The average diesel price in Vietnam from 15 December 2014 to 23 March 2015 was USD 0.75/l, rainging from USD 0.71 to USD 0.86 per liter. In comparison, the average global diesel price was USD 1.29/l.

can be very successful. The **South African** Thaba chrome mine incorporated a 1 MW PV plant into its diesel genset infrastructure after failing to obtain a grid connection with the national grid operator ESKOM. The PV plant reduced daytime diesel consumption by 60% and saved more than 450.000 litres of diesel per year, reducing diesel costs by approximately Rand 1 million per month (>USD 80,000).[69] The South African company Solea Renewables was involved in the project, taking charge of EPC and system management, together with Cronimet Energy South Africa, a subsidiary of the mine owner Croniment Mining AG.

Other examples of this model include PV hybrid systems in island tourism, where larger resorts or hotels are often powered by diesel generators.[70]

The **utility-based model** is another option that has been widely used at the global level. Utility companies generally have the necessary experience, financial resources and technical capabilities to carry out rural electrification projects. They can implement economies of scale and use their position to take advantage of financing options. However, many are also inefficient and lack commitment at the local level.

In **Viet Nam**, EVN has been involved in PV hybrid and mini-grid business models on islands in recent years. EVN seems to be interested in developing an ESCO business model with respective companies in the solar industry sector.

To **summarize the international experience** with PV hybrid and mini grids applications:

- Larger scale off-grid PV (mini-grid/hybrid) applications are often **still dominated by ODA-/public funding** models.
- However, **viable commercial business models** have been implemented in the past (ESCO/PPA models) in different public and commercial sectors (mining, tourism etc.).
- Best practice shows that thorough **technical system planning** and **capacity building for local stakeholders** (municipal Government, communities, SME enterprises, etc.) and **investors/commercial sectors** are key to successful and sustainable PV hybrid projects.

4.5 PV Residential Rooftop Grid-Connected

4.5.1 Status Quo

The segment for residential grid-connected PV in Viet Nam is in its early **inception stage**. Hardly any PV systems are in operation on private houses yet. The only systems comparable in size to residential PV units (usually up to 10 kWp for single-family houses and 10-50 kWp for multi-family houses or apartment buildings) are systems installed on top of research institutions or public buildings. These include the 2 kWp “Solar Villa” system on top of Solarlab in Ho Chi Minh City, installed in 2005; a 1kWp system on top of the Institute of Energy in Ha Noi installed in 2009; and the 12 kWp system on top of the Ministry of Industry and Trade (MoIT) in Ha Noi, installed in 2010. Table 5 gives a list of all the PV rooftop

[69] For an overview of the Thaba PV mining project in South Africa, see: http://www.cronimet-mining.com/site/assets/files/2562/cronimet_harnessing_sun_power_mining_mirror_november_2013_smaller.pdf.

[70] Among others, the Fiji islands have received a number of investments in PV hybrid systems. See http://www.irena.org/DocumentDownloads/events/2014/June/16_Clay.pdf.

systems installed by 2015 based on data collected by Solarlab/Mr Trinh Quang Dung (Dung, 2015).

Table 5: Grid-Connected PV-Systems in Viet Nam 2005-2015

PV System Site	Capacity (kWp)	City/Province	Year of Installation
„Solar Villa“ Solarlab	2	HCMC	2005
National Conference Hall	154	Ha Noi	2005
Institute of Energy	1	Ha Noi	2009
Tuan An Corp.	12	HCMC	2009
Tam Ky Hospital	3	HCMC	2010
Farm Green Grass	3	HCMC	2010
Ministry of Industry and Trade	22	Ha Noi	2010
Intel Corp.	220	HCMC	2012
XP Power (Industry Park)	40	Binh Duong	2012
Big C Di An (Industry Park)	200	Binh Duong	2012
Institute of Natural Resources and Environment	42	Ha Noi	2013
Biological Center	4	Da Nang	2014
UNDP Building	119	Ha Noi	2014
National Assembly	50	Ha Noi	2014
Hotel Lo Tus	11	HCMC	2015
Tea processing factory	10	Lao Cai	2015
Other roofs	20	HCMC	2010-14
Total installed capacity	**913**		

Source: Dung (2015) and author's own observations

The small number of systems is mainly due to the lack of a viable business case for private investors. With the LCOE for PV on small residential houses lagging behind the residential electricity tariffs of USD 0.07 to USD 0.12 (for a closer look at the PV LCOE, see the next section), there simply is no investment case. Electricity tariffs for dormitories or designated residential areas are even lower; the same applies to households in rural areas.[71]

Regarding industry capacities, a residential PV market could build on the existing domestic manufacturing sector with a sufficient production capacity for market take-off at least (see 3.2.4). A developed installer sector with sufficient technical capacities to scale up a residential PV market is lacking, at least in the short term.

To summarize the **key features of this market segment** in Viet Nam:

[71] See Chapter 2.3.1 for a general discussion on electricity tariffs and the latest electricity tariff adjustment Decision 2256/QD-BCT from 12 March 2015.

- The residential market segment is in the early **“inception stage”** with only very few systems installed so far (mostly institutional demonstration projects).
- There is **no viable business case** due to very low residential power price levels compared to a relatively high PV LCOE for small systems.
- **The domestic PV industry** is in the **early development stage** with small component manufacturing and EPC/O&M capacities in general. Installer expertise related to residential PV applications is very rare.

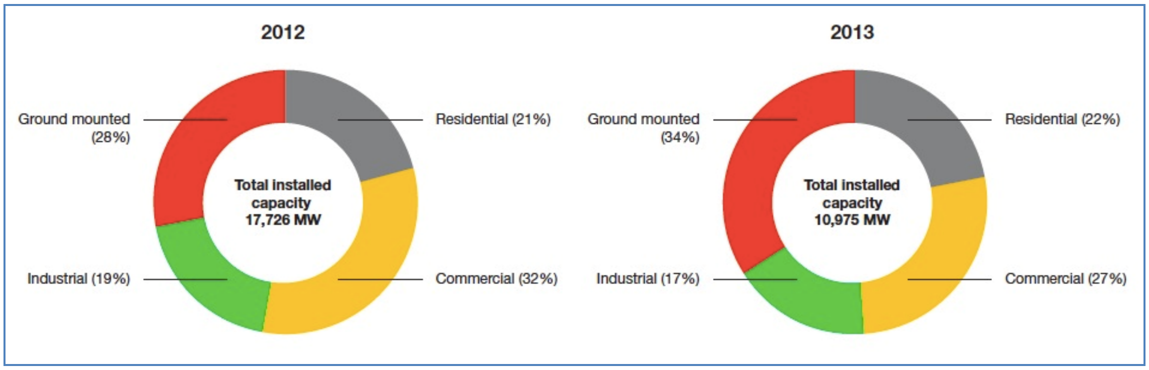
4.5.2 Energy Market and Industry Potentials

Due to the rather large competiveness gap for PV systems in the residential sector, its potential increasing renewable energy supply and reducing GHG emissions and fossil fuel import dependencies is limited, at least in the short and medium term. This will depend on the future development of electricity tariffs in this segment.

However, recent developments show that the general power price policy of the Vietnamese Government aims to keep the burden for citizens low, with commercial power consumers cross-subsidizing the residential sector. This could mean that residential power tariffs stay low compared to tariff increases for other consumer groups in the short and medium term. Of course, with an estimated 100 million residents in 29 million households by 2030 (World Bank/ESMAP 2015, see Figure 26, the residential sector has a tremendous potential in the long term. The high congruency of solar production with peak power demand in residential areas, mostly due to air-cooling demands, makes solar PV a very suitable technology for reducing peak network loads in the future.

Available international data shows that the residential sector has a substantial market share in most solar markets. In European countries, residential PV accounts for more than 20% of the installed capacity (see Figure 29.). This is closely related to the implementation of initial support schemes that boosted market development for residential PV applications before power retail price parity (“socket parity”) was reached in this segment.

Figure 29. European PV Market Segmentation 2012 and 2013



Source: EPIA (2015)

With this substantial long-term potential for residential PV applications, the possible contributions of this segment to meet renewable energy targets could be relevant for Viet Nam in the long run if PV system prices decline and residential electricity tariffs increase further.

As international experience with residential PV markets show, the small-scale and dispersed nature of these applications leads to the development of locally- and regionally-oriented installer SMEs. In addition, most of the more mature residential PV markets developed new forms of business models that focus on energy services, such as solar leasing. This also creates business opportunities for domestic energy industries.

To summarize **market potentials and possible benefits** of the further development of residential PV on-grid applications:

- There is a **high renewable energy potential in the long term** if there are further PV cost reductions and substantial increases in residential power price levels.
- However, the **short- and medium-term potential is very limited** due to the existing competitiveness gap.
- There is a high (long-term) potential for **peak power demand reduction** in the case of extensive deployment.
- A sustainable and growing residential PV market could **foster domestic industry development** (manufacturing of components and BOS) and the development of **domestic installer** (installation and O&M) and **ESCO** businesses.

4.5.3 Framework Conditions and Existing Restrictions

Current framework conditions in Viet Nam do not permit investments in residential PV applications. In addition to the low electricity tariffs, there are substantial regulatory barriers that prevent the realization of viable business models, as already highlighted in Chapter 2.3.2:

- First of all, **no financial or sufficient fiscal support measures** (such as Feed-In-Tariffs or the possibility of net-metering or net-billing) that could close the gap between PV LCOE and retail electricity tariffs are being implemented.
- Secondly, there is **no standardized interconnection code** (grid code) and **connection procedure** for PV systems. A current project which involved EVN, the energy authorities in Da Nang City and the International Copper Association Southeast Asia (ICA-SEA) very recently made first steps in this direction and developed a proposal for an interconnection standard for PV as well as a general net-metering scheme. Within this project, it was debated if a net-meetering scheme would be feasible and up to which project size a net-metering scheme could be applied.[72]
- Thirdly, there is **no effective regulation on the sale of excess solar electricity** generated by private PV systems.

[72] See ICA-SEA (2015). National Interconnection Standards and Net-metering for Rooftop Solar PV in Vietnam. Consultation Workshop Report, January 7th, 2015. The discussion was, whether PV systems >100kWp should be eligible to take part in the net-metering scheme or only smaller systems.

- Finally, due a lack of market experience, there is **very low public awareness** of solar energy.

4.5.4 Lessons from International Experience

Most successful support policies for residential PV markets combined financial market support measures, such as fixed **feed-in tariffs (FIT)**[73], **net-metering/net-billing**[74] or **tax incentives** with accompanying measures to lower investment barriers, such as **priority grid access**, **streamlining of bureaucratic procedures** and additional **financing support** with soft loans or similar instruments.

By the end of 2013, **98 countries**, federal states or provinces had implemented some form of **FIT**, with more than half being developing countries (REN21, 2014). Starting in the 2000s, many European countries began implementing FITs that guaranteed long-term fixed prices (20-25 years) for solar electricity generation.[75] Power producers would typically sell 100% of their power to the electricity grid – even if their systems were located on-site (as typical for rooftop PV). FIT payments for PV on-site generation were generally higher than retail electricity prices in most countries. However, decreases in the cost of solar PV systems led to decreased rates.

Germany is an example for the effective development of a residential PV segment with feed-in tariffs differentiated by size. By the end of 2014, around 1 million small-size PV systems were in operation on residential or small commercial roofs nationwide.

From 2004 onwards, the German FIT scheme (EEG) defined a specific tariff category for systems of 0-30 kWp in size, aiming at typical residential systems. Later on, this category was defined more narrowly for systems of 0-10 kWp in size. The fixed tariff is guaranteed for 20 years. The FIT scheme is refinanced through a levy on retail electricity tariffs (EEG surcharge). From the very beginning, the FIT was accompanied by guaranteed priority access to the grid for all renewable energy systems within the FIT scheme and additional financing support via a soft loan program run by the State-owned KfW development bank.

Today, the PV LCOE levels for new, small-scale residential PV in Germany are less than half the current residential retail rate. This decline will continue to move Germany beyond the point of "socket parity," incentivizing a greater number of households and businesses to install behind-the-meter PV systems to reduce the amount of power they consume from the network (self-consumption). After incentivizing on-site consumption for a few years, Germany has now reversed this development by starting to oblige these "prosumers"[76] to share the costs of the EEG surcharge and grid-related costs.

In the early 2000s, **France** utilized a FIT system for a range of renewable energy technologies, while also procuring a number of renwable technologies, such as biomass and

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[73] In the context of this study, the term **"feed-in-tariff"** refers to the traditional definition of an administratively set and long-term fixed price contract for solar power delivered to the grid.

[74] The term **"net-metering"** refers to a support scheme in which the solar system output offsets the retail electricity purchases of the system owner. Excess generation can be applied as a credit to future electricity purchases. **„Net-billing"** refers to a net-metering scheme in which the rate at which solar power producers are compensated or credited, differs from the retail rate they pay.

[75] For a review of European FIT experience, see Couture et al. (2010) or Jacobs (2012), among others.

[76] PV system operators are power consumers and (solar) power producers at the same time.

offshore wind energy through tenders. The FIT scheme applied mostly to smaller systems (under 12 MW), while the tendering scheme was used to procure larger projects (>12 MW). In March 2011, France expanded its use of tenders to smaller projects and introduced a tender for rooftop solar PV projects between 100 kW and 250 kW in size (the "simplified" tendering approach), and a tender for rooftop projects between 250 kW and 12 MW in size (the more "complex" tendering approach). Systems below 100 kW are still eligible for fixed FIT rates. As a result, France has managed to encourage a wide range of project sizes and investor types to participate in its RE policy.

The example of France demonstrates that retaining a FIT for smaller project sizes can help drive significant investment in projects typically owned by individual citizens or residents. France successfully attracted interest in smaller projects and achieved more balanced project development across all project size classes. (NREL-CESC, 2015).

In many solar markets, **net-metering** policies have been introduced to support investments in small-scale residential PV applications in particular. In 2014, more than 40 countries and federal states had implemented net-metering schemes to promote solar PV (REN21, 2014). Net-metering in general refers to a support scheme in which the solar system output offsets the retail electricity purchases of the system owner (the meter reverses) and excess generation can be applied as a credit to future electricity purchases. Typically, the access electricity (or the credit) is reimbursed at the same value as the current retail tariff. In cases in which the credit is higher than the retail tariff, the scheme is refered to as **"net-billing"**.

Net-metering is typically implemented in combination with other incentives, such as tax rebates or grants, since net-metering on its own has historically been insufficient to drive market growth. This has different causes, one of which is the low cash flow compared to feed-in-tariffs in particular, which raises financing issues for investors. In many net-metering systems, especially in the USA, these issues are addressed through accompanying tax rebates or investment grants and the option of third-party-ownership financing models.

The net-metering schemes implemented so far differ largely according to design options. Some have limitations for eligible system sizes or have total program caps, e.g. they limit the capacity of renewable energy systems that are allowed to take part in the program to a certain percentage of the respective utilities peak loads. Other programs are restricted to certain RE technologies or exclude certain types of utilities from the obligation to offer net-metering to their customers. Finally, the limits of credit transfer over different billing periods (e.g. monthly or annually) differ from program to program. Table 6 gives an overview of best practice and worst practice (in terms of support scheme effectiveness) from a larger survey of net-metering programs in different US federal states. In late 2014, 44 US federal states were implementing net-metering policies.[77]

[77] See www.freeingthegrid.org

Table 6: Best Practice and Worst Practice of Net-Metering Programs in the USA

Design Options	Best Practice	Worst Practice
System Size Cap	No limitation	<20 kWp
Program Cap	No limitation	Less than 0.1% of peak load of the utility
Technology Eligibility	PV, Wind and other RE technologies	PV and wind are excluded
Customer Eligibility	No restrictions	Only private households can use the net-metering scheme
Utility Eligibility	All utilities are obliged to offer net-metering	Only investor-owned utilities are obliged to offer net-metering
Credit Transferability	Unlimited transfer of credit possible	No transfer of credits to next billing period possible

Source: Rose et al. (2010) and Jacobs/Rickerson (2011)

The overall assessment of net-metering policies implemented worldwide indicates that this type of support scheme needs to be accompanied by additional incentives, such as tax incentives, investment grants or tradeable renewable energy certificates, in order to effectively foster investments and PV system deployment. Experience in the region supports these findings, such as the net-metering scheme implemented by Thailand in 2002 – the first of its kind in a developing country - as part of its Very Small Renewable Energy Power producers Program (VSREPP).

However, in such comprehensive policy mix strategies, net-metering schemes have been quite successful in the past, particularly in fostering market growth in small-scale residential but also larger-scale commercial PV segments.

To **summarize the international experience** in PV roof-top residential markets:

- Most internationally **successful support schemes for residential PV** markets are based on financial market support measures, in particular **feed-in tariffs and net-metering schemes.**
- These financial support measures are usually accompanied by **measures to lower investment barriers,** such as **priority grid access** and **streamlining of bureaucratic procedures.**
- In some countries (mostly developed countries), different forms of **tax incentives** (e.g. USA) have also proven to be effective.
- Additional financing support measures, such as **debt finance** (soft loans), **financial equity** mechanisms **and non-financial support** for investors and industry (R&D, capacity building, awareness-raising) have helped foster market development.

4.6 PV Grid-Connected Rooftop Commercial/Industrial

4.6.1 Status Quo

The market for grid-connected commercial PV systems is the inception stage. There have only been a few investments so far, including the **Intel Corporation's 220 kWp** system, **XP Power Corporation's 40 kWp** system and **Big C's 200 kWp** system**.** A few smaller investments have been realized on top of hotels or food processing facilities (see Table 5). Most of the bigger PV systems are pilot and demonstration projects funded by ODA or public relations budgets, such as the PV systems on the UN building or the National Conference Hall.

However, interviews with private sector stakeholders showed that there is an increasing interest in PV technology amongst companies in different commercial sectors. However, due to the restrictive framework conditions there is still a high level of reluctance regarding real investments.

A closer look at the current electricity tariffs for commercial and industrial businesses[78] in Viet Nam and possibly achievable solar PV LCOE reveals that a **business case** for PV investments might be **within close reach:**

- Current electricity tarrifs for **"industry" consumers** (22 kV to 110 kV grid connection) on weekdays during the day range from VND 1,405/kWh (USD 0.07) during normal-tariff hours to VND 2,556/kWh (USD 0.12) during peak hours. An average solar production day in southern Viet Nam (from 6am to 6pm) comprises 9 normal-tariff hours and 3 peak hours with higher tariffs. Calculations of the daily solar yield curve and the respective electricity tariffs throughout the course of a day show that the **average value per solar power-generated kilowatt-hour** is **USD 0.08/kWh** for this type of consumer.
- The same calculation for **"commercial"** consumers (6 kV to 22 kV grid connection) is more attractive from an investment point of view: The current tariffs for weekdays during the day range from VND 2,287/kWh (USD 0.107) during normal-tariff hours to VND 3,829/kWh (USD 0.179) during peak hours. The same calculation including the daily solar yield curve arrives at an **average per solar power-generated kilowatt-hour** of **USD 0.13/kWh** for this type of consumer.
- The **solar PV LCOE** for self-consumption would **have to be less than USD 0.13/kWh** to be cost competitive with power purchases from the grid for commercial consumers.
- PV LCOE calculations conducted by the Institute of Energy (IoE) for a 10 MWp reference system in southern An Giang province (with an estimated solar yield of 1,455 kW/kW/year) estimate a **range of USD 0.11-0.17/kWh** with an average **of USD 0.14/kWh** (see IoE, 2015).
- Since large PV rooftop systems can reach similar cost structures to ground-mounted systems, it appears that a **business case** for "commercial" power consumers **is no longer a distant reality**.

[78] See Decision 2256/QD-BCT from 12 March 2015 approved by the Ministry of Industry and Trade on regulating electricity tariffs.

To summarize the **key features of this market segment** in Viet Nam:

- The market for commercial PV roof-top applications is in the early **“inception stage”**.
- There are only a **few systems installed** so far, but there is growing interest among commercial/industrial investors.
- Most non-residential rooftop systems are **pilot/demonstration projects** (ODA or PR budgets).
- A viable **business model is within close reach** (self-consumption, if possible with excess power sale, investment or ESCO model). The **PV LCOE** has almost obtained a **parity with grid power costs** for certain power consumers with high daily loads during peak hours.
- **The domestic PV industry** is in an **early development stage** with small component manufacturing and installer/EPC/O&M capacities.

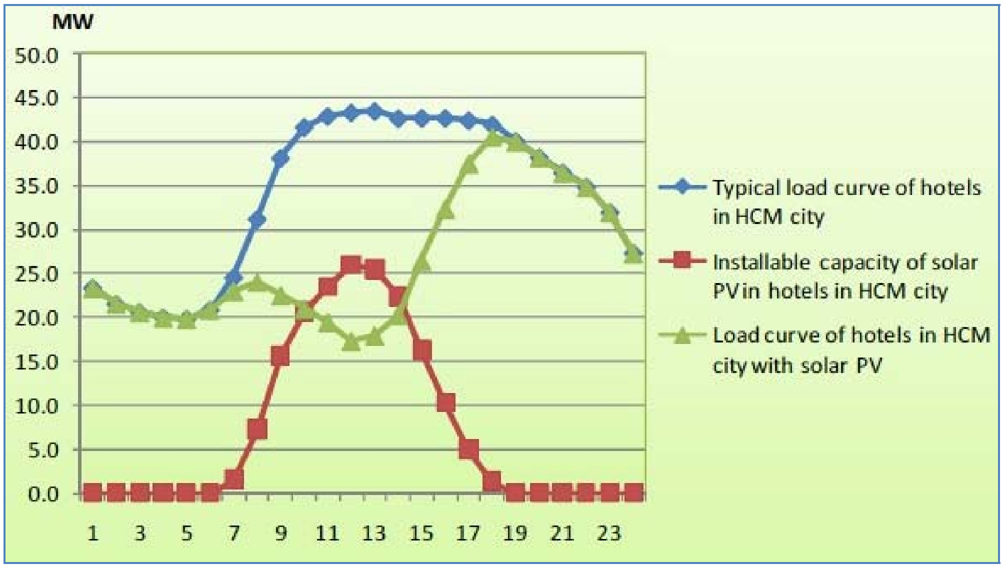
4.6.2 Energy Market and Industry Potentials

The market potential for commercial and industrial PV applications is substantial considering its short-term perspective to reach cost competitiveness as well as its possible capacities to meet the demand of commercial and industrial sectors. No estimates have been conducted on the overall industry potentials yet, except for a few surveys on solar potentials for selected business sectors in Ho Chi Minh City.

Nguyen (Nguyen, 2013) calculated estimates for HCMC, looking at the hotel sector and office buildings, and their typical load curves. Figures 30. and 31. show the estimated load curves for hotels and office buildings in HCMC and the potential demand that solar PV could cover during the day.

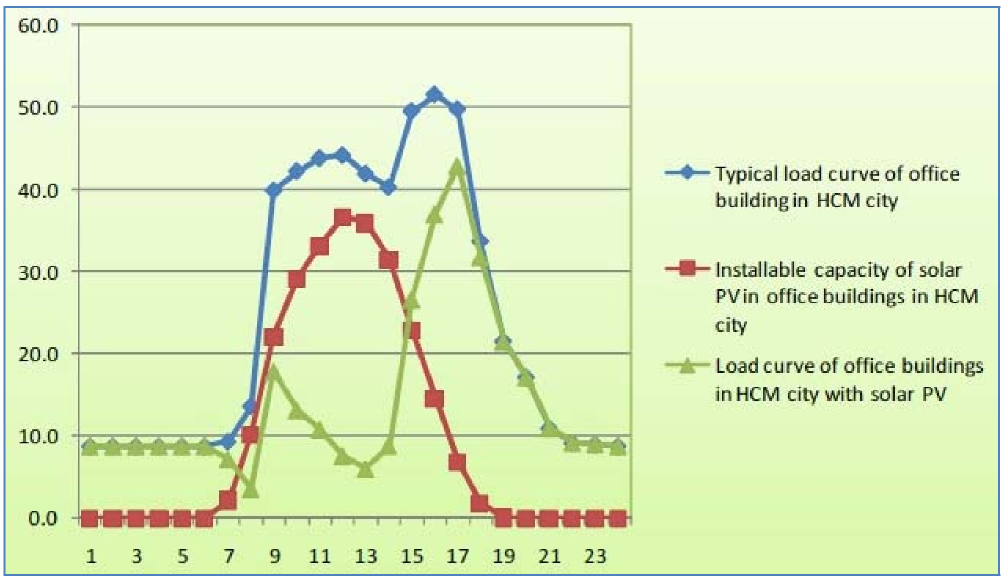
For hotels in HCMC this estimate arrives at a demand-driven solar PV **potential of 47 MWp**. For office buildings, Nguyen estimates a solar PV **potential of 66 MWp**, totaling a joint demand-oriented potential of **113 MWp**. Considering there are numerous business sectors with comparable power loads for cooling demands or production processes allover Viet Nam, the overall potential of this market segment is substantial and could account for **several Gigawatt**.

Figure 30. Typical Daily Load Curve for Hotels in HCMC



Source: Nguyen (2013)

Figure 31. Typical Daily Load Curve for Office Buildings in HCMC



Source: Nguyen (2013)

The load curves of these estimates show another potential benefit of commercial solar PV deployment: During the day, solar power generation **reduces peak power demands** substantially, at least the morning and midday peaks, as well as a substantial part of the afternoon and evening peaks in summer. This could contribute to reducing investments in grid expansion and costly fossil peak power supply.

To summarize the **market potentials and possible benefits** of the further development of commercial PV on-grid applications:

- There is a **medium potential for** increasing **renewable energy supply** and reducing GHG emissions and fossil fuel import dependencies in the **short term**. The short-term potential in southern Vietnamese cities and business sectors could amount to **some hundred Megawatt** within the next few years (more thorough estimates of sector potentials have yet to be undertaken).
- **The renewable energy potential in the medium term is high** in case PV costs continue to decline and commercial/industrial power prices increase.
- There is a **high** (long-term) **potential** for **peak power demand reduction** in the case of an expansive deployment and successful grid integration management.
- There is **small potential** for **industry development** (manufacturing of components) and a **sound potential** for **installation/EPC, O&M and ESCO businesses** in this commercial market segment.

4.6.3 Framework Conditions and Existing Restrictions

Current framework conditions in Viet Nam do not limit investments in commercial PV applications as long as they are "in-fence" investments for self-consumption only. As soon as a grid connection and the feeding in of excess energy is required or desired, investments face substantial barriers. In addition to the very low electricity tariffs, substantial regulatory barriers hinder investments, as already highlighted in Chapter 2.3.2:

- First of all, **no effective financial and fiscal support measures** (such as Feed-In-Tariffs or the possibility of net-metering or net-billing) that could close the gap between PV LCOE and retail electricity tariffs are being implemented.
- Secondly, there is **no standardized interconnection code** (grid code) and **connection procedure** for PV systems.
- Thirdly, there is **no effective regulation on the sale of excess solar electricity** generated by private PV systems.
- Finally, due the lack of market experience, there is a **very low level of public awareness** of solar energy.

4.6.4 Lessons from International Experience

In general, international experience in supporting commercial and industrial PV rooftop applications is widely comparable to the smaller rooftop segments (see Section 4.5). Most **FIT schemes** target this segment with specific tariffs that are usually lower than those for residential applications due to the lower investment costs per kWp that can be achieved in larger-scale projects. However, commercial and industrial enterprises expect shorter ROI periods and reach socket parity later than residential customers, since retail power prices in many countries are lower for commercial enterprises with substantially higher power demands. In Viet Nam, this is not the case, since commercial and industrial power tariffs are higher than those for private households, bringing the former consumer group closer to a viable business case with solar PV than the latter (see Section 4.6.1).

Net-metering schemes combined with tax incentives have also been successful in attracting commercial investments in PV rooftop systems of medium size, typically ranging from 50 to 500 kWp or more. As discussed before, these net-metering schemes were mostly combined with other incentives, since they have not yet proven to be sufficient.

In addition, commercial investors are usually more responsive to **tax incentives** or specific **soft loan programs** than private investors. These support mechanisms are often successful in attracting investments when combined with other instruments such as FITs, net-metering programs or renewable portfolio standards (RPS).

Germany, for example, has developed a strong commercial PV market through its **FIT scheme** and accompanying soft loan program and priority access to the grid (see Section 4.5.4). In 2014, almost 50% of the newly installed PV capacity was generated by 10 to 1,000 kWp systems, with 35% of newly installed capacity generated by 40 to 1,000 kWp systems. Once commercial size PV systems reach socket parity with average commercial electricity tariffs, self-consumption business models increasingly drive this market segment. However, for these investments the additional incentive of the FIT for excess energy is still nececcary for a transition period until investments are fully paid off by power purchase savings for these customers.

An increasing number of countries are **combining FIT schemes with competitive tendering** (auctioning) to develop the larger-scale commercial PV market. With tendering, national governments add a capacity-related instrument to the price-related FIT in order to achieve better control over the amount of installed capacity and the amount of subsidies spent on the incentive mechanisms.

In 2009, the **Taiwanese** government enacted its national Renewable Energy Development Act (REDA). At the time, Taiwan anticipated achieving the target of 75 MW in new solar PV projects. Since then, Taiwan has significantly expanded its PV target to 6.2 GW of solar PV by 2030. In late 2014, Taiwan was estimated to have a total installed solar PV capacity of just over 600 MW (NREL-CESC, 2015).

In order to achieve its ambitious target, Taiwan is using a FIT policy and a competitive tendering scheme. Winning bidders are allowed to sell electricity to Tai-Power at a constant rate for twenty years under fixed price contracts. However, Taiwan allows certain project categories to be formally exempted from the tendering process, offering a twenty-year FIT contract instead. FITs are currently offered, at different tariffs, in the following cases 1) projects between 1 kW and 10 kW that are owned by individual residents; 2) projects smaller than 30 kW; 3) projects up to 5 MW in size that are owned directly by local Government or by State-owned enterprises; and 4) projects on Government buildings that are rented to private owners and receive formal approval from local Government. This means that PV projects of less than 30 kW in Taiwan can technically apply to participate in the tendering scheme, or apply to participate in the FIT, provided they qualify. More flexibility is also given to particular project types, such as those owned by local Government.[79]

[79] In Taiwan, the administratively set rates offered under the FIT policy act as “tariff ceilings”. This means that projects that qualify for exemptions from the tendering scheme are effectively given preferential treatment: they benefit from higher tariff values and a less burdensome administrative process to obtain a contract. They also face a lower risk that their project proposal will fail to result in a contract to build. In this way, Taiwan has attempted to make it easier and more attractive for small projects under 30 kW and projects owned by local Government to participate (NREL-CESC, 2015).

Despite these efforts to retain the FIT alongside the tendering scheme and streamline the process for certain project types, more large-scale size projects, especially in the commercial size category from 100 kW–499 kW, than small-scale projects have been implemented. This includes larger FIT projects owned by local Government as well as projects that participated in the tendering scheme.

This suggests that even though a FIT (of more than USD 0.28/kWh) is offered to small-scale solar PV projects (<10 kW), this incentive does not necessarily lead to increased investments, as intended by the Government of Taiwan. However, a range of other factors could be responsible for limiting uptake. The example of Taiwan shows that while FITs may in theory reduce barriers to investment, they may not be sufficient to ensure robust market development. Thus, more attention needs to be paid to related factors, such as the availability of debt financing, administrative barriers and the total costs of project development, as well as practical challenges, such as physical access to roof space (ibid.).

To **summarize the international experience** in commercial and industrial PV rooftop markets:

- Most internationally **successful support schemes for commercial/industrial PV** rooftop markets are based on financial support measures, in particular **feed-in tariffs (fixed or tendered), feed-in market premiums or adders, tendered PPAs and net-metering schemes** (for small- and medium-size power producers)**.**
- These financial support measures were usually accompanied by **measures to lower investment barriers,** such as **priority grid access** and **streamlining of bureaucratic procedures.**
- In some countries (mostly developed countries), different forms of **tax incentives** (e.g. USA) have also proven to be effective.
- In markets where "socket parity" with retail power tariffs has been reached, **self-consumption business models**, often with third-party-ownership and ESCO models, are increasingly attractive for investors. These markets are often supported through tax credits or minimal financial incentives for excess power sale.
- Additional financing support measures, such as **debt finance** (soft loans), **financial equity** support **and non-financial support** for investors and industry (R&D, capacity building, awareness-raising) have helped foster market development.

4.7 PV Ground Mounted Utility-Level

4.7.1 Status Quo

The market for grid-connected utility PV plants is in the early inception stage. So far, there are no larger ground-mounted PV systems in operation yet. However, there a number of investment plans in utility-size PV power plants were recently announced.

According to media reports in January 2015, a **30 MWp PV plant** is currently **under development**. Located in **Quang Ngai province**, it will be connected to the grid by the end of this year. The project received investments of USD 60 million.[80]

Plans for a **100 MWp PV plant** in Central **Quang Nam Province** were announced in the media in March 2015. A Russian energy company, with Singaporian and Vietnamese investment partners, is investing USD 140 million. They are currently negotiating with EVN on market prices.[81]

However, these projects have not been implemented yet. The current framework conditions for PV investments show that is not yet a business case for the larger deployment of ground-mounted PV power plants.

The utility-scale solar PV LCOE has not reached parity with conventional energy sources yet, such as coal-fired power plants. However, fossil fueled-power generation costs are expected to increase in the near future. The UNDP Fossil Fuel Fiscal Policy Project estimates that the future price of power generation with **imported coal** will be **USD 0.10/kWh** or more once CO_2-prices of USD 5-10/ton are included. If CO_2-prices are not included, coal power generation costs will stay below USD 0.10/kWh or even USD 0.09/kWh (see GreenID, 2015).

In comparison, the PV LCOE for utility-size power plants could reach this level in the medium term in Viet Nam. **Initial estimations** conducted on the achievable **PV LCOE** by the same UNDP project consortium range from **USD 0.11 to USD 0.17/kWh** for a 10 MWp reference system at a site in Southern Viet Nam (see IoE, 2015).

In case a commercial consumer with a comparatively high electricity tariff (a customer classified as "commercial" could replace grid electricity purchases with solar power at an average value of USD 0.13/kWh, see Section 4.6.1) is located near a suitable PV power plant site, a self-consumption business model could even be implemented. Feeding solar power into the grid and selling it to EVN would depend on the negotiated power purchase agreement for this individual project. Individually negotiated PPAs or contracts with EVN for each project would of course substantially increase transaction costs for investors.

However, more detailed feasibility studies should be conducted to assess the PV LCOE and possible business models in more depth.

To summarize the **key features of this market segment** in Viet Nam:

- The utilty scale PV market in Viet Nam is in an early **"inception stage"**.
- There are **no larger PV power plants installed** so far. A small number of planned investments for multi-megawatt systems have been announced.
- **A viable business model for this segment is within reach in the medium term** (PPA for grid injection or for direct consumption in proximity of PV plant, substitute for grid expansion/enforcement), but there is **still a gap between PV LCOE** and **fossil fuel generation costs**.

[80] See http://vietnamnews.vn/economy/265316/quang-ngai-to-switch-on-60m-solar-power-station-this-year.html.
[81] See http://www.thanhniennews.com/business/russian-firm-plans-to-build-vietnams-first-solar-power-plant-40189.html.

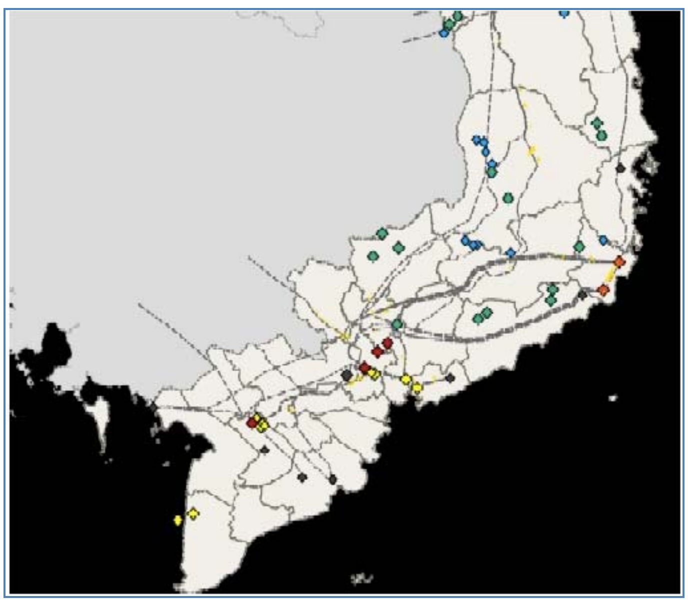
- The **domestic PV industry** is in an **early development stage** with small component manufacturing and EPC/O&M capacities.
- So far, there is no domestic experience with utility-scale PV project development, but experienced **international EPC capacities** are available in the region (e.g. Thailand).

4.7.2 Energy Market and Industry Potentials

With regard to the market potential for ground-mounted PV plants, the main restriction, apart from the economic feasibility of investments, is the availability of suitable sites. Ideal sites for ground-mounted PV plants have high solar irradiation, flat and accessible land (possibly available at low costs), and are close to medium or high voltage grid lines or high loads, such as urban or industrial areas.

In the context of a GIS-assisted research project, Nguyen (2013) identified suitable areas for **ground-mounted PV** capacities in Viet Nam, estimating an overall **potential of 22,000 MW**, mainly concentrated in Southern regions with high irradiation levels 5 kWh/m^2/day or more (Nguyen, 2013). The GIS project identified an area of 441 km^2 that meets the predefined criteria, such as those listed above.[82] Ninh Thuan province has the highest potential (approx. 4,600 MW).

Figure 32. Potential Sites for Ground-Mounted PV Plants in Southern Viet Nam (GIS-Analysis)



Source: Ngyuen (2013)

[82] The selection critera were: Solar irradiation of 5 kWh/m^2/day or more; waste land with flat topography (land slope of 5° or less), road access (distance of less than 2km) and proximity to a suitable power line (distance of less than 5km). See Nguyen (2013).

The high capacity potential for utility-scale PV power plants, especially in the South of the country, could be very benefitial for the geographical balance of power generation distribution. The demand for power in the South of Viet Nam is on the rise due to the increasing concentration of industrial production. The need for **additional power transport capacities** from the North could be reduced substantially if utility-scale PV power plants are deployed. In addition, solar power supply during times of peak load could **reduce the need for costly fossil fuel peak power** generation.

To summarize the **market potentials and possible benefits** of the further development of utility-scale PV on-grid applications:

- **There is a high potential for** increasing the **renewable energy supply** and reducing GHG emissions and fossil fuel import dependencies in the **medium term** due to the large size of the systems and the expected high number of suitable sites in Viet Nam (first estimates have identified a capacity of more than 20 GWp for Viet Nam).
- There is a **high** (medium-term) **potential** for regional **peak power demand reduction** and the **reduction of grid extension needs.**
- There is a **small potential** for domestic **industry development** (manufacturing of components and BOS, EPC, O&M).

4.7.3 Framework Conditions and Existing Restrictions

Current framework conditions in Viet Nam are not benefitial for investments in utility-scale PV applications. Since it requires grid connection and the feeding in of the energy produced, investments face substantial barriers. In addition to the very low electricity tariffs, substantial regulatory barriers hinder investments, as already highlighted in Chapter 2.3.2:

- First of all, there are **no financial or fiscal support measures** (such as Feed-in-Tariffs) in place that could close the gap between PV LCOE and alternative power generation costs.
- Secondly, there is **no standardized interconnection code** (grid code) and **connection procedure** for PV systems. Individual grid connection agreements would have to be negotiated with EVN.
- Thirdly, there is **no effective regulation on the sale of excess solar electricity** generated in private PV systems. Individual PPAs with EVN, Viet Nam's single-buyer of electricity, would have to be negotiated for each project, which substantially increases transaction costs for investors.
- Furthermore, there are very **limited domestic industry capacities** (manufacturing, EPC, O&M) that could help implement projects of this size.
- Last but not least, the **lack of an ambitious political target** for solar PV makes it more difficult to attract and foster investments in large-scale PV power plants. However, this could change with the upcoming revised PDP VII.

4.7.4 Lessons from International Experience

Most internationally successful support schemes for large-scale ground-mounted PV systems are based on **financial market support measures**, in particular **FITs** (fixed or tendered), **tendered PPAs or market premiums/adders, Renewable Portfolio Standards (RPS)** and **priority grid access.**

Utility-scale PV is different to rooftop PV in many respects. Typically, utility-scale PV involves professional investors and project developers rather than private investors, small businesses or communal stakeholders. Furthermore, the need for land instead of roof areas on top of buildings involves far more stakeholders in projects' planning and procurement stages. Most importantly, the necessary investment volumes often require the stronger involvement of local utility companies. Utilities are often found on both sides, as an investor and a purchaser of the power produced. Large-scale PV competes with wholesale power prices rather than with (typically much higher) retail tariffs. This means that utility-scale PV has not yet reached competitiveness in many countries, since it competes with low power generation costs, while rooftop PV might have already reached socket parity in the same country.

However, with the PV LCOE declining further, solar electricity generation is approaching fossil fuel power generation costs in many countries with high solar irradiation. A solar PV LCOE of USD 0.10/kWh is no longer uncommon, and the first PPA at USD 0.06/kWh was signed in Dubai in late 2014. This is an indication of how solar generation costs could in the future once optimal conditions are established (see Section 3.1.1).

In many countries, **feed-in-tariffs** have paved the way for ground-mounted PV of multi-megawatt size. In **Germany**, the EEG law_introduced a differentiated tariff for ground-mounted PV systems in 2004 (without system size restrictions to start with, later adding a system size cap of <10 MWp) in combination with requirements for eligible sites (e.g. exclusion of certain agricultural areas to avoid conflicts with different land uses in this sector). This differentiated feed-in tariff, boosted all the main market segments (residential and commercial/industrial rooftop and ground-mounted large-scale applications). Ground-mounted PV increased its share in the annual installation capacity from 10% in the beginning to 40% in peak years when the FIT was the most attractive and restrictions for the use of agricultural land were less strict. Tariffs for ground-mounted systems in Germany declined from EUR 0.32/kWh in 2009 to EUR 0.09/kWh (USD 0.1/kWh) in March 2015. With the latest EEG law amendment in 2014, the Government made a major change towards a competitive bidding system for ground-mounted PV instead of the fixed feed-in-tariff. In February 2015, the first bidding round for 150 MW started with a ceiling price of EUR 0.113 (USD 0.125).

Other countries have also chosen **competitive bidding/auctions** to achieve a price competitive large-scale PV development, either instead of fixed feed-in-tariffs or as a pricing mechanism for a market-based determination of feed-in-tariffs instead of administrational tariff setting.

China, for example, introduced renewable energy auctions in 2003 for onshore wind energy, but soon expanded them to solar PV, offshore wind and CSP. The **auctions** have been used **to determine the real price of renewable energy**-based electricity, and subsequently set the level for the FIT. As for grid-connected solar PV, a unified FIT was introduced in 2011 after two rounds of auctions for preselected sites in 2009 and 2010. The average contract price of the two bidding rounds was USD 0.16/kWh in 2010, and USD 0.13 and USD 0.107 for the two sites in 2011. The price difference of 17% and 33%, respectively, between the two bidding rounds was due to decreasing technology costs and an increasing level of competition and development in China's solar industry (IRENA, 2013).

South Africa started renewable energy auctions in 2011 to replace the national REFIT program adopted in 2009. The Renewable Energy Independent Power Producer Procurement (REIPPP) program is the leading support scheme for renewable energies and the only tariff-based support scheme currently in place in South Africa. It is mainly used to auction installations with a capacity of more than 5 MW. However, a capacity of 100 MW is reserved to auction small-scale projects with capacities of less than 5 MW. These projects are auctioned under the umbrella of the Small Projects Renewable Energy IPP Program and will be auctioned by 2016.[83] During the auction process, PV contract prices decreased by 68% over the first 3 bidding rounds in 2011-2013, from USD 0.21/kWh to USD 0.073/kWh in the final bidding round.[84] The outcome of the fourth bidding round that started in August 2014 has not yet been disclosed, but further price drops can be expected.

In order to balance price competition with investor diversity, policymakers have also attempted to combine policies in a range of different ways, including using policies such as **auctions and FITs in parallel** to encourage projects of different sizes.

Following this approach, auctions are typically used to procure larger and ground-mounted systems (e.g., >1 MW), while FITs are used to procure smaller projects (e.g., <100 kW). The aim of a combined use of instruments is to encourage investor diversity by keeping entry barriers low for certain kinds of market participants, while at the same time encouraging competition among larger project developers to secure lower prices for consumers.

France was one of the first countries in the world to combine the use of FITs and auctions for different project sizes starting in 2001, using FITs for all projects under 12 MW and a form of tendering for all projects above 12 MW. **Taiwan** followed suit in 2011, combining FITs and auctions together in a slightly different way, and remains one of the leading examples of the two being used together outside of Europe. Moreover, both Taiwan and France have used the policies to achieve similar objectives, including encouraging a wider diversity of investors, and reducing the barriers to entry for certain project sizes (NREL-CESC, 2015, p.5).

The **USA** implements **Renewable Portfolio Standards (RPS)** to create a "demand-pull" for renewable energies, mainly fostering the development of price competitive larger-scale PV systems.[85] Typically, RPS obligations are placed on the final retailers of power, who must either purchase a portion of renewable power or the equivalent amount of green certificates. Capacity-based standards mandate a fixed amount of capacity by a given date, while generation-based standards set out a given percentage of electricity generation that must come from renewable sources. Usually, RPS are most effective in more developed markets that are already in the "take-off stage" (ACE, 2013). US power utilites in many federal states are therefore obliged to meet a certain renewable energy share within their respective power portfolios. These RPS programs, implemented in 29 federal US states, have driven the creation of 1/3 of the current US non-hydropower renewable electricity (USPREF, 2012). However, studies indicate that RPS alone are not sufficient to foster substantial market

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[83] See South African Alternative Energy Association (SAAEA): http://www.saaea.org.

[84] See http://www.triplepundit.com/2014/12/south-africa-awards-contract-100-mw-concentrating-solar-power-plant/.

[85] For an overview of RPS in the USA, see USPREF (2012) and Barbose (2013).

growth for solar energy and have to be complemented with further incentives, such as FIT or auctioning schemes (ibid.).

To **summarize the international experience** in commercial and industrial PV roof-top markets:

- Most internationally **successful support schemes for large-scale ground-mounted PV** are based on financial market support measures, in particular **FIT** (fixed or tendered), **tendered PPAs or market premiums/adders, Renewable Portfolio Standards (RPS)** and **priority grid access.**
- Additional financing support measures, such as **debt finance** (soft loans), **financial equity** mechanisms **and non-financial support** for investors and industry (R&D, capacity building, awareness-raising) have helped foster market development.

5. Developing Solar Energy in Viet Nam – Assessment of Solar Market Segments and Recommendations for Future Support Strategies

This chapter assesses the market segements, prioritizes them using a comparative approach and recommends further steps of actions. Section 5.1. starts with an assessment and prioritization based on defined criteria. Subsequently, Section 5.2. contains recommendations regarding further in-depth analyses and further measures to develop the political framework as well as domestic capacities.

5.1 Assessment of Solar Market Segments and Applications for the Further Development of Support Measures

Chapter 4 analyzed the different solar market segments and applications with regard to aspects of current and potential developments and international best practice. In this section, the market segments are assessed based on a list of defined criteria.

The aim of this comparative assessment is to prioritize solar market segments and applications with development potential for Viet Nam, i.e. a high renewable energy potential that can be developed in Viet Nam with cost-effective political and financial measures and a possibly high contribution of private sector investments. **Annex I** summarizes this assessment and prioritization in form of a **matrix overview**.

Criteria for the Assessment of Solar Market Segments and Applications

Development Potential: An important criterion for this assessment of solar market segments and applications is their potential contribution to increasing the share of renewable energies in power capacities and power generation. Short- and medium-term potentials are rated higher than long-term potentials. The existence of larger investor and consumer groups with a good match of the respective load curves of these consumers with solar generation, and the ability to invest in solar energy improves the development potential and the rating in this assessment. A high increase of renewable energy capacity and energy generation also creates further benefits, such as reduced GHG-emissions, reduced needs for conventional fossil fuel energy capacities and reduced dependencies on fossil fuel imports.

Readiness for business case: The readiness for business case describes the level of cost competitiveness that a solar application has already reached in Viet Nam so far, but with a particular perspective of private investors in mind. An application with a high readiness for business case needs less financial or non-financial support to trigger market development and investments.

Existing framework conditions: The criterion "existing framework conditions" applies to both the political and administrative framework for investments on the one side (legal framework, administrational procedures and requirements etc.) and the market environment on the other side (developed value chain, level of market competition, financing environment etc.). A developed market environment that supports investments as permitted by the political framework conditions improves the rating. In turn, a complex market structure and investor environment impact negatively on the assessment rating. Since framework conditions, especially the political framework, can and should change over the course of the implemention of support and development strategies, this criterion is weighted less than the first two criteria. However, the existing framework conditions are a very important criterion at this point of the assessment, because it marks the starting point for further support.

Co-benefits for Viet Nam: The criterion "co-benefits" describes the contribution of the respective solar market to economic development in Viet Nam, such as domestic industry and job prospects. Furthermore, potential benefits for the overall energy system, such as reduced demand for additional conventional power capacities, reduced demand for costly peak power demand or a reduced need for grid-expansion, improve the rating. Further potential socio-economic benefits, such as increased access to energy for remote households and marginalized communities, are also taken into account. Since the main benefits of the solar market segments are linked to the development potentials (see the first criterion) and industry effects are often difficult to quantify, the criterion 'co-benefits' is weighted less than the first two criteria.

The application of these criteria highlights

- two market segments with a **high development potential:** *PV grid-connected commercial rooftop* applications and *solar thermal commercial hot water* applications
- two with a **medium development potential:** *solar thermal commercial/industrial heat* applications and *PV ground-mounted utility scale*
- and one with a **medium-low potential:** *PV large-scale off-grid* applications.

A strategy that comprises political and market-related (e.g. capacity building, awareness raising) development measures is recommended for these applications. Section 5.2 (and Annex II as a summary) formulates recommendations for future action.

Two other solar market segments, namely **PV on-grid residential applications** and **PV off-grid small-scale applications,** were found to have a much lower development potential based on the selected assessment criteria.

Since the resources for developing solar energy are limited, it is recommended **to concentrate on the priority segments** when formulating the political framework for solar energy in Viet Nam and developing appropriate support measures. The following section highlights these prioritized applications and their main characteristics.

PV Grid-Connected Roof-Top – Commercial Applications

The further development of commercial PV rooftop applications should be a **high priority**:

Energy/market potential: There is a **high long-term potential** for increasing renewable energy supply within the country if the PV generation costs continue to decline and the commercial and industrial electricity tariffs continue to increase as predicted. Even in the short and medium term there is a sound potential for the deployment of commercial PV applications. First estimates for Ho Chi Minh City alone show that there is a commercial demand for some hundred Megawatts of solar power.

Readiness for business case: With the current value of solar power rivaling alternative power prices at USD 0.13/kWh[86], a **viable business model is within close range** for many enterprises in various business sectors. This applies especially to self-consumption applications that are connected to the grid for sale of excess energy. As soon as current barriers regarding grid connection and power sales are removed, other business models for the sale of excess energy will become feasible, such as e.g. direct sales through third party off-takers.

Existing framework conditions: Market conditions are rather beneficial for these applications: There is a **high readiness to invest** within the business sector. Interviews and consultations with private sector stakeholders and investment corporations showed a high interest in solar PV, especially for self-consumption purposes. However, the **political framework is rather restrictive,** with a lack of regulation on grid-connection and power sales, which is the main barrier for business models that are not solely based on self-consumption of the solar power produced. These barriers should be addressed before developing further support measures for this market segment (see the following Section 5.2).

Possible co-benefits: There is a **high potential** for **peak power demand reduction** in case of high deployment and successful grid integration management. Possible negative impacts on distribution grids due to intermittent power production are manageable, at least in the short and medium term, if the right measures and a thorough monitoring system are applied.

Furthermore, there is a **small potential for PV industry development in the manufacturing sector** (manufacturing of components such as modules and inverters) and a **sound potential for installation, EPC, O&M** and the development of **ESCO business models.** Estimates reckon that the further development of solar PV in Viet Nam, including a strong commercial rooftop segment, could create a **solar PV industry sector with 15,000 to 25,000 green jobs**.

Solar Thermal Hot Water – Commercial Applications

The further development of commercial ST hot water applications should be a **high priority**:

Energy/market potential: There is a **high long-term potential** for increasing renewable energy supply within the heat energy sector. This applies to commercial applications in business sectors in particular, such as hotels, office buildings and apartment complexes, etc. Since the market for residential hot water applications seems to develop already largely

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[86] See Chapter 4.6.1 for details.

without major public support measures and has already developed a nationwide retailer infrastructure, the focus of public support efforts should be on the commercial applications.

Readiness for business case: Solar thermal domestic hot water applications have **already reached cost competitiveness** in commercial applications compared to alternative sources of hot water generation (mainly electric boilers). Investments in the hotel sector usually achieve return on investment periods of 3-5 years. With increasing system sizes and decreasing investment costs per m^2, cost competitiveness is set to increase. With expected further increases in commercial and industrial electricity tariffs, the cost competitiveness for solar thermal hot water applications will improve even further.

Existing framework conditions: With regard to the political framework for solar thermal applications, there are **no substantial regulatory barriers.** However, there are **also no supporting measures** or regulations in place that would positively affect system installation or investments. The **main barrier** for investments in this segment is related to market conditions (e.g. lack of capacities in the value chain) and a **very low level of awareness and knowledge** on the technology. This applies to public and private sector stakeholders.

Possible co-benefits: There is a **high potential** for **peak power reduction in urban and commercial power networks** if the application is deployed widely.

In addition, there is a **small potential** for **industry development** (manufacturing of components such as collectors and water storage tanks) and a **sound potential** for **installation, O&M and ESCO business models.** The further development of solar thermal in Viet Nam, including a strong commercial hot water segment, could create a **solar thermal industry sector with 9,000 to 13,000 green jobs**.

Solar Thermal Process Heat – Commercial/Industrial Applications

The further development of commercial and industrial solar thermal process heat applications should be a **medium priority**:

Energy/market potential: In general, solar thermal hot water and heat applications for commercial uses within a temperature range <120°C are widely comparable in technical terms. This applies to domestic hot water uses and low temperature industrial uses in a number of sectors, such as textile manufacturing, laundry services, food processing or pulp and paper production. However, the overall market **potential for industrial process heat applications** is only **medium** compared to the high potential for commercial domestic hot water uses due to the limited number of industrial manufacturing facilities with suitable heat processes (such as certain processes in textile, food processing or paper production).

Readiness for business case: Solar thermal process heat applications have **already reached a level of cost competitiveness** in industrial applications compared to alternative sources of hot water generation (electric or gas boilers). Initial investments in the textile sector show return on investment periods of 3-5 years. Compared to domestic hot water uses, e.g. in hotels, the **heat load profiles for industrial processes often suit the solar production curve** better since industrial processes have no demand peaks in times of low solar irradiation during the day. Furthermore, industrial applications do not require any hygiene measures for the hot water generated. This reduces investment costs compared to domestic hot water systems. With increasing system sizes and decreasing investment costs per m^2, cost competitiveness will increase. With expected further increases in commercial and industrial electricity tariffs, solar thermal process heat applications will become even more cost competitive.

Existing framework conditions: **No substantial regulatory barriers** to system installation or investments are in place, but there are **also no supporting measures** or regulations. The **main barrier** to investments in this segment is related to market conditions and a **very low level of awareness and knowledge** about the technology. This applies to public and private sector stakeholders.

Possible co-benefits: If deployed widely, there is a **medium potential** for **peak power reduction in urban and commercial power networks** using solar thermal process heat applications**.** Due to the high power demand of industrial heating processes, the effects of peak power reductions can be significant for local networks.

In addition, there is a **small potential** for **industry development** (manufacturing of components such as collectors and water storage tanks) and a **sound potential** for **installation, O&M and ESCO business models.** Estimates reckon that the further development of solar thermal energy in Viet Nam, including a developed industrial heat segment, could create a **solar thermal industry sector with 9,000 to 13,000 green jobs**.

PV Ground-Mounted – Utility-Scale

The further development of ground-mounted PV of utility-size should be a **medium priority**:

Energy/market potential: Due to the rather large amount of technically suitable sites and the large size of the installed systems, there is a **high long-term potential** for ground-mounted PV systems to increase the renewable energy supply in Viet Nam. Initial estimations based on a GIS-analysis of suitable sites identified a potential of **more than 20 GW** in Viet Nam[87].

Readiness for business case: **A viable business case** for investments in ground-mounted PV systems is only within **reach in the medium term.** Despite the lower investment costs per kW for large systems (due to economies of scale effects), there is still a substantial gap between PV LCOE and fossil fuel generation costs, at least as long as external costs (i.e. environmental and health costs caused by fossil fuel emissions) are not considered. Initial estimates on the utility-scale **PV LCOE** were calculated by the Institute of Energy, identifying a range of **USD 0.11-0.17/kWh** with average cost **of USD 0.14/kWh**. In comparison, future LCOE for new coal power plants, including a limited amount of external costs and the cost of coal imports ranges at USD 0.10/kWh.

In case a **direct commercial consumer** is located in proximity to a ground-mounted PV plant, a viable business case could be within close range. PV power could then replace power purchases from the grid at retail price level.

Existing framework conditions: Currently, the **political framework** for ground-mounted PV power plants is **rather restrictive** with a lack of regulation on grid-connection and power sales. However, some planned investments in large-scale PV power plants were announced in early 2015. Without a regulatory framework these investments depend on individual contract terms negotiated with EVN as the prospective purchaser of the power produced.

[87] See Chapter 4.7.2 for details.

Furthermore, there is currently no regulatory framework in place to deal with the potential of direct sales arrangements.

Possible co-benefits: There is a **small potential for PV industry development** in the manufacturing sector (manufacturing of components such as modules and inverters) and a **sound potential** for **EPC, O&M** and the development of **ESCO business models** in the case of large-scale development of PV ground-mounted PV with small or medium size systems up to 10 MWp. In the case of larger-scale systems (possibly only a few in number), it is more likely that international project developers will cover most of the value chain and system components. The creation of jobs directly related to a large-scale PV segment will be limited for the same reasons as for distributed roof-top PV. So far, there is no domestic industry capacity and experience with multi-MW PV power plants.

With regard to the power network integration, large-scale PV power plants could have **positive impacts** on **peak demand supply** and on local **grid stability** by delivering reactive power or other grid functions, especially in the Southern parts of Viet Nam.

PV Off-Grid Large-Scale Applications

The further development of PV off-grid large-scale applications with a focus on island applications should be a **medium/low priority**:

Energy/market potential: The overall **potential for large-scale PV Off-Grid** applications to increase renewable energy supply in Viet Nam **very limited**. This is mainly due to the very high level of electrification. Futhermore, other means of electrification "compete" with off-grid solar applications in the remaining non-electrified areas, especially in the mountaineous regions, such as small hydropower facilities and, in the long term, grid connection. However, there is **some potential** to electrify Viet Nam's **islands** that are currently supplied with costly diesel-generated electricity.

The electrification of islands with reliable and clean power sources is a **high priority for the Vietnamese Government**. This political aim is embedded into Government's overall electrification and energy access strategy.

Readiness for business case: For some large-scale PV off-grid applications a viable **business model is within close reach**. This applies in particular to PV applications that replace diesel-generated electricity in remote areas and on islands where diesel costs are substantially higher due to additional transport costs. These **"fuel saver" business models** are already cost competitive with diesel-generated electricity costs of USD 0.30 to USD 0.40/kWh compared to a PV off-grid LCOE of USD 0.20 to USD 0.30. This may also be viable in comparison to grid connection costs.

A **few larger PV off-grid systems, often implemened as hybrid** systems in combination with diesel generators, wind turbines and/or battery storage, have already been installed on Vietnamese islands. Furthermore, the first commercial ESCO business models are under development.

Existing framework conditions: The political framework for off-grid applications is mainly shaped by the **national rural electrification strategy** and the various **support measures** implemented by the Vietnamese **Government** and **international donor and financing institutions**.

From an investor point of view, „competition“ with the politically-driven **grid expansion** might hinder further private sector investments in this sector (some bigger islands such as Phu Quoc and Ly Son have already been connected to the grid). In other rural areas, the existing financial **Government and donor support** might also discourage further private sector investments.

However, the strong political support for electrifying the remaining rural areas and islands could be a **good starting point for the development of tailor-made support measures** in order to develop this sector in an effective and cost efficient manner. This political objective would have to be backed by substantial public financial support, as the current retail tariff structure does not allow for cost coverage for private sector investment models.

Possible co-benefits: There certainly is a small potential for the development of an off-grid focused EPC and O&M sector. A few domestic companies already have experience in planning, constructing and operating off-grid PV and hybrid systems. These industry capacities could be strengthened and developed further through a growing off-grid PV market. A highly valued benefit of expanding off-grid PV is the increased access to energy for remote and marginalized communities and islands that otherwise only have limited or costly access to electricity. Again, strong publicly funded incentives would have to be put in place to reap these benefits.

Other Solar Market Segments and Applications with Less Development Potential

The assessment identified two solar market segements with less overall development potentials, making the further development of these applications a low priority:

Firstly, **residential PV roof-top applications** are least likely to become **a business case without substantial financial support**. With very low residential power tariffs and the comparatively high LCOE for small-scale PV rooftop systems, the gap between solar generation costs and residential electricity tariffs is substantial, at least in the mid-term perspective. Despite the generally high long-term potential of residential PV that could cover substantial parts of household peak power demands (e.g. for airconditioning) in the future, the short- and mid-term perspectives are not promising when considering cost effectiveness. Facing the same restrictive political framework as the commercial rooftop segment, residential PV cannot rely on large investor groups to invest in solar PV. Support measures would have to include substantial financial support to cover the competitiveness gap and motivate private house owners to invest.

Secondly, **small-scale PV off-grid applications,** such as Solar Home Systems up to 1 kWp size, BTS or applications for public use, also lack an overall development potential and are therefore not recommended for priority development. These applications have **limited possibilities to develop business models** (such as pricing models for power charging stations, leasing schemes for solar water pumps or SHS). Potential customers for these business models often lack the ability to invest even small amounts of money. Furthermore, the Government and international donor activities are already focussing on this segment with the objective of increasing access to energy in rural areas.

5.2 Key Recommendations and Future Fields of Action

Following the above comparative assessment of the solar market segments and applications, those solar market segments with a high or medium overall development potential should be developed strategically.

Due to the similarities between **solar thermal commercial hot water** and **industrial process heat** applications, both in technical and marketing terms, an **integrated strategy** could be developed for those two segments.

Although the potential for the further development of **large-scale PV off-grid applications** is only medium/low, they can still play a role in the future due to the **high political value** of increasing access to energy and supplying islands with cost-efficient and clean energy. As mentioned above, the deployment of these applications would have to depend on strong public financial support.

Depending on future research and available resources for support measures, **all four market segments** (**PV commercial rooftop**, **ST commercial hot water/process heat**, **PV ground-mounted utility-scale** and **PV off-grid large-scale**) should be developed and respective support measures should be implemented.

The **commercial and industrial solar PV and solar thermal hot water applications** have the highest development potential and the smallest need for support. In case of limited resources for support measures, a solar energy development strategy should therefore **focus primarily on the market segments** that are **the highest priorities** and continue developing the other segments as resources become available.

An integrated and incremental development strategy for each of these solar market segments can be divided into **four steps** (for an overview of these recommended measures see the **matrix overview in Annex II**):

In-Depth Stock-Taking

Firstly, **further in-depth stock-taking analyses** should be done. A main objective of this further analytical work should be to collect more detailed and valid data on **the market conditions and/or energy demand potentials** for different consumer or investor groups. It would then be possible to **preselect high-potential and suitable sub-sectors** for further development and support measures (such as the textile or hotel sector).

With a more technical perspective on grid-connected PV, more concrete analyses could focus on **grid integration capacities** and the possible effects of the large-scale deployment of distributed PV in certain power network areas or typologies.

Feasibility Studies

Subsequent to further in-depth analyses, **feasibility studies** for selected solar applications could help better understand development potentials and detailed support needs for the related market segments. This should also include the assessment of the different available business models and financing mechanisms.

In case of available resources it would be beneficial to build one or two **pilot projects for demonstration,** awareness-raising and technical training in the context of subsequent capacity building measures. Ideally, such pilot projects should be sustainable investments and operate in the long term. Therefore, it would be beneficial to involve private sector investors and/or power purchasers to create viable business models for their operation.

Development of Political Framework

The next step includes the **development of the political framework** and the implementation of political support measures or adjustments to the legal-administrative framework.

This entails an **in-depth analysis of international political best practice,** possibly including study tours and match-making events for political decision-makers and other key stakeholders.

Furthermore, this step should include an **extensive political dialogue** and **exchange with key stakeholders** in the private sector in particular.

Each development strategy for solar market segments should implement **measureable short-, mid- and long-term targets,** such as the German "1,000 Rooftop Program".

In addition to possible financial support measures, such as a net-metering scheme for PV rooftop applications or a tendered FIT for utility-scale PV systems, further **financing support measures** (such as soft loan programs) should be considered and developed in case of available resources. Furthermore, an accelerated tax depreciation process for solar energy equipment, as suggested by many investors and private sector stakeholders for Viet Nam, has proved to be a successful investment trigger in other markets. Accelerated tax depreciation can help to overcome investment barriers related especially for new technologies that are cost competitive but not yet introduced in markets.

Capacity Building

Finally, in addition to shaping political framework conditions, capacity building measures should be developed based on the specific needs of certain solar market segments. This should include **industry development** in selected parts of the value chain (e.g. EPC and technical system planning capacities for commercial and industrial solar thermal applications), quality issues related to solar components and system design, and operation or business model development.

Furthermore, a strong focus should be placed on **awareness-raising and knowledge transfer** related to technical (technical potentials of solar energy in different applications) and economic issues (economic feasibility of solar energy applications, business models, etc). These measures are particularly important for market segments such as commercial and industrial solar thermal applications that have already reached a high level of cost competitiveness but struggle with reluctant customers who have limited knowledge of the technology and its concrete potentials for their respective business operations.

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Annex I. Matrix - Assessment of Solar Market Segments and Applications for Viet Nam

Annex II. Matrix - Future Fields of Action

Annex III. List of Stakeholders Interviewed and Consulted

ANNEX I. MATRIX - ASSESSMENT OF SOLAR MARKET SEGMENTS AND APPLICATIONS FOR VIET NAM

Solar Thermal	Status Quo Viet Nam	Potential/Co-Benefits (Energy/Socio-Econ.)	Framework Conditions/Barriers	International Best Practice/Experience	Overall Assessment of Market Segment*	
ST Domestic Hot Water **Commercial**	• Market in **"Take-off phase".** • **Already commercial**/ general cost competitiveness reached with **no substantial need for financial support** measures. • Most **mature solar market** segment in Viet Nam (approx. **100,000 systems**/ **285** MW_{th} installed). • **Investments driven by business model** (power savings) without substantial subsidies. • **Developing industry** with small domestic component manufacturing and EPC capacities, and larger capacities for **distribution and O&M**.	• **High potential** for increasing **renewable energy supply** and reducing GHG emissions and fossil fuel import dependencies in case of short-/mid-term expansion of deployment. • **Relatively "Low-cost" support measures** could scale up investments and market development. • High potential for **peak power demand reduction** in case of high deployment (commercial DHW applications). • **Small potential** for **industry development** (manufacturing of components) but **good potential** for **installation, O&M and ESCO.**	• **No political target** for solar thermal energy. • **Not included in energy efficiency strategy** for buildings. • **No substantial subsidies** (except a VND 1 million grant program). • **No substantial** market/ regulatory **barriers** for system installation or investments. • **Limited domestic industry capacities** (installation, EPC, O&M).	• Integrated **RE** and **energy efficiency** strategy. • **Financial incentives** (investment grants, soft loans, tax credits) for scaling up investments. • **Public R&D programs** for industry support. • **Solar building obligations** in further developed markets. • **Pilot and demonstration projects** for awareness-raising (larger commercial applications). • **Capacity building for industry** (system integration, EPC/ O&M) and **investors** (business models).	**Development Potential** (market development and solar energy capacity deployment) **Readiness for Business Case** (level of competitiveness/ investment attractiveness without financial support) **Existing Framework Conditions** (political/market-related, beneficial/restrictive) **Co-Benefits for Viet Nam** (industry/job development/energy system) **Overall Priority**	↗ ↗ → ↗ **High**
ST Heat **Industrial**	• Market in **"Inception phase"**. • Only a **few systems** installed (process heat, no solar cooling projects so far). • Investments mainly driven by **business model** (energy savings, ROI in 3-5 years) without substantial subsidies. • Public sector and **first mover** private sector players (EPC, ESCO, domestic and international).	• **Limited potential** (short-term) for increasing **renewable energy supply** and reducing GHG emissions and fossil fuel import dependencies**.**. • **Long-term potentials** are **medium** due to a limited number of industrial manufacturing processes. • **"Low-cost" financial support measures/effort** could trigger investments and market development. • **Small potential** for industry development (EPC, system integration/ planning, component manufacturing).	• **No political target** for solar thermal energy. • **Not included in energy efficiency strategy** for industry. • **No substantial subsidies or support measures**. • **Low awareness** on technology, potentials and benefits (even lower on solar thermal cooling). • **High capacity building demand**. • **Lack of financing** (high up-front costs). • **Ambitious ROI expectations** (<3 years)	• **Financial incentives** (investment grants, soft loans, tax credits) for scaling up investments. • **Public R&D programs** for industry support. • **Pilot and demonstration projects** for awareness-raising. • **Capacity building for industry** (system integration, EPC/ planning) and **investors/industrial sectors**.	**Development Potential** (market development and solar energy capacity deployment) **Readiness for Business Case** (level of competitiveness/ investment attractiveness without financial support) **Existing Framework Conditions** (political/market-related, beneficial/restrictive) **Co-Benefits for Viet Nam** (industry/job development/ energy system) **Overall Priority**	→ ↗ → → **Medium**

PV Off-Grid	Status Quo Viet Nam	Potential (Energy/Socio-Econ.)	Framework Conditions/Barriers	International Best Practice/Experience	Overall Assessment of Market Segment*	
PV Off-Grid, Small **Pico-Solar/SHS/...**	• **No "market",** investments **dominated by Government and ODA funding or corporate CSR** budgets (no viable business models for power consumers). • Only **limited possibilities to develop business models** (solar power charging stations/SHS-lease/ solar water pumps). • About **10-15.000 small scale systems** installed (Pico PV, SHS, BTU etc.). • Government and ODA focus on **socio-economic objectives** ("access to energy" in rural areas/for poor and marginalized communities).	• **Very limited potential** for increasing **renewable energy supply** and reducing GHG emissions and fossil fuel import dependencies (**98% rural electrification** already accomplished). • Small potential for **development of local/ domestic manufacturing/ installer/O&M sector**. • Increased **access to energy** in remote/rural areas is **important political aim** of the Vietnamese Government.	• **Government target** of **100% electrification** by 2020 (rural electrification program). • Politically-driven **grid expansion** is "competing" with RE investments in rural electrification. • Strong financial **Government and donor support**, partly discouraging private sector investments. • **No viable business models** for commercial applications so far. • Existing **corporate CSR programs** (e.g. Schneider Electric). • **Lack of local capacities/ skills/ information** regarding solar energy opportunities/ technology/ O&M/ business development).	• Small-scale domestic and non-domestic off-grid PV **dominated by ODA-/public funding** models. • Some **commercial business models implemented** with financing support (e.g. SHS-leasing in Africa). • **Capacity building for local stakeholders** (municipal governments, communities, SME enterprises etc.) and **investors/commercial sectors**.	**Development Potential** (Market development and solar energy capacity deployment)	↘
					Readiness for Business Case (Level of competitiveness /investment attractiveness without financial support)	↘
					Existing Framework Conditions (Political/market-related, beneficial/restrictive)	↘
					Co-Benefits for Viet Nam (Industry/job development/energy system)	↘
					Overall Priority	**Low**
PV Off-Grid, Large **Mini-Grid/PV Hybrid**	• Market in **"Inception phase"** but still dominated by Government/EVN/ODA funding. • Viable **business model within reach** (fuel saver/ substitute for grid connection). • A **few larger mini-grid and PV hybrid** (diesel, battery, wind) **systems** have been implemented, mainly on islands. • First commercial **ESCO business models** under development (PPP with EVN/Navy).	• **Very limited potential** for increasing **renewable energy supply** and reducing GHG emissions and fossil fuel import dependencies (**98% rural electrification** already accomplished, limited number of communities/islands with no access to grid). • Small potential for **development of local/ domestic manufacturing EPC/O&M sector.** • Increased **access to energy** in remote/rural areas is **important political aim** of the Vietnamese Government.	• **Government target** of **100% electrification** by 2020. • Politically-driven **grid expansion** is "competing" with RE investments in rural electrification (e.g. Phu Quoc, Ly Son). • Strong financial **Government and donor support** and **EVN and Navy involvement**, partly discouraging private sector investments. • **Lack of local capacities/ skills/information** regarding solar energy opportunities/ technology/ O&M/business development.	• Larger scale off-grid PV (mini-grid/hybrid) **still** often **dominated by ODA-/public funding** models. • **Viable commercial business models implemented** with financing support (ESCO/PPA models) in public and commercial sector (mining, etc.). • **Capacity building for local stakeholders** (municipal governments, communities, SME enterprises, etc.) and **investors/commercial sectors**.	**Development Potential** (Market development and solar energy capacity deployment)	↘
					Readiness for Business Case (Level of competitiveness /investment attractiveness without financial support)	→
					Existing Framework Conditions (Political/market-related, beneficial/restrictive)	→
					Co-Benefits for Viet Nam (Industry/job development/energy system)	↘
					Overall Priority	**Medium/ Low**

PV Grid-Connected	Status Quo Viet Nam	Potential (Energy/Socio-Econ.)	Framework Conditions/Barriers	International Best Practice/Experience	Overall Assessment of Market Segment*	
PV Grid-Connected Residential Roof	• Market in early **“Inception phase”**. • **Only very few systems** installed so far. • **No viable business case** due to very low residential power prices compared to relatively high PV LCOE for small systems within short-term reach. • **Domestic PV industry** in **early development stage** with small component manufacturing and installer/EPC/O&M capacities.	• **Limited potential for** increasing **RE supply** and reducing GHG emissions and fossil fuel import dependencies in the **short term**, due to a lack of competitiveness. **High potential in the medium and long-term** in case of further PV cost reductions and increases in residential power prices. • High (long-term) potential for **peak power demand reduction**. • **Financial support** measures could be **“high cost”** if implemented to early. • **Small potential** for **industry development** (manufacturing) but **good potential** for **installation, O&M and ESCO businesses.**	• **Political target** for solar PV in the revised PDP VII is still unclear. • **No substantial financial support** (not included in FIT scheme). • **Substantial** market/regulatory **barriers** for **grid connection** and excess **power sales** (no standard regulations). • **Low public awareness** of technology, potentials and benefits. • **Limited domestic industry capacities** (manufacturing, EPC/ installation, O&M).	• Most internationally **successful support schemes for residential PV** are based on financial market support measures, in particular **FIT, net metering and priority grid access.** • In some countries (mostly developed countries), **tax incentives** (e.g. USA) have been effective. • Additional **debt finance** (soft loans), **financial equity** mechanisms **and non-financial support** for investors and industry (R&D, capacity building, awareness-raising).	**Development Potential** (Market development and solar energy capacity deployment) **Readiness for Business Case** (Level of competitiveness /investment attractiveness without financial support) **Existing Framework Conditions** (Political/market-related, beneficial/restrictive) **Co-Benefits for Viet Nam** (Industry/job development/energy system) **Overall Priority**	→ ↘ ↘ → **Low**
PV Grid-Connected Commercial / Industrial Roof	• Market in **“Inception phase”**. • Only a **few systems have been installed** but there is growing interest among commercial/industrial investors. • Most non-residential rooftop systems are **pilot/demonstration projects**. • Viable **business model within close reach** (self-consumption, if possible with excess power sale, investment or ESCO model), **PV LCOE** almost in **parity with grid power costs.** • **Domestic PV industry** in **early development stage** with small manufacturing and installer/EPC/O&M capacities.	• **Medium potential for** increasing **RE supply** and reducing GHG emissions and fossil fuel import dependencies in the **short term**. • **High RE energy potential in the medium term** in case of further PV cost reduction and increase of commercial/industrial power prize level. • **High** (long-term) **potential** for **peak power demand reduction** in case of high deployment and successful grid integration management. • **Small potential** for **industry development** (manufacturing of components) but **good potential** for **installation/EPC, O&M and ESCO businesses.**	• **Political target** for solar PV in the revised PDP VII is still unclear. • **No substantial financial support** (not included in FIT scheme). • **Substantial** market/regulatory **barriers** for **grid connection** and excess **power sales** (no standard regulations). • **Growing awareness and interest** among commercial power consumers. • **Limited domestic industry capacities** (manufacturing, EPC/ installation, O&M).	• Most internationally **successful support schemes for commercial/industrial rooftop PV** are based on financial market support measures, in particular **FIT, premiums/adder, net metering** (for medium size power producers) **and priority grid access.** • In some countries **tax incentives** (e.g. USA) have been effective. • Additional **debt finance** (soft loans), **financial equity** mechanisms **and non-financial support** for investors and industry (R&D, capacity building, awareness-raising).	**Development Potential** (Market development and solar energy capacity deployment) **Readiness for Business Case** (Level of competitiveness /investment attractiveness without financial support) **Existing Framework Conditions** (Political/market-related, beneficial/restrictive) **Co-Benefits for Viet Nam** (Industry/job development/energy system) **Overall Priority**	↗ ↗ → ↗ **High**

PV Ground-Mounted/Utility Scale	• Market in **“Inception phase”**. • **No larger PV power plant has been installed** so far, some recent announcements of planned investments in multi-megawatt systems. • **Viable business model within medium reach** (PPA for direct consumption in proximity of PV plants, substitute for grid expansion/enforcement) but there is still **a gap between PV LCOE** and **fossil fuel generation costs**. • **Domestic PV industry** is in **its early development stage** with small component manufacturing and EPC/O&M capacities. • **Limited domestic experience with multi-MW-PV,** but international **EPC capacities** are available in the region.	• **High potential for** increasing **renewable energy supply** and reducing GHG emissions and fossil fuel import dependencies in the **medium term** due to the large size of systems. • **High** (medium-term) **potential** for regional **peak power demand reduction.** • **Small potential** for **industry development** (manufacturing of components and BOS, EPC, O&M).	• **Political target** for solar PV in the revised PDP VII is still unclear. • **No substantial financial support** (not included in FIT scheme). • **Substantial** market/regulatory **barriers** for **grid connection** and excess **power sales** (no standard regulations). • Initial **expert/stakeholder inputs** are paving the way (solar maps, grid code draft, etc.). • Recent interest of investors (announcements for multi-MW-PV-investments). • **Limited domestic industry capacities** (manufacturing, EPC, O&M).	• Most internationally **successful support schemes for large scale ground-mounted PV** are based on financial market support measures, in particular **FIT** (fixed or tendered), **tendered market premiums/adders, Renewable Portfolio Standards (RPS)** and **priority grid access.** • Additional **debt finance** (soft loans), **financial equity** mechanisms **and non-financial support** for investors and industry (R&D, capacity building, awareness-raising).	**Development Potential** (Market development and solar energy capacity deployment)	↗
					Readiness for Business Case (Level of competitiveness /investment attractiveness without financial support)	→
					Existing Framework Conditions (Political/market related, beneficial/restrictive)	↘
					Co-Benefits for Viet Nam (Industry/job development/energy system)	→
					Overall Priority	**Medium**

*** CRITERIA FOR THE ASSESSMENT OF SOLAR MARKET SEGMENTS AND APPLICATIONS:**

Aim of the assessment: The aim of this comparative assessment of solar market segments is to prioritize solar applications with high renewable energy potentials that can be developed in Viet Nam through cost-effective political and financial measures and a possibly high contribution of private sector investments. Subsequent to this prioritization, further in-depth analyses are recommended before technical, financial and capacity development support can be developed (see also Annex II with an overview of recommended future fields of action).

Development potential: An important criterion for the assessment of solar market segments and applications is their potential contribution to raising the share of renewable energies in power capacities and power generation. Short- and medium-term potentials are rated higher than long-term potentials. The existence of larger investor and consumer groups with a good match of respective load curves with solar generation and with the ability to invest in solar energy will improve the rating. A high increase in renewable energy capacity and energy generation will also create additional benefits, such as reduced GHG-emissions, reduced needs for conventional fossil fuel energy capacities and reduced dependencies on fossil fuel imports.

Readiness for business case: The readiness for business case describes the level of competitiveness that a solar application has already reached in Viet Nam so far, i.e. the level of socket parity or generation parity with alternative sources of energy supply. This in turn means that an application with a high readiness for business case needs less financial or no financial support to trigger market development and investments.

Existing framework conditions: The criterion “existing framework conditions” applies to the political and administrative framework for investments and the market environment. A developed and beneficial market environment that fosters investments if political framework conditions are attractive will improve the rating. In contrast, a non-beneficial market environment will downgrade the assessment rating. Since framework conditions, especially the political framework, change throughout the implementation of support and development strategies, this criterion is weighted less than the first two criteria. Nonetheless, the existing framework conditions are a relevant criterion at this point of the assessment, marking the potential beginning for further support efforts.

Co-benefits for Viet Nam: The criterion “co-benefits” applies to the possible contributions of the respective solar market segment to economic development in Viet Nam, such as domestic industry and job effects. Furthermore, potential benefits for the overall energy system, such as reduced demand for additional conventional power capacities, demand for costly peak power demand or a reduced need for grid-expansion, will improve the rating. Further potential socio-economic benefits, such as increased access to energy for remote households and marginalized communities, are also taken into account. Since the main benefits of developing solar market segments are related to the respective development potentials (see the first criterion) and industry effects are often difficult to assess, the criterion “co-benefits” is weighted less than the first two criteria.

ANNEX II. MATRIX – FUTURE FIELDS OF ACTION FOR KEY SOLAR MARKET SEGMENTS

ST – Commercial Domestic Hot Water/Process Heat

In-Depth Stock-Taking

- **Analysis of high potential business sectors for ST hot water applications (tourism, office providers, apartment housing, etc.) and low temperature process heat (laundries, food processing, textile, etc.).**
- **Selection of 2-3 high-potential business sectors for future analytical and support measures.**
- **In-Depth-Analysis of political framework, existing regulatory gaps** (integrated RE-EE strategy), **industry capacities and investment barriers (detailed stakeholder interviews)**.

Feasibility Studies

- **Feasibility Studies in the selected sectors for different applications (domestic hot water and process heat <120°C, generation costs, ROI)**.

Development of Political Framework

- **In-Depth-Analysis of international best practice and exchange of experience (1-2 study tours).**
- **Political and Stakeholder-Dialogue**.
- **Development of political support measures (tax incentives, grant program, 1,000-roof-program, pilot systems, etc.).**
- **Development of Financing Component (soft loan program, grant fund for 1,000-roof-program, etc.).**

Capacity Building

- **Awareness-raising** in high-potential business sectors **(stakeholder workshops, training, match-making events).**
- **Capacity building for industry** (quality of components/systems, EPC-capacities, business models, solar business association).

PV – Off-Grid Islands/Hybrid

In-Depth Stock-Taking

- **Analysis of realizable potentials for solar PV/hybrid** on islands.
- **In-Depth-Analysis of investment conditions, existing regulatory gaps, industry capacities** and **investment barriers** in dialogue with EVN, Vietnamese navy and other stakeholders and potential private sector investors.

Feasibility Studies

- **Feasibility Studies** for different applications (PV-diesel, PV-Wind-Diesel, battery).
- **1-2 pilot PV-hybrid projects on selected islands** as models and for further capacity building measures.
- **Assessment** of possible **PPP-approaches** and **related business models** to attract more private investments.

Development of Political Framework

- **In-Depth-Analysis of international best practice** and **exchange of experience** (1-2 study tours).
- **Political and Stakeholder-Dialogue.**
- **Development of political support measures** (tax incentives, grant program, 100-island-program with 10 pilot systems, etc.).
- **Development of Financing Component** (soft loan program, grant fund, etc.).

Capacity Building

- **EPC capacities: technical system planning.**
- **System operation, maintenance and management.**
- **Business-model development.**
- **Capacity building for local stakeholders** (municipal Government, communities, SME enterprises, etc.).

PV – On-Grid: Commercial Roof

In-Depth Stock-Taking

- **Analysis of high potential business sectors** for PV self-consumption applications (retailers, hotels, office providers, manufacturing, etc.).
- **Selection of 2-3 high-potential business sectors** for future analytical and support measures.
- **In-Depth-Analysis of political framework, existing regulatory gaps, industry capacities** and **investment barriers** (detailed stakeholder interviews).
- **(Analysis of grid integration capacities for distributed PV** in different grid typologies/regions).

Feasibility Studies

- **Analysis of prospective business models** (self-consumption, PPA etc.) and **Feasibility Studies** (respective PV LCOE/IRR to determine demand for support).

Development of Political Framework

- **In-Depth-Analysis of international best practice** and **exchange of experience** (1-2 study tours).
- **Political and Stakeholder-Dialogue**.
- **Development of political support measures** (tax incentives, Net-metering, FIT, 1,000-commercial-roof-program, pilot systems, R&D program for industry, etc.).
- **Development of Financing Component** (soft loan program, grant fund, etc.).

Capacity Building

- **Awareness-raising in high-potential business sectors** (stakeholder workshops, training, match-making events).
- **Capacity building in different parts of the PV value chain** (EPC, O&M, product and system quality, business models, solar business association, etc.).

PV – On-Grid: Ground-Mounted

In-Depth Stock-Taking

- Analysis of **high-potential sites** in different regions (South/Central, GIS-analysis, including grid capacity analysis).
- **In-Depth-Analysis of political framework, existing regulatory gaps, industry capacities** and **investment barriers** (detailed stakeholder interviews).
- **Pre-selection of 3-5 high-potential sites** (e.g. for FIT-setting auctions).

Feasibility Studies

- **Analysis of prospective business models** (self-consumption, PPA, etc.) and **Feasibility Studies** (respective PV LCOE/IRR to determine support demand).

Development of Political Framework

- **In-Depth-Analysis of international best practice** and **exchange of experience** (1-2 study tours).
- **Political and Stakeholder-Dialogue**.
- **Development of political support measures** (fixed/auctioned FIT, auctioned PPA, tax incentives etc.).
- **Development of Financing Component** (soft loan program, grant fund, etc.).

Capacity Building

- **Capacity building in different parts of the PV value chain** (EPC, O&M, product and system quality, business models, solar business association, etc.).

Annex III – List of Stakeholders Interviewed and Consulted

Institution	Name	Position
AECID - Embassy of Spain to VN	Juan Pita	General Coordinator of Cooperation
AEE Institute for Sustainable Technologies, Austria	Christoph Brunner	Head of Department for Industrial Processes and Energy Systems
Artelia Group	Nicolas Jallade	Senior Project Manager
Aschoff Solar, Germany	Carsten Aschoff	General Director
BTC Belgian Development Agency	Jerome Meessen	Technical Advisor on Green Growth Strategy Facility
CIEMAT, Madrid/Spain	Jesus Polo	PV Solar Energy Researcher
Delegation of the European Union to Viet Nam	Antoine Vander Elst	Program Officer Budget Support & Blending Operations
Dragon Capital	Gavin Smith	Director Clean Development
ECC HCMC	Nguyen Van Phu	Renewable Energy Department Officer
ECC HCMC	Diep The Cuong	Vice Chief of Renewable Energy Department
Energy Consultant	Nguyen Quoc Khanh	Independent Consultant
EuroCham	Ywert Visser	Chairman of Green Growth Sector Committee
German Chamber of Commerce	Le Hai Duong	Head of Projects
German Chamber of Commerce	Marko Walde	Chief Representative
Green Innovation and Development Center	Maarten Akkermann	Researcher
ICASEA-SEA (International Copper Association Southeast Asia)	Vu Quang Dang	Consultant
METRO VN	Nguyen Truong Thanh	Technical Operations Officer
Schneider Electric	Meriem Kellou	Social Responsibility Officer
SNV Netherlands Development Organisation	Dagmar Zwebe	Sector Leader Renewable Energy
SNV Netherlands Development Organisation	Nguyen Thi Thu Ha	Renewable Energy Advisor
Solar BK	Nguyen Duong Tuan	General Director
Solar BK	Nguyen Anh Tuan	Marketing Director
Solar ESCO	Hoang Thi Uyen	Deputy Director Investments and Corporations
Solareo	Pratik Goshal	Business Development Director
Terramar VN	Luong Tat Hung	Project Officer Solar Energy
Terramar VN/German Business Association	Alexander Bischoff	CEO/Member of GBA Board
UNDP	Koos Nefjes	Policy Advisor Climate Change
UNDP	Dao Xuan Lai	Head Sustainable Development Unit
UNDP	Maureen Boyle	Energy Efficiency and Renewable Energy Officer
USAID/Winrock International	Joseph Deringer	Chief of Party

USAID/Winrock International	Vu Thi Kim Thoa	Deputy Chief of Party
VietESCO/ECC HCMC	Tran Hieu Trung	Deputy Director
WK Management Consulting	Werner Koldehoff	Solar Energy Consultant
World Bank	Franz Gerner	Energy Sector Coordinator