Vietnam: Achieving 12 GW of Solar PV Deployment by 2030

An Action Plan

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Analysis and Report by the World Bank Energy Team: Sabine Cornieti, Franz Gerner, Clara Ivanescu, Oliver Knight, Martin Schroeder, and Ky Hong Tran

Peer Reviewers: Gabriela Elizondo Azuela, Oliver Behrend, and Razvan Purcaru

Editor: Steven Kennedy

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EXECUTIVE SUMMARY

Solar power is an increasingly attractive electricity generating option for Vietnam thanks to recent cost reductions, fast construction, and the contribution solar power can make to ensuring energy security and environmental sustainability. To meet the country's target of having 12 GW of solar power capacity installed by 2030, the Government of Vietnam should consider a deployment strategy that builds experience, lowers costs, and maximizes economic benefits. This document has been developed based on the results of studies conducted for Vietnam by the World Bank, including (i) economic and financial modelling; (ii) grid integration analysis; (iii) geospatial analysis encompassing solar power potential and land availability; (iv) a review of the options for financing renewable energy projects; (v) an analysis of the solar photovoltaic supply chain; and (vi) an analysis of deployment options.

Key Findings

- **A well-organized solar auction in Vietnam in 2019 could result in power purchase agreements with prices of US$0.055–0.065/kWh over 25 years** (in levelized real terms and with an appropriate allocation of contractual risk). The key parameters in achieving these low tariffs are high solar irradiation, low capital expenditures, a low cost of capital, and bankable long-term contractual agreements (primarily power purchase agreements and government support agreements).
    - The South of Vietnam has the highest solar irradiation, with four provinces standing out (Binh Thuan, Ninh Thuan, Binh Phuoc, and Tay Ninh).
    - Capital expenditures can be reduced through strong competition between equipment suppliers and construction companies, economies of scale (larger projects), and deployment schemes in which the government provides land and builds transmission lines to the grid, as in solar park schemes.
    - The cost of capital (debt and equity) is influenced primarily by the allocation of contractual risk—such as off-taker risk, curtailment, force majeure, and expropriation—as spelled out in the power purchase agreement and the government support agreement. A balanced allocation of risk between the independent power producer and the government will reduce sponsors' equity requirements and the cost of debt provided by lenders, yielding the lowest possible sustainable cost of electricity.

- **Based on results of a grid integration analysis, about 3.2 GW of variable renewable energy could be integrated in the southern provinces by 2020 without specific dispatch upgrades**. This is largely thanks to the new 500 kV backbone line and planned upgrades to other transmission lines under Power System Development Plan 7. Through strategic geographic deployment of solar capacity (connecting solar projects to medium- and high-voltage transmission lines and co-locating solar and hydropower plants), the amount of variable renewable energy that can be integrated into the grid can be maximized, while keeping the cost of integration low.
- **According to the geospatial analysis, enough non-agricultural and arid land is available for the 12 GW target to be comfortably achieved**. In the four provinces with the highest irradiation alone (those in which solar irradiation exceeds 4.2 kWh/m^2/year of production), the generation potential of the

land (with 75 percent of the “available” land discounted[1]) represents 22 GW in Binh Thuan, 6 GW in Ninh Thuan, 49 GW in Binh Puoc, and 25 GW in Tay Ninh. The potential of solar projects co-located and jointly operated with dams in the areas with the best irradiation (above 4 kWh/m^2/year) is about 4.5 GW, using 20 percent of the reservoirs of identified dams. Given these figures, 12 GW represents only 3 percent of the total “available” land identified.

- **Vietnamese commercial banks are not yet proposing the sort of lending terms (long tenors at fixed interest rates) needed to enable deployment of low-cost solar at scale**. The short-term nature of their deposits makes it difficult for them to structure financial products that can match their short-term deposits with cash flows from long-term projects. Local banks often lack the in-house technical expertise that would allow them to evaluate renewable energy projects, thereby increasing their perceived risks.
- **Vietnam is a major manufacturer of solar photovoltaic equipment and currently exports most of its production. A strong solar deployment strategy could shift the focus toward domestic use**. Vietnam holds 7 percent of the global solar photovoltaic market and produces enough cells and panels each year to generate 5 GW of electricity. The country is well positioned to maintain or increase its share of the global market thanks to low input costs and access to international markets under World Trade Organization rules and other free trade agreements Vietnam signed.
- **Realization of the goal to have 12 GW of solar generating capacity installed by 2030 would result in 25,000 full-time-equivalent jobs in solar consultancy and construction.**
- **Regular and frequent auctions, combined with a clear deployment strategy, are essential for reducing prices in power purchase agreements.** To encourage serious and qualified independent power producers to invest, the government must signal not only the target for the amount of solar PV capacity to be installed, but also the timeline and the scheme selected for achievement of the target.

Recommendations

- **Vietnam could move to a system of auctions to reduce prices in power purchase agreements through price transparency and competition, starting with some early pilots**. Although feed-in-tariff schemes are a very effective way to support a nascent solar industry, auctions have proven to be the best way to foster competition in the market and decrease the cost of solar generation, provided the power purchase agreement and the government support agreement allocate contractual risk fairly. If necessary to reduce uncertainty, feed-in-tariffs and pilot solar auctions can if necessary be applied in parallel where they are addressing different market segments or geographical areas.
- **Two auction strategies (solar parks and standard auctions) could be piloted in parallel, and then rolled out in accordance with the lessons learned from the pilots and following consultation with the provinces and developers**. Standard auctions, in which developers identify and develop their own site and construct their own grid interconnection, are a natural follow-on to the feed-in-tariff regime and would provide some continuity. However, it is recommended that the government also explore solar park auctions, in which sites are identified ahead of time and developed by a competent public

[1] Specific land use categories such as arid and non-agricultural land are considered as “available” for solar projects. However, as land use is analysed geospatially, there is a potential error that is being “discounted”

sector agency, with technical and financial assistance from multilateral development banks if needed. In solar park auctions, developers are invited to bid to construct their projects within a given park. They offer the possibility of lower tariffs owing to substantial de-risking, a coordinated approach to land acquisition and compensation, and the assurance of a supplied grid interconnection.

- **The government should endorse a solar auction program to achieve 12 GW by 2030 that includes both types of auctions, and subsequently start with a series of initial pilots**. Specifying short- and medium-term capacity targets and announcing at least a tentative schedule of future auctions will allow early lessons to be incorporated and help build investor confidence.
- **After the feed-in-tariff expires, pilot standard auctions and solar park auctions could be used to contract 500 MW for commercial operation beginning in 2022**, based on further discussions with stakeholders. According to the revised Power Development Plan VII, 850 MW are planned to begin commercial operation by 2020 and therefore would be developed under the existing feed-in-tariff, which expires in mid-2019 but could be extended based on the current discussions between the government and the provinces. By 2025, another 3.15 GW are planned to be commissioned. Therefore, following the initial pilots, 2–3 GW could be developed during the 2022–2025 period, with another 8 GW added to the grid in the 2025–2030 period.
- **As part of the ongoing development of Power System Development Plan 8, the government should also start developing a comprehensive strategy for integrating variable renewable energy into the grid.** There is a need to consider the long-term potential of solar and wind (onshore and offshore) to provide least-cost power in combination with other sources, and to plan the upgrades to the grid required to make the best use of variable sources. The resulting plan will help inform the location of future solar parks and the guidance and incentives that are given to developers to site their projects appropriately under future standard auctions.
- **To make domestic lenders more comfortable with non-recourse financing and induce them to lend for longer terms at competitively low interest rates, specific actions will have to be taken at the regulatory and banking sector level.** Part of the problem is the absence of interest-rate swaps, which would make it possible for lenders to offer long-term loans (15–20 years) at fixed rates. Another problem is the lack of liquidity in the Vietnamese debt market. Both are regulatory and banking sector level issues that need to be discussed with the relevant agencies such as the Central Bank. Plus, to reassure Vietnam’s commercial banks about non-recourse financing and induce them to provide longer-term loans at lower rates, it may be necessary to encourage them to partner with international banks in financing new deals.

1. INTRODUCTION

1.1 Background

In 2017, Vietnam's installed electrical generating capacity was 42.1 GW. Of this, 26 GW (accounting for 61 percent of the total power system) was owned directly by Vietnam Electricity (EVN) and the generating companies operating under its aegis (EVN GENCOs 1, 2, and 3). 6.1 GW (15 percent) was owned by two state-owned enterprises, PetroVietnam and VINACOMIN, and 10 GW (24 percent) was owned by BOTs and other private investors (EVN 2017).

In March 2016, Vietnam's Prime Minister approved, in Decision 428/QD-TTg, the Ministry of Industry and Trade (MOIT)'s proposed revisions to the National Power Development Plan VII (Revised PDP 7) for the period 2016–2020 with a vision to 2030. Under the plan, the total installed capacity is expected to be 60 GW in 2020, 96 GW in 2025, and 130 GW in 2030. Vietnam's solar potential is illustrated in figure 1.1.

Revised PDP 7 places greater emphasis than the previous PDP on renewable energy development. It outlines an ambitious strategy for generation development, in which renewable energy is to be prioritized. The plan sets a target of 6.5 percent of generation from renewable sources (excluding large-scale hydropower) by 2020 and 10.7 percent by 2030. It also stipulates a target of 850 MW of installed solar photovoltaic (PV) capacity by 2020, 4 GW by 2025, and 12 GW by 2030.

To achieve these ambitious deployment targets, the Government of Vietnam will have to promote solar and wind power through a clear and sustainable strategy while also ensuring that their deployment does not impede economic development by imposing additional costs. To support the development of solar PV, the government, in April 2017, issued Decision 11/2017/QD-TTg, which established a feed-in-tariff (FIT) policy that is set to expire in June 2019 as per the current regulation. The policy laid out how IPPs could apply for the FIT and set a tariff of VND 2,086/kWh (fixed at US$0.0935/kWh) for 20-years power purchase agreements (PPAs). There are discussions over the possibility of extending the FIT in certain Provinces.

Germany's GIZ, the United Nations Development Programme (UNDP), and the World Bank have been supporting the Government of Vietnam by recommending solar PV deployment options and conducting geospatial analysis.

1.2 World Bank Technical Assistance

In late 2017, the Government of Vietnam decided that upon the expiration of the FIT policy, the deployment of solar PV generation would be set through competitive bidding. The government sought the support of the World Bank to chart a plan to the target of 12 GW of solar generation by 2030 and to provide technical support in organizing an auction for solar generation. This document fulfills that request.

The present *Action Plan to 12 GW by 2030* presents key findings based on six analyses: (i) an economic and financial analysis, (ii) a grid integration study, (iii) a geospatial analysis, (iv) a review of the financing options for renewable energy projects in Vietnam, (v) an analysis of the solar PV supply chain, and (vi) a review of deployment policies.

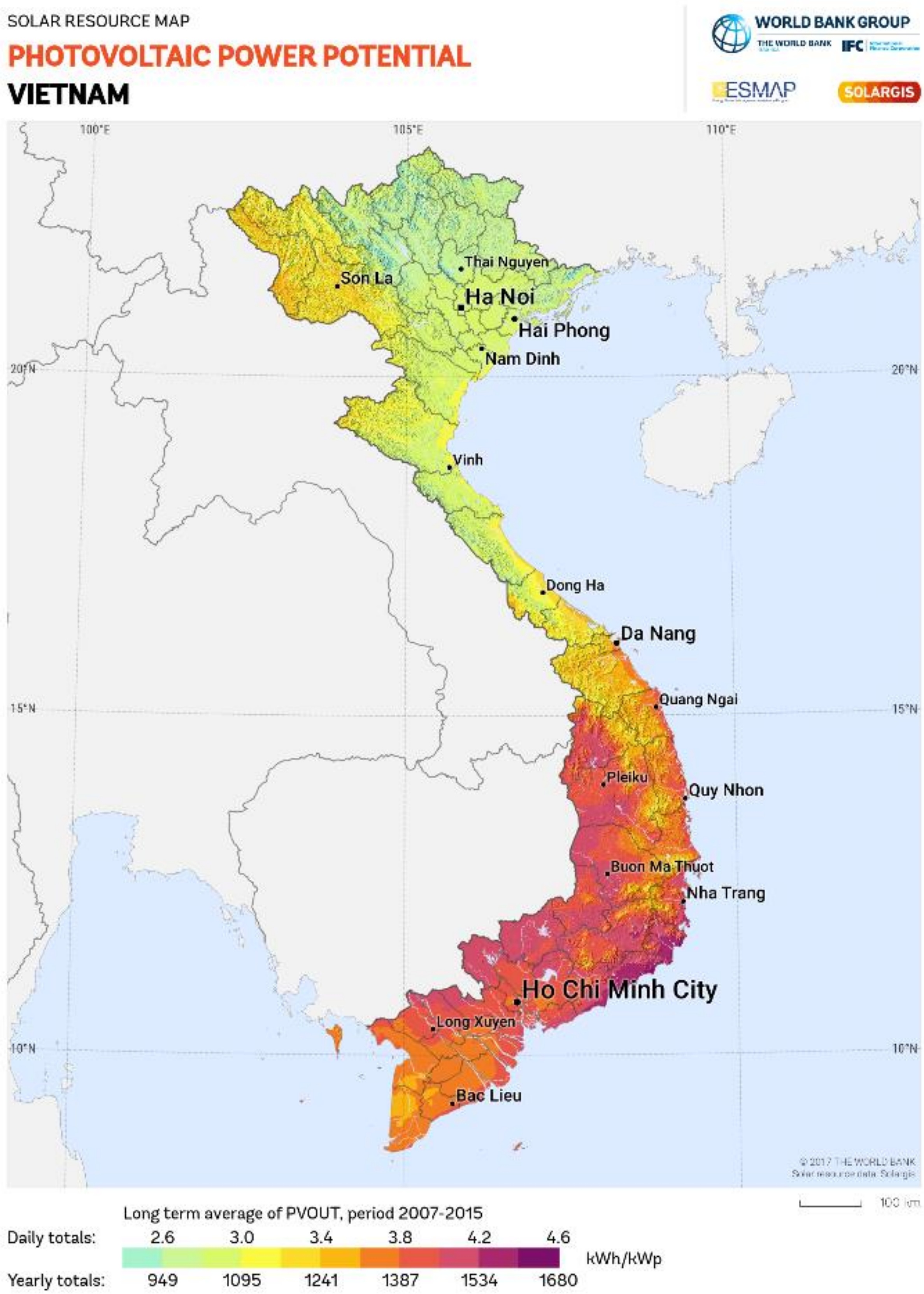


Figure 1.1 Solar photovoltaic power potential in Vietnam (*Source*: https://globalsolaratlas.info)

Data were gathered from Vietnamese sources such as EVN, MOIT, the Institute of Energy, and the Ministry of Natural Resources and Environmental, as well as from international sources such as the International Energy Agency and the World Bank Group (including the World Bank's Global Solar Atlas). Interviews were conducted with renewable energy developers and IPPs active in Vietnam, private and public lenders, and bilateral and multilateral organizations working in Vietnam's electricity sector, such as the Asian Development Bank (ADB), DANIDA, the French Development Agency (AFD), GIZ, and UNDP.

1.3 Objectives

The objective of this report is to present an action plan that will allow the Government of Vietnam to reach its goal of 12 GW of installed solar power capacity by 2030. As noted, the plan is based on technical and analytical work conducted by the World Bank for the Government of Vietnam.

1.4 Report Outline

Section 2 presents the results of the economic and financial analysis. Section 3 outlines the preliminary results of the grid integration analysis. Section 4 is devoted to the geospatial analysis, with a focus on land availability and solar PV irradiation. Section 5 offers a snapshot of the state of lending for renewable energy projects in Vietnam. Section 6 describes the results of an analysis of the solar PV supply chain. Section 7 focuses on the deployment policy analysis. Section 8 presents the proposed action plan to reach 12 GW of solar generating capacity by 2030.

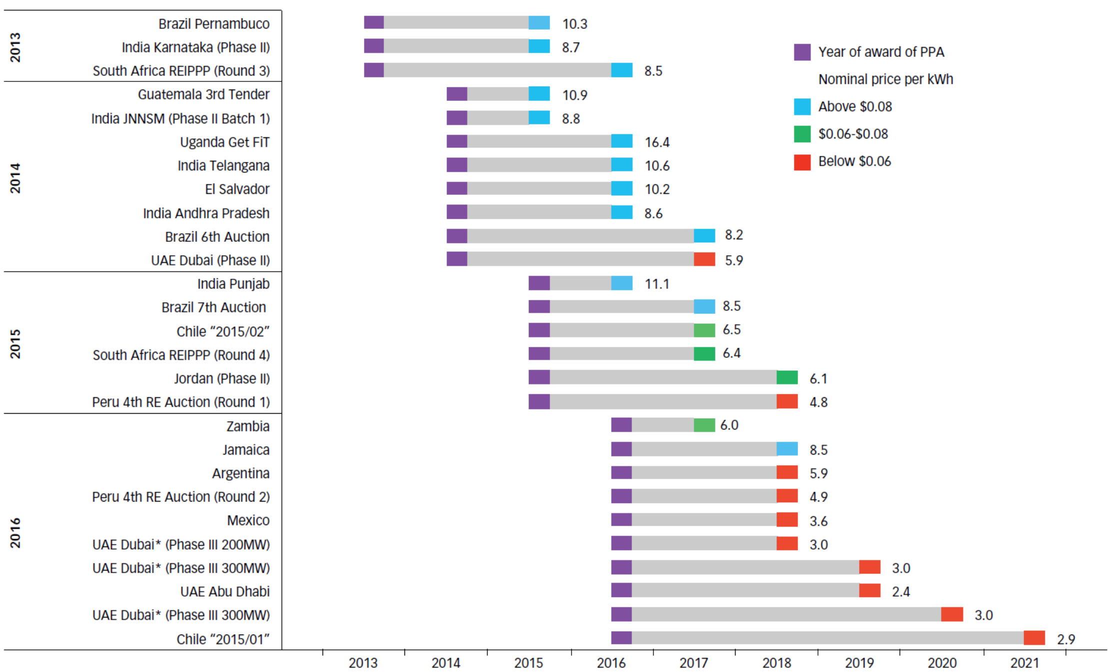
2. ECONOMIC AND FINANCIAL ANALYSIS

Section 2 presents the results of an economic and financial analysis undertaken to show how solar irradiation, capital expenditures (CAPEX), the cost of capital, and the length of PPAs affect the PPA prices.

2.1 Trends in Solar PV Prices

The prices of solar PV electricity reflected in PPAs are decreasing rapidly, dipping below US$0.05/kWh in Argentina, Chile, Dubai, India, and Zambia (figure 2.1).

Figure 2.1 Results of major auctions, by date of PPA award



Source: World Bank (2017).

The main reasons for the declining trend are:

- **Lower cost of equipment and construction.** Thanks to a market now in the 100 GW range and substantial competition between equipment suppliers and companies specializing in engineering, procurement and construction (EPC), EPC prices per installed MWp fell from US$4 million in the early 2000s to US$2 million in 2010 and to less than US$1 million at present, largely thanks to reductions in module prices.[2]

- **Economies of scale**. Solar PV projects are larger than before, having grown from kW size in the early 2000s to 100 MW+ today.

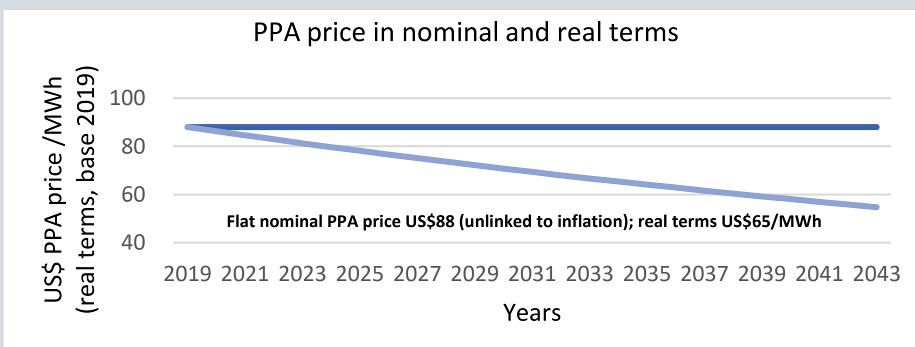
[2] EPC prices include the costs of construction and equipment. Quoted prices assume no local-content requirements and no obstacles to the shipment of equipment or training of construction workers in the area.

- **More efficient PV technology**. Inverters and solar panels have become more efficient and more resistant to humid climates.
- **Reduction in lenders' perceptions of technology risk** after 15 years of successful large solar projects. Lower risk perceptions mean that lenders can offer better loan terms.
- **Enhanced solar deployment schemes.** New schemes, such as solar park auctions, have reduced actual and perceived risks for IPPs by providing land and permits as part of the auction package, and by fostering competition within easy-to-understand procurement schemes.
- **Emergence of solar-specific developers and IPPs** with extensive know-how and access to low-cost capital. Ties with EPC companies and suppliers and a large pipeline of projects enable them to lower the cost of equipment and construction.

Box 2.1 Comparing PPA tariffs

PPA tariffs are difficult to compare because they are rarely determined in the same way. That is, they may be pegged to inflation, to the dollar, or the euro; they may contain fixed increases, be flat, or be decreasing.

To compare tariffs, economists normally use the levelized real price, which takes into account inflation and the opportunity cost of capital. In this analysis, the World Bank team presents both the levelized real price and the nominal price (fixed for the duration of the PPA). In the graph below are compared a PPA price linked to inflation and one flat based on real terms for a 25 years PPA. It is key to be able to know how the PPA tariff is structured to be able to compare it with another and not simply take one number and compare it against another one as it may not be accurate.



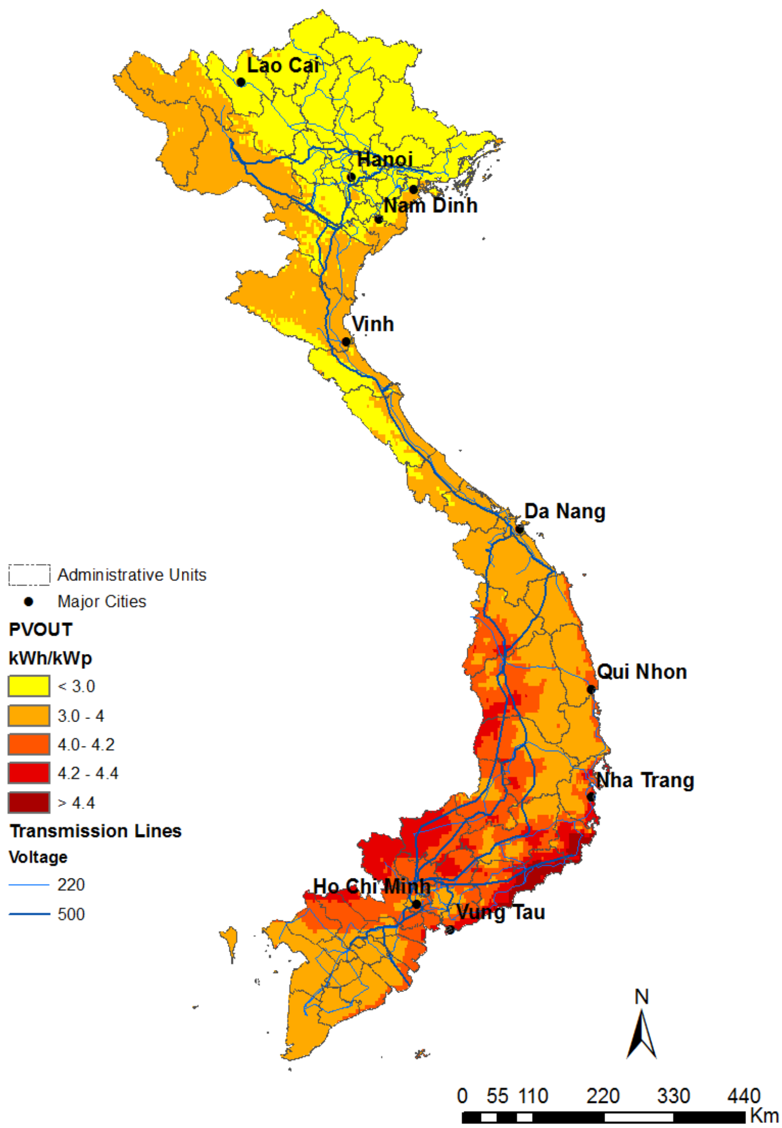
2.2 Key Parameters to Achieve Low PPA Prices

The following parameters are critical to achieve low PPA prices for solar PV:

- **High solar irradiation.** This parameter varies with the site and affects the plant's production level.
- **Low CAPEX.** Substantial costs are incurred before a plant begins operation. These include EPC costs, the cost of transmission line from the plant to the grid, project development costs, land acquisition costs (unless land is leased), and financing costs. Because solar plants have low operating expenditures, require no fuel, and are easy to maintain, CAPEX represents the main cost to the IPP.

- **A low cost of capital.** The cost of capital encompasses the cost of debt and the cost of investors' equity. Perceived risks by lenders and investors, such as political and off-taker risks, and actual risks, such as curtailment and *force majeure*, are the main reasons why the cost of capital differs from one country to the other. Lowering the cost of capital depends on an appropriate allocation of contractual risk between the off-taker and the IPP as presented in the PPA and the government support agreement, such that the IPP can access long-term financing at attractive interest rates.
- **Long PPA.** The longer the PPA, the easier it is for lenders to provide long-term loans. A long PPA enables the IPP to repay investors over a longer period of time.
- **Clear and advantageous fiscal policies.** Fiscal incentives have a direct impact on the PPA price. Examples include exemptions from value added taxes, import duties, and corporate taxes.

Figure 2.2 Solar irradiation classes in Vietnam



The effects of solar irradiation, CAPEX, and the cost of capital on PPA tariffs are shown in tables 2.1–2.3. The numbers were compiled based on a simplified financial model using Vietnam's current fiscal incentives for renewable energy. The numbers should be read more as an indication of how the parameters affect tariffs than as a representation of the current situation in Vietnam or as a prediction of a likely tariff.

2.2.1 Solar irradiation

Holding other parameters equal, the level of solar irradiation has a large impact on prices—as much as US$0.02/kWh for sites in Vietnam.

Solar irradiation at a given site depends on cloud cover, pollution, altitude, and other factors. Levels of solar irradiation in Vietnam are shown in figure 2.2, separated into five classes.

Table 2.1 Impact of solar irradiation on PPA prices

100 MW plant	Low irradiation	Medium irradiation	High irradiation	Highest irradiation
Location in Vietnam	**Hanoi**	**Da Nang**	**Loc Ninh** (Binh Phuoc)	**Phan Thiet** (Binh Thuan)
Capacity factor (percent)	**14.5**	**16**	**18**	**19.2**
kWh/m2/day (PVout[3])	**3.5**	**3.8**	**4.3**	**4.6**
Total CAPEX (US$ million/MWp)	0.9	0.9	0.9	0.9
Cost of US$ debt (interest rate)	6	6	6	6
IPP expected return on equity (percent)	14	14	14	14
Debt/equity leverage (percent)	75	75	75	75
Debt tenor (years)	15	15	15	15
PPA term (years)	25	25	25	25
Levelized real price, inflation included (US$/MWh)	**78**	**71**	**64**	**60**
Nominal price, fixed for the duration of the PPA (US$/MWh)	105	96	86	80

Source: World Bank internal data, based on a simplified financial model with Vietnam's current fiscal incentives for renewable energy.

2.2.2 Capital Expenditures

CAPEX encompasses all costs that must be disbursed before the plant begins operation. The main costs in the CAPEX category are:

- Equipment (panels, inverters, cables)
- Plant construction (balance of plants)
- Transmission line (unless financed by the government)
- Land purchase (unless land is leased or acquired by the government)
- Development costs (permits, analysis, staff, etc.)
- Financing fees (such as loan commitment and upfront fees) and interest during construction.

EPC companies may propose a fixed-price, turnkey contract under which the company is responsible for the plant's design, procurement, and construction until it is commissioned and handed over to the IPP. If

[3] "PVout" is the computed electricity generation after taking account of the impact of temperature, inverter conversion losses, cable losses, and other losses. PVout is expressed in kWh/m2/day.

there is a problem during construction (one not caused by the IPP or the government), the EPC company is financially and technically responsible. Similarly, if there are delays in construction (not caused by the IPP or the government), the EPC company is responsible, and penalties may apply.

To reduce its EPC cost, the IPP may consider contracting separately for equipment and construction. In that case, however, the overall risks of construction/completion become the IPP's responsibility.

Table 2.2 Impact of capital expenditures on PPA prices

100 MW plant	Very low CAPEX	Low CAPEX	Medium CAPEX	High CAPEX
Capacity factor	18	18	18	18
Total CAPEX (US$ million/MWp)	**0.65**	**0.75**	**0.9**	**1.2**
Costs of debt (interest)	6	6	6	6
IPP expected returns on equity	14	14	14	14
Debt/equity leverage	75	75	75	75
Debt tenor (years)	15	15	15	15
PPA term (years)	25	25	25	25
Levelized real price, including inflation (US$/MWh)	**50**	**55**	**64**	**80**
Nominal price (fixed for the duration of the PPA)	67	74	86	108

Source: World Bank internal data, based on a simplified financial model with Vietnam's current fiscal incentives for renewable energy.

EPC costs are falling rapidly owing to the global reduction in equipment cost. (For example, prices in India are close to US$600–700,000 per MWp installed.) To achieve further reduction in EPC prices, competition between EPC companies will be required. An important spur to such competition is a large pipeline of projects under construction.

2.2.3 Cost of Capital

The weighted average cost of capital is the average of all capital sources—debt and equity. The equity is provided by investors/IPPs; the debt, by banks. As presented below, a well-organized auction with clear contractual risks will bring down the weighted average cost of capital. As a result, PPA prices could approach US$50/MWh in levelized terms.

Table 2.2 Impact of cost of capital on PPA prices

100 MW plant	**Baseline**	**High interest rates and short debt tenor**	**Low interest rates**	**Low equity expectation**	**Low equity and interests**
Capacity factor (percent)	18	18	18	18	18
Total CAPEX (US$ million/MWp)	0.9	0.9	0.9	0.9	0.9
Cost of debt (interest rate)	6	**9**	**4**	6	**4**
IPP expected return on equity	14	14	14	**10**	**10**
Debt/equity leverage (percent)	75	75	75	75	**80**
Debt tenor (years)	15	15	15	15	**18**
PPA term (years)	25	25	25	25	25
Levelized real price, including inflation (US$/MWh)	**64**	**71**	**59**	**57**	**51**
Nominal price, fixed for the duration of the PPA (US$/MWh)	86	96	79.5	77.5	69

Source: World Bank internal data, based on a simplified financial model with Vietnam's current fiscal incentives for renewable energy.

In Vietnam, the main power producers are state-owned enterprises whose risk appetite is quite different from the diverse appetites of international IPPs, investors, or smaller Vietnamese companies not linked to the government.

When setting their expectations for return on equity for a given country or project, international investors typically look at:

- The country risks (for example, security, investment climate, investor protections)
- How risks are contractually allocated between the government and the IPP (as stated in the PPA and in the government support agreement)
- Tariff affordability
- The creditworthiness of the off-taker—that is, its ability to make any payments due to the IPP under the PPA
- The time and money the IPP spends during development (development risk).

Domestic investors other than state-owned enterprises would not be as risk adverse as international investors, because they are more accustomed to the country's ways of doing business and to finding solutions to local problems. However, the access of such investors to competitive international debt terms (long tenors and very low interest rates) and the lowest equipment and construction prices will be less than that of larger IPPs that enjoy preferential relationships with suppliers.

The IPP weighs the various risks (security, expropriation, breach of contract) against its expectations for return on equity. If the risks are too high, the IPP will not invest in the country.

Lenders will go through the same exercise as the IPP in deciding whether to invest, weighing the risks posed by the project, off-taker, sponsor, and country. They will provide financing accordingly (e.g., non-recourse project financing or corporate financing, as defined in Section 5.1). If lenders will provide only corporate financing, the IPPs will be unable to leverage more than their balance sheet, PV deployment may be limited, and tariffs may not be optimal.

2.2.4 Duration of Power Purchase Agreement

The length of the PPA is important for IPPs because solar panels, which are the main technology in which they are investing, can operate at high performance (above 85 percent) for 25–30 years, according to test results. A 2012 study of panel degradation found that Tier 1 (best quality) panels have an average annual decline in energy output of just 0.5 percent (NREL 2012). This means that after 25 years, they will be operating at 88 percent of their original capacity. Inverters, the second-most-important piece of equipment in a solar power plant, are typically warranted to last between 10 and 15 years. Therefore, IPPs would replace them once during the time of the PPA. Because fuel and O&M requirements are minor compared to the upfront investment, the longer the PPA, the lower the price (table 2.3).

Lenders set their debt terms based on the country risk, the off-taker, the PPA risks, and the strength of the IPP's cash flow.

Table 2.3 Impact of length of PPA on PPA prices

100 MW plant	20-year PPA (short debt)	20-year PPA (long debt)	25-year PPA	25-year PPA (longer debt)
Capacity factor (percent)	18	18	18	18
Total CAPEX (US$ million/MWp)	0.9	0.9	0.9	0.9
Cost of debt (interest rate)	6	6	6	6
IPP expected return on equity (percent)	14	14	14	14
Debt/equity leverage (percent)	75	75	75	75
Debt tenors (years)	**12**	**15**	**15**	**18**
PPA term (years)	**20**	**20**	**25**	**25**

Levelized real price, including inflation (US$/MWh)	**70**	**67**	**64**	**61**
Nominal price, fixed for the duration of the PPA (US$/MWh)	90	87	86	82.5

Source: World Bank internal data, based on a simplified financial model with Vietnam's current fiscal incentives for renewable energy.

2.3 Achieving the Lowest PPA Prices

The foregoing parameters affect the final PPA price in different proportions. Those that have the greatest impact are solar irradiation and CAPEX. Therefore, as the cost of equipment is expected to continue to drop over the medium-term, PV deployment should begin where the solar irradiation is highest, postponing the development of sites with average irradiation until reductions in CAPEX ensure their competitiveness.

3. REQUIREMENTS FOR VARIABLE RENEWABLE ENERGY DISPATCH AND GRID INTEGRATION

Section 3 presents the results of the two analyses the World Bank is conducting on integration of variable renewable energy (VRE) into the power grid. Some potential leads are provided on how to increase Vietnam's ability to integrate more VRE.

3.1 Background

Global experience has shown that VRE can be integrated into the grid at rates of penetration well above Vietnam's current capacity, which is less than 1 percent. However, the prospect of dramatically increased PV deployment requires a detailed examination to ensure that it will not increase the cost of generation or exert negative effects on the grid.

The characteristics of PV-generated electricity—including variability, uncertainty, and nonsynchronous generation—present challenges to large-scale, cost-effective grid integration. One challenge to realizing the full energy value of PV is the need to accommodate the changing net load associated with high midday PV generation and low electricity demand. This situation can create overgeneration if conventional dispatchable resources cannot be backed down sufficiently to accommodate the supply of solar generation. Because the power system risks disruption when supply exceeds demand, system operators may be called upon to curtail PV output, thus reducing the economic and environmental benefits of PV energy. Similarly, net load changes resulting from high PV penetration reduce the ability of solar PV power plants to displace conventional generation capacity during periods of high demand (ESMAP 2015).

Accommodating the changes in net load resulting from increased VRE penetration requires enhancements to the power system's flexibility, defined as the ability of the grid and the generation fleet to balance supply and demand over multiple time scales. Numerous technologies and strategies for increasing flexibility have been developed to enable cost-effective and safe integration of VRE. NREL (2016) presents six strategies:

- **System operation**. Changing the way the grid is scheduled and dispatched, including changes to market rules, does not require new technologies and is often the least costly way to support VRE integration.
- **Flexible generation.** By increasing ramping rates and ranges and enabling more frequent starts and stops, generators can respond better to the net load shape created by additional PV.
- **Reserves and stability services from VRE**. As inverter-based wind and solar plants come to make up a larger proportion of the generation fleet and new mechanisms are developed, such plants can fulfill the grid's frequency response needs.
- **Transmission and coordination**. Balancing supply and demand over larger areas reduces net variability of both load and renewable resources owing to the greater spatial diversity of VRE resources.
- **Demand response**. Voluntary load reduction, or load shifting, can aid in the effort to integrate solar resources and reduce curtailment. One way it does this is by reducing dependence on partially loaded

synchronous generators (to provide frequency stability and operating reserves) and by changing the shape of the net load, which can reduce ramping rates, better align solar supply with demand, and reduce peak capacity needs.

- **Energy storage**. Like demand response, energy storage can provide reserves, change the net load shape to minimize ramping requirements, and shift supply of VRE to periods of increased net load. The cost of electrical storage (Li-ion, Zinc Air, Flow, etc.) is dropping rapidly, raising the feasibility of storage strategies and suggesting that storage may become part of future solar auctions.

3.2 Vietnam-Specific Analysis

In 2018, the World Bank supported two studies related to VRE integration into the grid in Vietnam: (i) a load-flow analysis to analyze grid constraints in Ninh Thuan, Binh Thuan, and Dak Lak Provinces and (ii) a power-system-planning study to analyze the impact of integrating higher levels of VRE generation on fuel costs, total investment costs, and system reliability at the national level.

Vietnam's greatest electricity demand is in the South, whereas most generation occurs in the North. A 500 kV backbone transmission line running from North to South improves the stability of the grid while enabling the production in the North to be sent South. To improve the stability of the grid, a second backbone transmission line is under construction, and further work is planned to improve the connection between the regions.

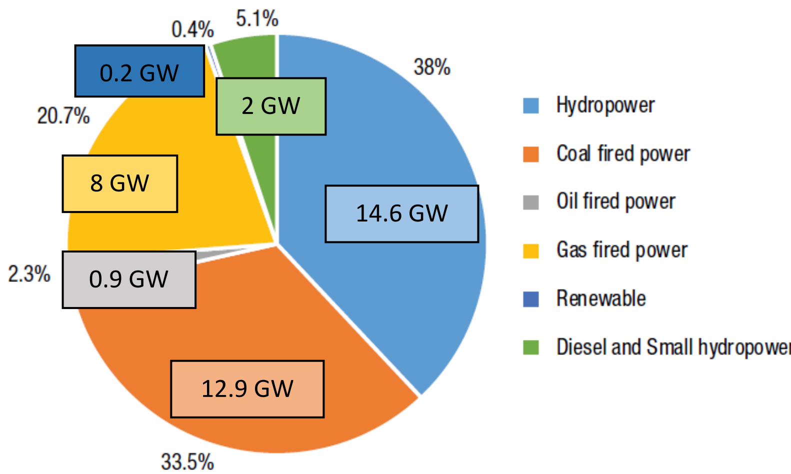
3.3 Early Stage Findings

3.3.1 Flexible Generation

In a properly functioning grid with good dispatch control and flexibility in generation, 15–20 percent of generation can come from VRE without requiring major upgrades to infrastructure, according to international experience. Hydropower plants, gas combined cycle plants, and diesel fuel generators are very flexible and can provide spinning reserve and reactive power as well as flexibility in dispatch. For the dispatch team to maximize the whole system, a strong SCADA system and automatic dispatch control at each plant are required.

About 50–60 percent of the electricity generated in Vietnam comes from hydropower and gas (figure 3.1). Such generators provide important flexibility to the grid. Thanks to their presence, the variability of the solar and wind plants expected to be commissioned before 2030 can be at least partially compensated through these plants, depending on the commercial arrangements that EVN has with the generators and potential constraints in transmission, which are dealt with in the next section.

Figure 3.1 Generation capacity in Vietnam (2016)



Source: EVN (2016).

3.3.2 Transmission Constraints

The results of the grid-integration study indicate that the existing 500 kV backbone and line upgrades expected by 2020 will be sufficient to permit integration of larger amounts of VRE in the South (from 1.8 GW today to about 3.3 GW in 2020) without specific dispatch upgrades. In Ninh Thuan about 800 MW of VRE could be added without upgrades; in Binh Thuan, 1 GW. To integrate more than these amounts, the 220 kV Da My-Xuan Loc transmission line may have to be upgraded. In Dak Lak, the limit on additional VRE without upgrades was estimated to be about 1 GW; to increase it, the 500/220 kB Pleiku2 transformers (2 x 450 MW) might have to be upgraded. Upgrades could be financially beneficial for the system to the extent that they lower the cost of solar generation and thus keep it competitive in areas where solar irradiation is not as great as elsewhere. As noted in Section 2, solar irradiation has a strong impact on the final PPA price.

3.3.3 Coordination and Strategic Positioning

The amount of solar PV that can be integrated into the grid can be maximized through strategic positioning of solar power plants—for example, by connecting plants to several substations and feeding their production into larger voltage transmission lines. As presented in Section 7, solar park auctions are a deployment scheme in which the government determines the location of the solar site. Such auctions make possible controlled development of solar PV based on grid availability. Hydro-connected PV, where solar generation is dispatched in coordination with the hydropower plant with which it is collocated, is another deployment scheme that supports grid stability. Finally, through specific modifications to standard auction design (preferred areas, named feeders, bonuses, etc.), governments can encourage IPPs to develop projects in areas that are more favorable to integration of VRE.

3.3.4 System Operation and Commercial Flexibility

Technical constraints in dispatch potential are critical, but commercial constraints are usually just as important. When grid codes and PPAs fail to demand flexibility from generators that can easily provide it (such as gas and hydropower operators) the grid's potential for flexibility is compromised. To support flexibility in the system, it is important to price ancillary services such as spinning reserves and reactive power.

The Federal Energy Regulatory Commission (1995) in the United States defines ancillary services as follows:

> "[T]hose services necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system."

Ancillary services can be divided into three broad categories. The fastest-responding ancillary service is *regulation reserve*. Units that provide this service must have equipment installed that responds automatically and in real time to signals from the system operator's energy management system to control the output of generation units and dynamic load resources within a prescribed area. Those signals are generated by the EMS in response to changes in system frequency. The second-most-responsive ancillary service is *spinning reserve*, where a generation unit is online and able to produce additional energy within a specified number of minutes. The least-responsive ancillary service is *non-spinning reserve*, where the unit is not online, but can provide additional energy within a specified amount of time. Also, typically classified as ancillary services are *voltage support* and *black start*. However, in most restructured electricity supply industries, these services are procured through either a long-term procurement process or a cost-of-service regulatory process (Wolak, 2011).

Standard take-or-pay agreements for gas or hydropower plants are usually not advised where the goal is to optimize VRE integration because they restrict rather than encourage the flexibility that such plants can provide to the system.

If most of the targeted 12 GW of solar PV is to be concentrated in the South, a system for pricing ancillary services will need to be put in place, potentially through an ancillary service market or as part of future PPAs.

3.3.5 Energy Storage

Battery storage connected to the grid or directly to plants will play a crucial role in supporting VRE integration by compensating for the variability of the electricity production and therefore the need for flexible generation. Storage can also support a shift of solar PV dispatch to the high demand hours of the day. The cost of Li-ion battery storage fell by 70 percent between 2010 and 2016 and is expected to fall by an additional 50–60 percent by 2030 (IRENA 2017), lowering the cost of integrating a growing share of VRE into the power system while also protecting the grid and dispatching power during peak demand. After 2022, the cost of battery storage is expected to drop below US$150,000 per MWh (IEA, 2017).

In the case at hand, the first gigawatt of VRE is not expected to require storage because Vietnam's grid is already flexible enough to accommodate it, according to the results of the grid-integration study. Thus, discussions of adding battery storage to new VRE projects should be reviewed at a later stage, if the grid appears to require it.

4. GEOSPATIAL ANALYSIS

This section presents the results of a countrywide geospatial analysis conducted to determine where solar generation could and should be developed as a function of levels of solar irradiation, grid development, and land and rooftop availability.

4.1 Background

The geospatial analysis combines Vietnam's solar irradiation potential with data on land use and land cover. It also considers factors such as elevation, slope, and proximity to urban centers and protected areas. Four categories of land were identified as suitable for PV development and used in the analysis: (i) agricultural land (annual crops, perennial crops, and other agricultural land), (ii) forest land (timber production), (iii) urban and built-up land (cities, plus land used for power generation or irrigation), and (iv) unused land (barren, range land). The main criterion for available land was that its elevation is not greater than 2,000 meters, its slope is less than 5 degrees, the population density is less than 400 persons per km^2, protected areas are at least 1 km from the site, and land cover is categorized based on their usage. To discount any potential constraints on site, the analysis discounted 75 percent of the identified land. It is important to note that this analysis will require further work with the provinces to properly identify the land best suited for potential solar projects.

The analysis of land availability was then merged with data on solar PV irradiation.[4] Not only is high solar irradiation a critical determinant of low PPA prices, it tends to occur over arid land that is not ideal for agricultural use.

4.2 Key Findings

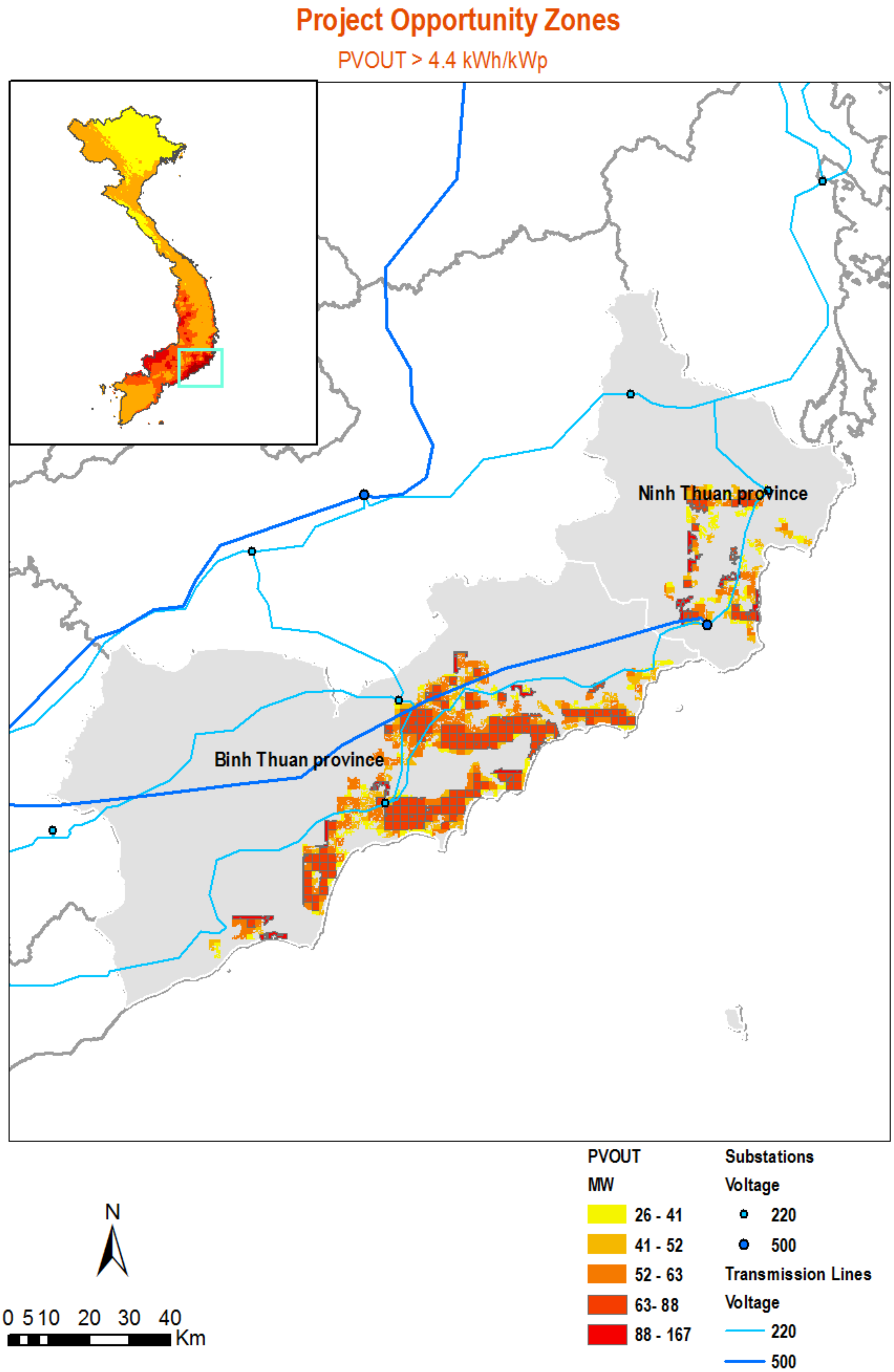
4.2.1 Best Solar PV Irradiation

The best solar PV irradiation (>4.4 $kWh/m^2/day$) is concentrated in two provinces: Ninh Thuan and Binh Thuan (figure 4.1). Enough land may be available to produce 5 GW of electricity in Ninh Thuan Province and 20 GW in Binh Thuan.

The predominant categories of available land in those provinces are unused land and agricultural land, and there are four grid substations sized between 220 kV and 500 kV. Most of the land is situated within a radius of 20 km from a substation. There is load demand from both provincial capitals, Phan Thiet and Phan Rang-Thap Cham, and the 500 kV backbone transmission line enables good dispatch management with the rest of the country.

[4] The resulting datasets from the geospatial analysis are provided as an ArcGIS geodatabase and in KMZ format.

Figure 4.1 Zones with the best solar PV irradiation



4.2.2 Very Good Solar PV Irradiation

Vietnam's very good solar PV irradiation (4.2–4.4 kWh/m^2/day) is concentrated in 12 provinces (table 4.1 and figure 4.2), with top potentials of 47 GW in Binh Phuoc, 24 GW in Tay Ninh, 14 GW in Gia Lai, and another 14 GW in Binh Thuan.

Table 4.1 Provinces and potential installed solar PV capacity (GW): very good potential

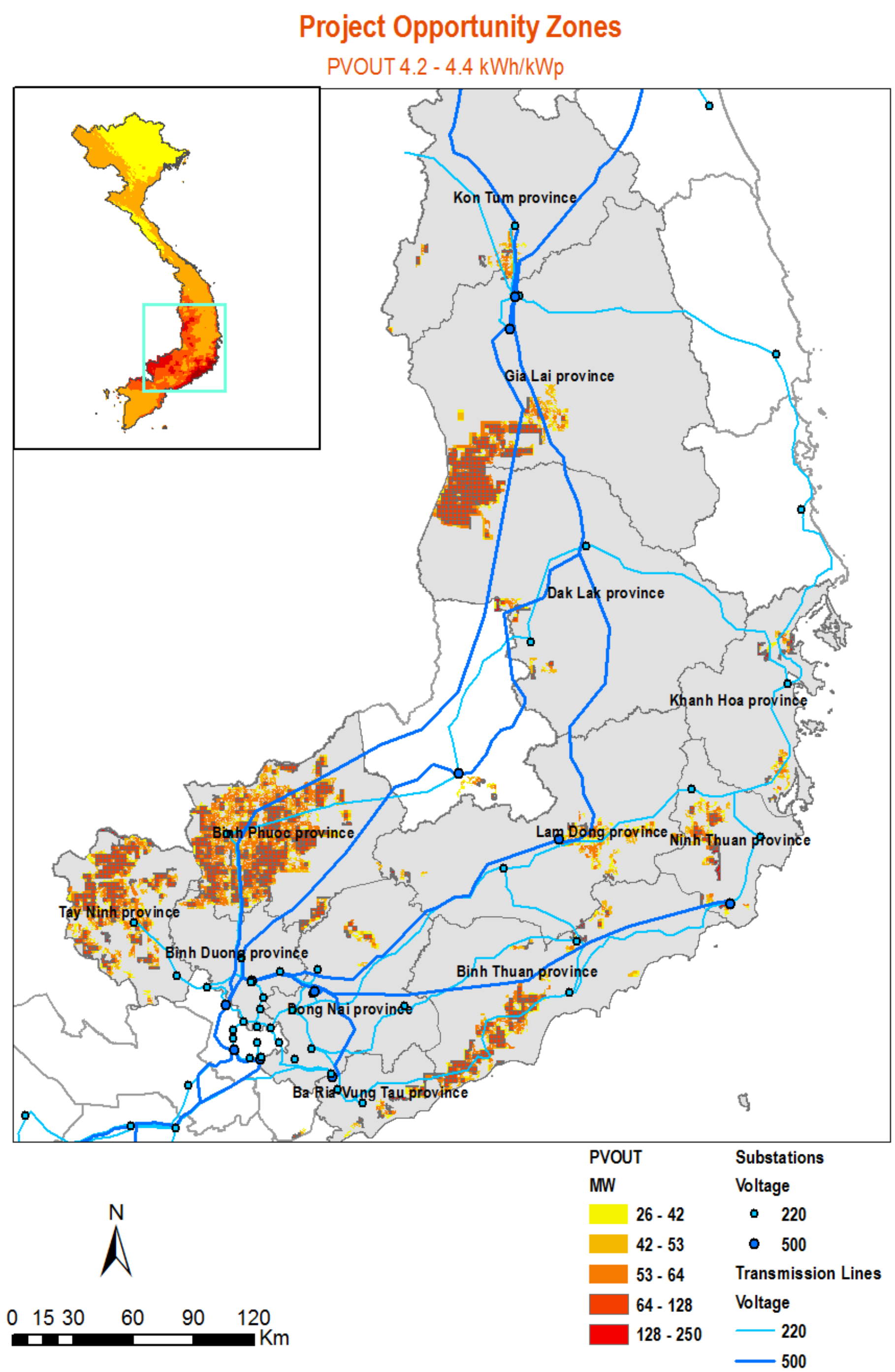
Name of Province	Capacity (GW)
Binh Phuoc	47.23
Tay Ninh	24.22
Gia Lai	14.65
Binh Thuan	14.19
Dak Lak	12.60
Lam Dong	6.53
Ninh Thuan	5.52
Khanh Hoa	3.04
Kon Tum	2.64
Ba Ria-Vung Tau	2.16
Dong Nai	1.50
Binh Duong	1.27

Source: World Bank.

The main land cover use is unused land, agricultural land and production forests. There are 18 substations of a size between 220 and 500 kV in these 12 Provinces. Most of the land is situated in a radius of 20 km from a substation.

There is a load demand in the Provincial capitals while the 500 kV backbone transmission line enables a better dispatch management with the rest of the country.

Figure 4.2 Zones with very good solar PV irradiation



4.2.3 Good Solar PV Irradiation

Good solar PV irradiation (4–4.2 kWh/m^2/day) is found in 19 provinces (table 4.2 and figure 4.2), with the greatest potential in Gia Lai (55GW), Dak Nong

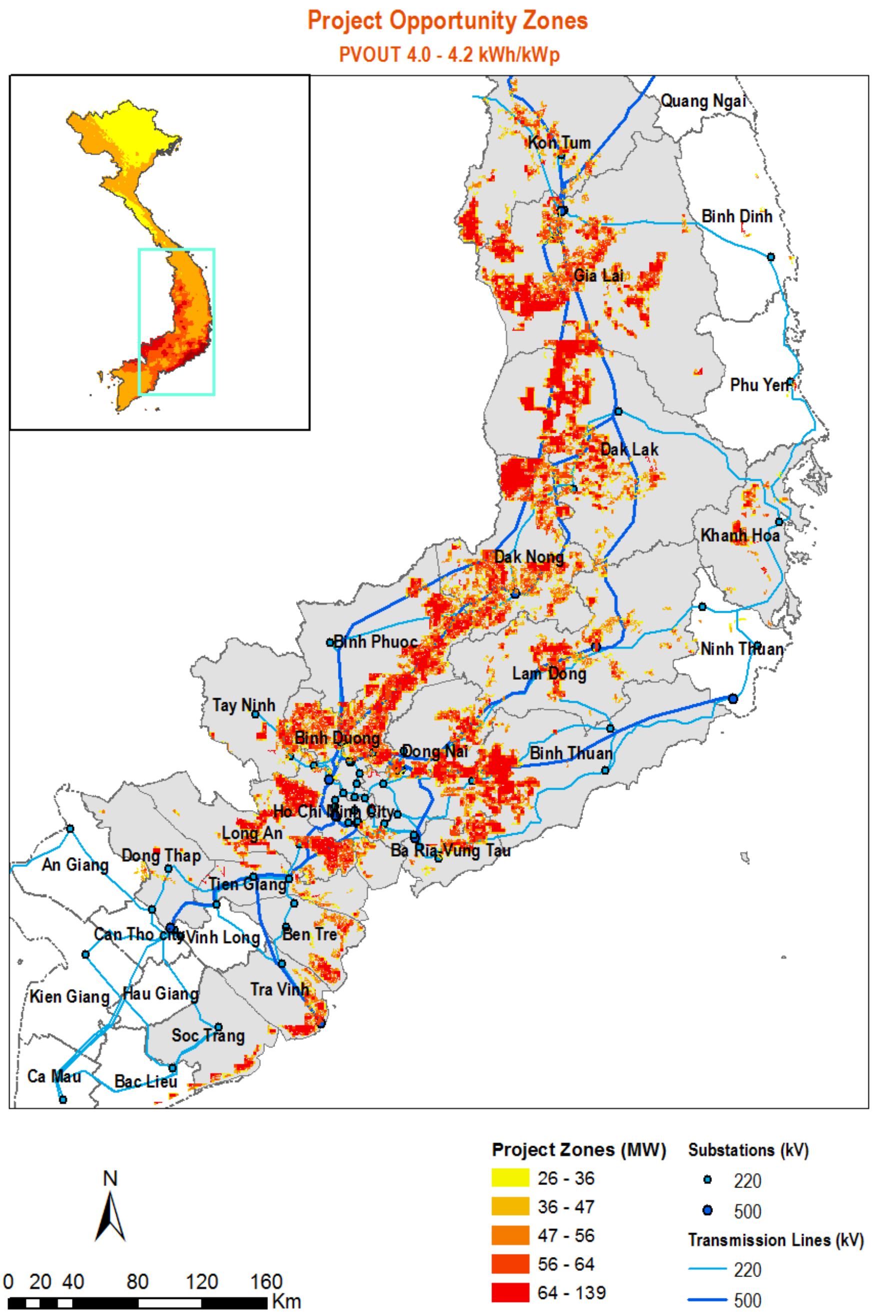
(44GW), and Dak Lak (40 GW). Most of the available land falls into the categories of unused land, agricultural land, and production forests. The 19 provinces contain 23 substations sized between 220 and 500 kV. Most of the land is situated within a radius of 20 km from a substation.

Table 4.2
Provinces and potential installed solar PV capacity (GW): good potential

Name of Province	Capacity (GW)
Gia Lai	54.69
Dak Nong	44.60
Dak Lak	40.75
Binh Phuoc	27.80
Dong Nai	25.05
Binh Duong	22.81
Long An	21.06
Lam Dong	20.22
Kon Tum	17.66
Binh Thuan	13.11
Ba Ria-Vung Tau	7.19
Ben Tre	6.91
Tra Vinh	6.34
Khanh Hoa	5.59
Tay Ninh	3.65
Tien Giang	3.17
Soc Trang	3.02
Ho Chi Minh city	2.82
Dong Thap	1.17

Source: World Bank.

Figure 4.2 Zones with good solar PV irradiation



4.2.4 Floating Solar PV

Floating solar PV (FSPV) is being used increasingly to reduce the need for land (around 1.5 hectares of land are required for 1 MWp of installed capacity in Vietnam) and to facilitate co-location with a hydropower plant and thereby improve dispatch of VRE.

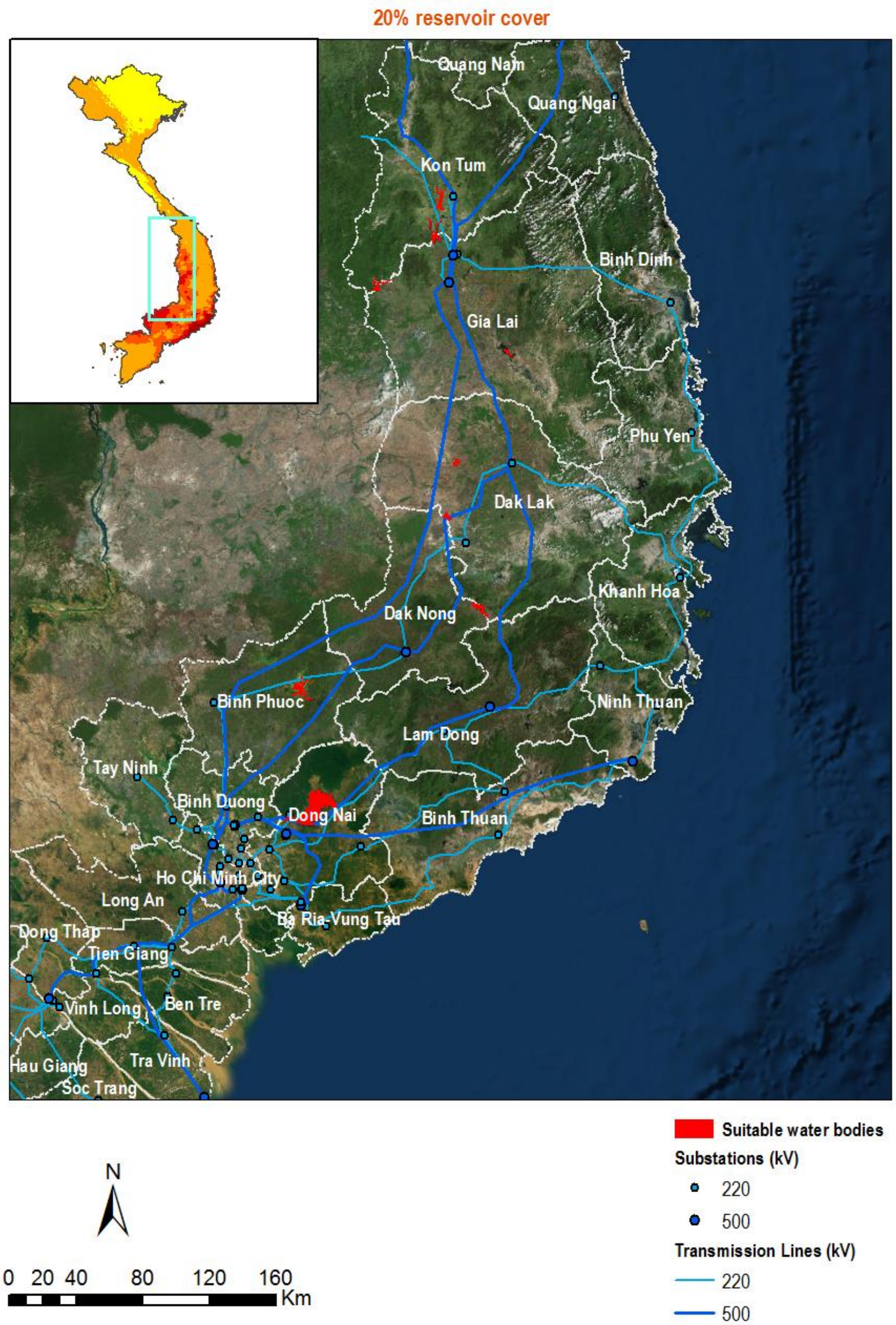
Although the EPC costs of FSPV are currently estimated to be about 10–20 percent higher than ground-mounted plants owing to limited competition in equipment production and the need for expensive anchoring structures, these additional costs are partially offset by a 10–12 percent increase in energy production thanks to the cooling effect and reduction in dust caused by the surrounding water

(World Bank Group, ESMAP and SERIS, 2018). The performance gains are highest in hot climates such as Southeast Asia, where the cooling effect is most important.[5]

Floating PV co-located with hydropower generation has many advantages, such as maximizing the hydro plant's infrastructure and grid connection, minimizing the effects of seasonal variations in power production, supporting daytime peak load, and reserving more hydropower for the evening peak.

Vietnam has nine hydropower dams of a size greater than 100 MW. Two of them, Tri An Lake and Thac Mo, meet the requirements that solar irradiation (expressed in PVout[3]) is at least 4 kWh/m^2/day and that no more than 20 percent of the reservoir can be covered. These two dams have combined a potential of 4.5 GW (figure 4.3).

Figure 4.3 Floating solar PV potential



4.3 Rooftop Solar PV

4.3.1 Background

A separate analysis was done to assess the technical potential of rooftop solar PV generation in Ho Chi Minh City and Da Nang. Satellite imagery at the highest resolution now commercially available (30 cm) was acquired over 370 km^2 in Ho Chi Minh City (population 8.6 million; per capita electricity consumption, 1,565 kWh) and over 175 km^2 in Da Nang (population, 1.45

[5] The World Bank is developing a study on Floating PV to be published in October 2018.

million; per capita electricity consumption of 1,565 kWh). Nearly a million rooftops were characterized for Ho Chi Minh City and 600,000 in Da Nang.

The imagery was processed using conventional image processing techniques (photogrammetry, classification) and advanced techniques (deep learning) to build a database containing information such as building footprint, building height, and land use, as well as several rooftop characteristics, including surface area suitable for solar PV system installation, shape, slope, orientation, and shadows. This information was combined with solar radiation data from the World Bank's Global Solar Atlas to assess the corresponding total power capacity (in MW) and the total generation potential (in MWh).

The rooftop database was complemented by a ground survey (interviews with building owners and various measurements) in both cities. The survey gathered detailed information on more than 200 buildings identified ahead of time as the most suitable for solar PV installation—including the name of the building owner, electricity consumption, electricity-related specifications, the owner's willingness to have solar panels installed, and rooftop material.

4.3.2 Key Results Analysis

The results show that Ho Chi Minh City could develop up to 6.4 GW of solar PV capacity. About a quarter of this potential corresponds to public and industrial buildings, which are the most suitable in terms of rooftop area and the ability/willingness of owners to install PV systems. In the case of Da Nang, the total solar PV capacity is 1.1 GW, of which 41 percent corresponds to public and industrial buildings.

Even if PV systems were to be installed on just 5 percent of all suitable rooftops, they could generate up to 900 GWh of electricity in Ho Chi Minh City and 160 GWh in Da Nang, meeting 6.6 percent of Ho Chi Minh City's electricity needs and 6.9 percent of Da Nang's needs.

Further work will be needed to develop business models to support rooftop PV development in Vietnam.

5. FINANCING FOR RENEWABLE ENERGY PROJECTS

Section 5 presents a snapshot of the current state of lending for VRE projects in Vietnam and the current limitations on non-recourse project financing.

5.1 Advantages of Non-Recourse Project Financing

Project finance denotes the structured financing of a specific economic entity—a special purpose vehicle (SPV) or special purpose company (SPC)—created by the project's sponsors. Lenders consider the cash flow generated by the SPV as the sole source of loan reimbursement. If the borrower defaults on its debt-service obligations, the lender has recourse to the SPV's shareholders only within the limits previously agreed upon. In so-called non-recourse situations, no action may be taken to collect losses from the shareholders. If the agreed recourse is not sufficient to remedy the default, lenders may seize the SPV and its assets, the value of which may not cover the amount due.

Long-term infrastructure, industrial projects, and public services are best financed using a non-recourse or limited recourse financial structure, referred to commonly as project finance, in which debt and equity are deployed to finance the project and paid back from the cash flow generated by it. Project finance is particularly well suited to power production, which presents low technological risk, reasonably stable cash flows, and the possibility of selling to a single buyer on a multi-year contract.[6]

In project financing, the allocation of contractual risk is of paramount importance. Before lenders will offer non-recourse financing, an acceptable allocation of risk must be presented in clear PPAs and government support agreements. If the off-taker is not considered bankable (that is, sound and reliable), an offtake payment guarantee, or other form of compensation in case of default, must be provided. If the PPA is in local currency, there must be a guarantee of foreign exchange convertibility. Such arrangements allow lenders to focus on the cash flow associated with the underlying project. In summary, the key considerations for lenders are (i) the experience of the project sponsor, (ii) the experience and financial strength of all parties, (iii) the terms and conditions in the PPA, (iv) the expected revenues and expenses (i.e., predictable cash flows), (v) risk (technology and market), and (vi) the regulatory environment.

If the project sponsor cannot access project financing because the foregoing requirements are not met, lenders may propose a loan under a corporate financing scheme. In that case, the sponsor uses a corporate guarantee from the mother company—and not just the SPV—to guarantee the credit provided by lenders.

The major drawbacks of corporate financing are (i) that it limits financing to what the IPP can obtain based on its own balance sheet and (ii) that the financing it obtains is likely to be of limited duration. Project financing, by contrast, can cover between 70 and 80 percent of a project's cost in the Southeast Asia region, with the Philippines at the low end of the spectrum and Thailand at the high end.

[6] Except in the rare case where the country's electricity market is very stable and the project can sell its electricity on a merchant basis on the spot market.

5.2 State of the Lending Sector in Vietnam

5.2.1 Vietnam's Financial System

According to the International Monetary Fund (IMF 2017), the assets of Vietnam's banking sector totaled 194 percent of GDP in 2016 and represented 96 percent of all financial sector assets (insurance companies: 3 percent; and securities and fund management companies: 1 percent). The four major state-owned credit banks account for 45 percent of banking sector assets and provide half of all credit, which, despite cutbacks in recent years, remains heavily tilted toward the state-owned enterprises. Commercial banks are the largest players in Vietnam's domestic debt market. Together with a few development banks, they had a total outstanding loan portfolio of about US$250 billion in 2016.

Despite progress in recent years, the regulatory and supervisory framework of Vietnam's financial sector is still relatively weak, and financing infrastructure is not optimal. The Government of Vietnam has put in place a strategy to develop the sector and has recently passed legislation to support banking sector reforms. Such reforms must be seen in the historical context of a fundamental transition from a centrally planned economy toward a more market-oriented system. Vietnam's "Financial Strategy to 2020" was approved in April 2016. Its aims are to (i) build a healthy financial system; (ii) ensure financial security; and (iii) stabilize the economy through monetary and fiscal policies, with a renewed emphasis on restoring the financial soundness and operational capacity of Vietnamese banks (ADB 2014). However, despite substantial connections between banks and the enterprise sector, commercial banks are constrained by their weak capital base and low capital adequacy ratios owing to poor asset quality and the need to make provision for nonperforming loans. Securitization of balance sheet assets to manage exposure is not practiced, owing to the absence of relevant regulations (World Bank 2018a).

Vietnamese banks typically provide short-term loans because they lack longer-term sources of funding to finance medium-term (1–3 years) and long-term lending (more than 5 years). Longer term loans are provided from short-term deposits based on a prudential ratio of 50 percent, creating an asset-liability mismatch and an intermediation problem for banks. The lack of long-term deposits can be traced to the flat yield curve for deposits, with only 80 basis points separating the interest rates paid on deposits longer and shorter than 12 months' duration. Interest rates on short-term loans are also high, currently ranging from 7.5 to 9.5 percent, although they are slightly lower for sectors (like energy) that are promoted by the government in the form of directed credit. The shortage of long-term lending reflects the short-term nature of deposits and constrains the ability of the banking sector to participate in infrastructure investment.

5.2.2 Limitations on Domestic Lending in Energy

Vietnam enjoys high levels of domestic savings, but a shrinking share of the savings pool has been reaching the energy sector (3.3 percent of total savings). Despite commercial banks' interest in financing renewable energy, they have not been able to close many deals for several reasons. First, the short-term nature of their deposits makes it difficult for commercial banks to structure financial products that can match their short-term deposits with cash flows from long-term projects. An interest-rate swap market would allow them to offer long-term fixed interest rates, which are essential for nonrecourse project finance. Second, local banks often lack the necessary in-house technical expertise to evaluate renewable energy projects, thereby increasing their perceived risks. They also lack familiarity capacity with respect to nonrecourse project financing.

As presented in Section 2, the competitiveness of solar energy depends on access to long-term debt at low interest rates. To become more comfortable with nonrecourse financing, local banks could initially partner with international banks or multilateral banks to finance projects, once the latter are satisfied with the risk allocation proposed under the PPA. As the expertise of local banks increases and the Vietnamese financial sector becomes more sophisticated (for example, by offering the interest-rate swaps that would permit the long-term fixed-rate lending essential to project finance), local banks could lend by themselves. This was the path taken in Thailand, where local banks now lead in providing fixed-rate project finance at tenors up to 18 years, enabling the government to propose PPAs in local currency.

5.2.3 Leveraging International Financing and Investments

Owing to the current contractual structure proposed by the government, most solar projects in Vietnam are expected to be financed under a corporate loan or at 100 percent equity, with refinancing possible at a later stage. Under such circumstances, the deployment of PV will be limited, as only investors with large corporate balance sheets, or willing to invest 100 percent equity, are able to undertake projects

Given the limited appetite of domestic investors for highly competitive solar projects and limited domestic lending, competent international IPPs and lenders could be invited to enter the market, bringing technical knowledge and international financing. To attract them, PPAs and government support agreements will have to be drafted to international standards, and off-taker payment guarantees may be required if the off-taker is not considered bankable over the term of the investment. EVN recently got assigned an Issuer Default Rating (IDR) of ‘BB’ with a ‘stable outlook’ for long-term foreign currency which may help lower perceived payment risk. EVN’s rating aligns with Vietnam’s sovereign rating.

The PPA template that accompanies Vietnam’s solar FIT regulations does not follow international standards, in that it contains imprecisions with regard to monthly payments, termination clauses, and curtailment. With a strong PPA, termination risks can be guaranteed by private insurance, such as that available through the Multilateral Investment Guarantee Agency. Vietnamese banks are able to provide debt without insurance against off-taker risk, but they provide only short-term corporate financing. It will be difficult to reach Vietnam’s 12 GW target solely with financing leveraged against the balance sheets of Vietnamese companies.

6. DEVELOPMENT OF THE PV SUPPLY CHAIN

Section 6 presents the key results of an analysis of PV supply chain development in Vietnam that was commissioned by the World Bank as an input to this work (World Bank, 2018b).

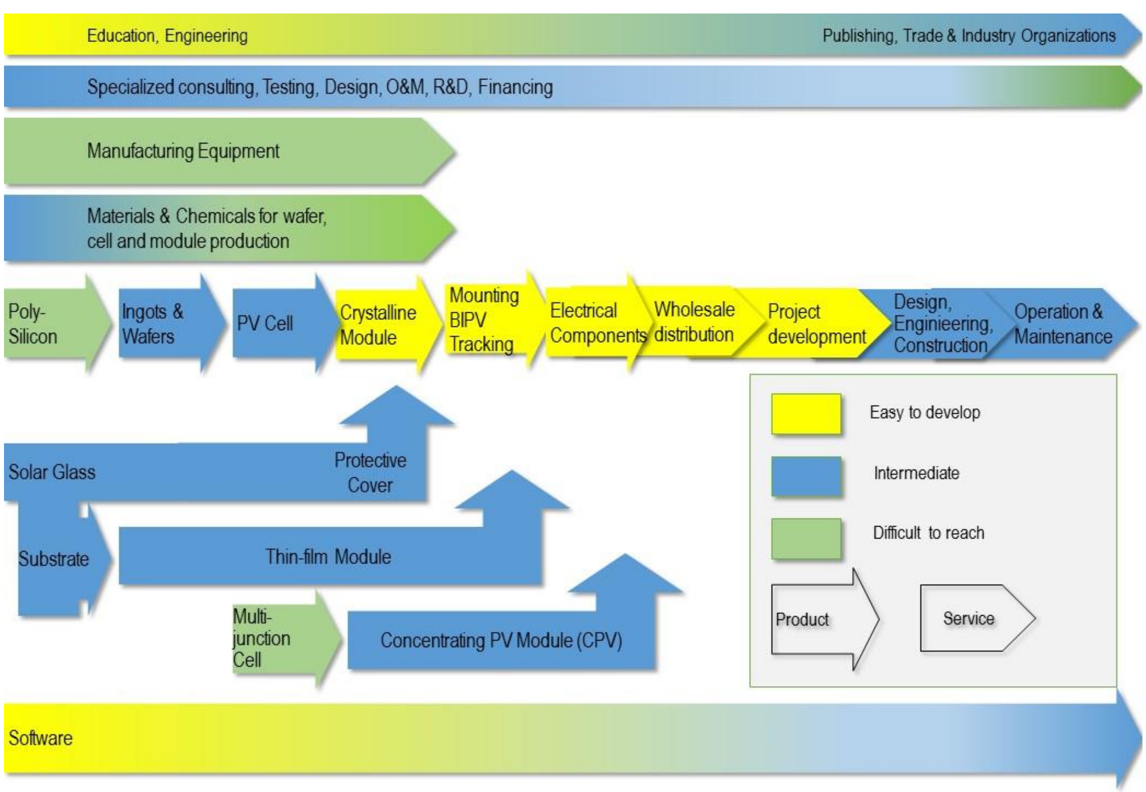
6.1 Analysis

Solar PV is a mature, fast-growing sector based on wafer-based crystalline silicon technology. China, Europe, and the United States are the main markets, but 80 percent of modules are manufactured in Asia. In Vietnam, modules are manufactured in collaboration with Chinese and American manufacturers. In 2017, 5 GW of panels were manufactured in Vietnam, representing 7 percent of the global market.

The domestic solar PV market is expected to reach a peak installation rate of around 1.8 GW/year under the targets specified in Revised PDP 7. The country's module-manufacturing capacity, presently dedicated entirely to exports, stands at 5.2 GW/year, about three times the maximum expected size of the local market. Under these conditions, given typical factory sizes, only a limited number of component manufacturers would be able to depend on the local market alone, so the present export orientation will continue to be necessary. But, importantly, charting a clear path to the 12 GW will encourage the creation of EPC companies and other local services in Vietnam to build the planned plants (figure 6.1).

Construction, operations, maintenance, and manufacturing for the local market have the potential to raise Vietnam's GDP by about 0.25 percent by 2030 and to create more than 25,000 jobs.

Figure 6.1 Economic activity associated with pursuit of Vietnam's 12 GW solar PV target



6.2 Key Findings

6.2.1 Vietnam's Industrial Attractiveness

Vietnam's competitiveness in solar PV manufacturing has been assessed on four parameters in order to compare it with selected benchmark countries (China, Malaysia, the Philippines, Thailand, and the United States). The four parameters are:

- Production factors (availability and cost of materials, labor force, and capital)
- Demand factors (local market and exports)
- Risk and stability factors (country risk, inflation, regulatory framework for renewable energy)
- Business support factors (infrastructure, place of industrial sector in economy, innovation and competitiveness)

Vietnam's competitiveness lags behind that of China, Malaysia, and Thailand in all solar PV industries except for frames and structures. Vietnam's key strengths are in production factors, particularly the labor market, the availability of materials for solar industries (particularly steel), and a favorable cost of energy for industrial consumers. Manufacturing of modules, cells, ingot/wafers, and eventually inverters will be mainly export-driven and will develop independently of local solar PV construction. Structures and services (such as project development, engineering, design, and O&M) will develop to serve the local market.

6.2.2 Potential Creation of Jobs

The 12 GW PV target is expected to support as many as 25,000 full-time jobs in project development, services and O&M annually in the period through 2030 (figure 6.2). Solar PV–related employment in Vietnam will derive from (i) development and operation of solar PV power plants, and (ii) manufacturing of equipment. The first category comprises jobs in development, design, construction, and commissioning of solar PV plants. Jobs created in connection with project implementation tend to be temporary and to disappear once the plant is commissioned and generating power. The implementation phase is followed by operation and maintenance, which extends for the duration of the plant's life cycle.

Job creation in manufacturing is expected to reach nearly 20,000 full-time equivalents by 2030. Most of these jobs will be export driven and depend on Vietnam maintaining its current share of the global solar PV market. That, in turn, will depend on the country retaining its attractiveness to international solar PV manufacturers.

Figure 6.2 Jobs in project development, services, and O&M expected to be created by achievement of Vietnam's 12 GW solar PV target, 2017–30

(Thousands of full-time equivalent positions)

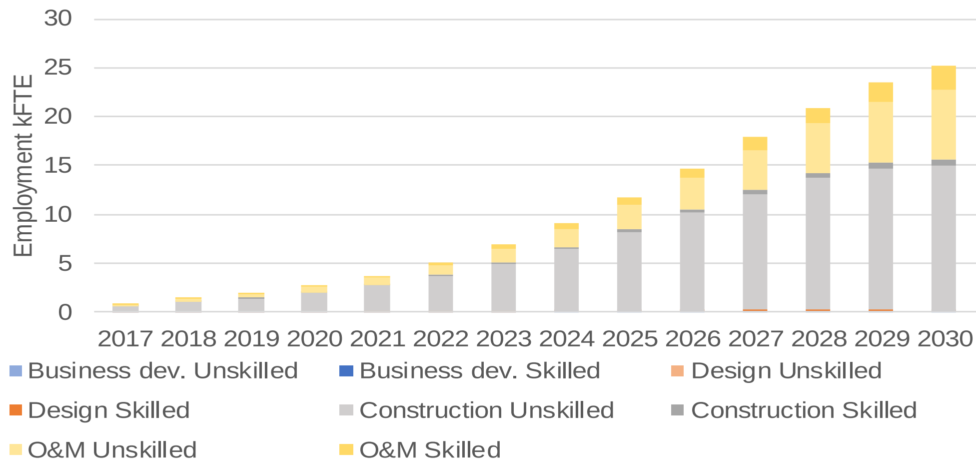
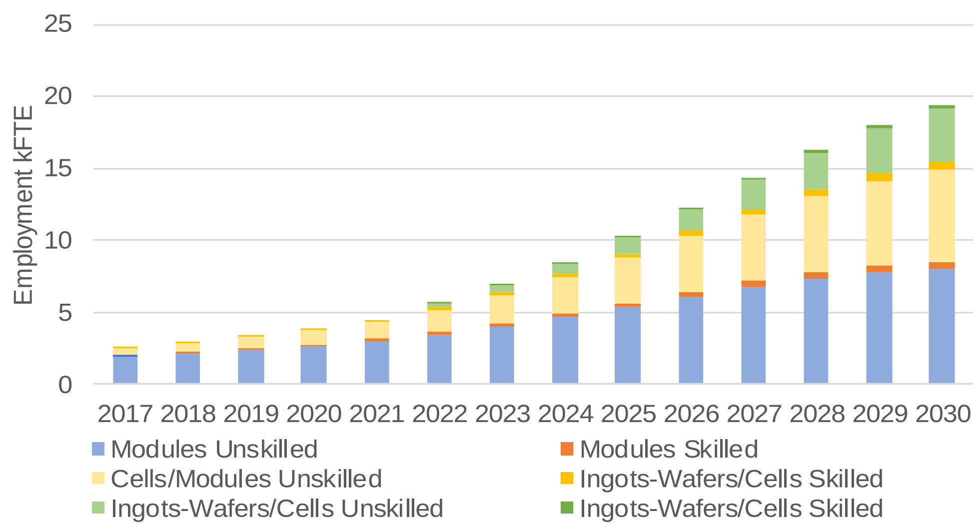


Figure 6.3 Manufacturing jobs expected to be created by achievement of Vietnam's 12 GW solar PV target, 2017–30

(Thousands of full-time equivalent positions)



6.2.3 Counterproductive Local-Content Regulations

Local-content regulations have yet to prove that they can stimulate domestic industries while also lowering the cost of producing electricity. The largest PV producers (notably China and India) did not require specific regulations to develop their supply chain, which developed naturally with the large amount of PV capacity built and installed in those countries. In Southeast Asia, local-content requirements are in force only in Indonesia. Similar requirements for solar PV installations in Vietnam would be unlikely to raise employment in the export-driven manufacturing sector. On the other hand, they could reduce or retard plant development, thus exerting a negative impact on employment at the national level.

7. DEPLOYMENT POLICIES

Section 7 describes various deployment policies that governments have implemented to promote solar PV.

7.1 Analysis

Governments can support the deployment of solar PV in three ways: through publicly financed projects, through privately financed projects, or under a public-private partnership. To encourage privately owned generation and leverage private capital, governments have two choices. They can set the price of the PPA up front by means of a FIT, in which case the quantity of power produced depends solely on each investor’s appetite. Conversely, they can set the quantity up front and invite investors to compete on price (expressed in US$ per kWh) through an auction in one of two basic forms: a standard auction or a solar park auction. In the first case, the IPP selects the site; in the second, the government provides it.

The price of each PPA needs to be considered in the context of its financial, technical, and fiscal benefits; risk allocation; type of scheme; and pricing format. As presented in table 7.1, tariff differences can be explained in terms of several parameters: the deployment scheme; whether land was provided; the duration of the PPA; access to debt financing; degree of solar irradiation; plant size; the allocation of risk in the PPA; and the experience of the government and participating utilities. Because most PPA prices are linked to inflation, it is important to compare them in levelized real terms (i.e., with inflation taken into account). Vietnam’s FIT, for example, is US$0.0935 /kWh in nominal (nonindexed) terms, but US$0.073/kWh when levelized, reflecting the effect of inflation on the FIT price over time.

Table 7.1 A breakdown of PPA prices by parameter

Parameter	Dubai 2016	Zambia 2016	S. Africa 2015	India 2014	India 2017 REWA
Type of deployment	Solar park	Solar park	Standard auction	Standard auction	Solar park
Benefits	Land and transmission line, low debt and fiscal incentives	Land and transmission line, low debt and fiscal incentives	Fiscal incentives	Fiscal incentives	Land and transmission line, low debt and fiscal incentives
Capacity factor (percent)	25	22	22	20	21
CAPEX US$ million/MWp	0.75	1.1	1.25	0.9	0.6–0.7
Cost of US$ debt (interest rate)	2	4–6	5–6	11–12	9–12 (INR)
IPP expected return on equity (percent)	5–7	Less than 12	11–14	13–15	9–12
Debt/equity leverage	85	70–75	75	75	80
Debt tenor (years)	25+	17–20	15	15	15–17

PPA term (years)	25	25	20	25	25
Date of delivery	2018–2020	2017	2018	2016	2019
Size of plant (MWp)	800	48	75	40	250
Project status	Announced	Announced	Permitted	Commissioned	PPA signed
Levelized real price, including inflation (US$/MWh)	**2.99**	**4.70**	**6.45**	**8.60**	**4.90**
Estimated flat nominal price for the duration of the PPA (US$/MWh)	3.80	6.02	8.30	11.2	6.30

Source: World Bank estimates based on simplified financial modelling.

Note: The parameters are indications of the debt, equity, and CAPEX needed to reach the stated PPA prices, based on discussions with lenders and IPPs.

7.1.1 Public Projects

Public projects are developed and owned by the government. They usually enable tighter control over production and are potentially less costly if the government has access to concessional financing (official development assistance). However, to the extent that public projects, such as PV solar generation, could be implemented efficiently by the private sector, scarce public resources could by allocated to projects that are more difficult to implement by private sector. Moreover, in the event of success, private operators may be in a better positioned to expand operations quickly. Finally, solar PV technology, unlike hydropower, is not a strategic asset that has other uses beyond electricity production.

7.1.2 FIT Schemes

FIT schemes center on a present tariff that is granted to an IPP once its solar PV project has reached the agreed level of development. They facilitate the entry of new players into the market by guaranteeing that electricity will be purchased at a set price. No time need be spent on price negotiation, as in the case of unsolicited business-to-business projects. And the long-term security provided by FIT scheme drives technological development. Their main disadvantage is that the processes of tariff setting and tariff adjustment are complex and mistakes can be costly for the government.

7.1.3 Standard Auctions

In standard auctions, prospective developers compete on the PPA price by selecting their own site. As in FIT schemes, they identify and develop the site. Unlike FIT schemes, however, standard auctions enable real price discovery and offer greater certainty about the quantities of power to be provided, since the quantity is set up front. However, poorly organized auctions can fail (e.g. with projects not being built because bid prices are too low) and, even if they succeed, it is difficult for planners to control whether the projects will be built on time. Interconnection agreements can address the latter problem, but a thorough grid-integration analysis must still be done, taking into account all projects approved and committed.

7.1.4 Solar Park Auctions

Solar park auctions are an innovative form of public-private partnership in which the government identifies a site prior to the auction and commits to develop the main infrastructure (notably the transmission line from the site to the main grid) and secure necessary permits. The auction winner is responsible for construction, financing, O&M, and an annual payment to the government for use of the infrastructure and land. The solar park scheme has been adopted in Dubai, India, and Zambia, among other countries.

Solar parks reduce IPPs' development risks by eliminating regulatory hurdles and other hazards of project development—finding land, securing an interconnection agreement, performing environmental studies. This reduction in development risk, as well as development time, elicits lower prices, since the IPP's expected return on equity can be set at a risk-free level. Furthermore, lenders are usually more confident with such projects, when well organized. Those terms can often be publicized ahead of the auction, so that the winner(s) need only sign documents prepared ahead of time.

That the government oversees land selection enables better network planning and integration.

7.2 Key Findings

7.2.1 Choice of Deployment Scheme in Light of Level of Industry Development

Based on international experience, FIT schemes are a successful way to support a nascent solar industry. They promote the development of the market with a stated PPA price, reducing pricing risks for developers. Once the market is in motion, auctions are the best way to increase competition in the market and so to decrease prices.

7.2.2 Optimized Risk Allocation

An optimized risk allocation is crucial when trying to reach the lowest PPA prices. The PPA document should cover all risks related to curtailment, payments, and other contingencies, and an offtake support may be required if the off-taker is considered too risky. The stronger the PPA, the lower the resulting prices.

As seen in Dubai, India, and Senegal, the solar park scheme usually yields the lowest prices by allocating risk optimally between the public and the private sectors. Under the scheme, as noted, all development risks—such as land acquisition, grid integration, and environmental and social permitting—are borne by the government instead of the IPP.

7.2.3 Well-Organized Standard Auction with Clear Requirements

In standard auctions, developers and investors compete for the right to build a project whose specifications (including required environmental studies, grid-integration permits, and a land-lease agreement) are publicized and communicated to potential bidders well in advance of the auction date—and typically four to six months in advance to the request for proposals.

All projects should be required to adhere to the grid code and provide high-quality production forecasts to the dispatch team.

7.2.4 Clear Long-Term Deployment Strategy

Regular, well-publicized auctions and a clear long-term deployment strategy are key to attracting serious IPPs and reducing PPA prices. Governments, such as India's, that have set high targets for installed generation and conduct yearly auctions of 1 GW and more have been the most successful in reducing prices, attracting manufacturers and EPC companies, and supporting a competitive solar IPP market. India and other governments that have elected to develop solar energy through auctions use a mix of standard auctions and solar parks auctions.

Vietnam has an ambitious installed generation target and now needs to lay out its deployment strategy to reach that target. Section 8 proposes a roadmap.

7.2.5 Simulation of Financing Results

Feed-in-Tariff

Under the current FIT—fixed at US$0.0935/kWh for 20 years (or US$0.073/kWh when levelized to account for inflation)—most solar PV projects will be likely developed by domestic IPPs and developers using corporate finance provided by local banks.

Standard Auctions Adhering to International Standards

Based on the simplified financial modeling presented in Section 2, if a well-organized standard auction with a fair risk allocation (as set forth in a PPA meeting international standards and geared to opening the Vietnamese market to international project financing) were launched in 2019, it could yield PPA prices in the neighborhood of US$0.055–0.065/kWh in levelized real terms over 25 years (US$0.075–0.085/kWh in fixed terms). After 2021, thanks to lower equipment and construction prices and the development of a competitive IPP market, levelized prices for solar PPAs resulting from standard auctions could fall below US$0.055/kWh.

Solar Park Auctions

Under optimal conditions, solar park auctions could bring PPA prices of US$0.05/kWh in levelized terms (about US$0.068/kWh in fixed terms). After 2021, assuming a few gigawatts are deployed, prices in PPAs emerging from solar park auctions should fall below that level.

7.2.6 Geographical Deployment

The Vietnamese provinces most likely to yield PPA prices competitive with the current average national generation cost are Ninh Thuan and Binh Thuan (both in the South), followed by other regions in the South and Center when the two Provinces will have exhausted their technical potential and if land cost stays stable. Once EPC costs fall further—bringing CAPEX closer to India's levels of US$500,000–700,000/MW —most regions will become competitive.

8. SUMMARY AND PROPOSED ACTION PLAN

8.1 Recommendations

- Limit the 12 GW target to utility-scale solar, keeping rooftop solar under net-metering or equivalent tariff regimes designed for distributed generation. It is difficult to impose a target on the development of rooftop PV, in part because smaller installations produce power mostly "behind the meter." However, large rooftop PV installations, including portfolios of multiple sites, should be allowed to participate in standard auctions alongside utility-scale ground-mounted projects.
- Implement a combination of standard auctions (ground-based and large rooftop) and solar park auctions (ground-based and floating PV) after the current FIT expires in mid-2019.
- Consider central government, provinces or appointing EVN to lead the development of solar parks. If EVN leads the development, this would also ensure that solar PV capacity is planned and implemented in a strategic and cost-effective manner, while minimizing grid-upgrade and system costs. However, central government and provinces may have better access to land than EVN.

8.2 Proposed Roadmap

Based on the analysis reported here and the Revised PDP 7 solar PV installed capacity targets, the World Bank proposes the following roadmap to reach Vietnam's 12 GW target, subject to further discussions with all stakeholders:

- **2020: + 850 MW** of capacity could be constructed by June 2019 as per the FIT scheme deadline and Revised PDP 7[7]
- **2021: + 800-1000 MW**
  - Pilot solar park auction of up to 500 MWp to be developed at an EVN site(s), with EVN and/or provinces owning the land, following expiration of FIT regime.
  - Pilot standard auction of 300-500 MWp for which developers put forward their own sites, launched after FIT expires.
  - The two pilots could be launched together or in close sequence in 2019 for COD timing in 2021.
- **2022–2025: + 2.5-2.65 GW**
  - Depending on the results of the pilot auctions, a mix of solar park (ground-mounted and/or hydro-connected) and standard auctions (possibly with a premium for certain locations that would not require grid upgrades)
- **2025–2030: + 8 GW**
  - Same as above, with a mix of deployment schemes depending on results obtained from initial auctions. Storage might be made a requirement if costs have fallen sufficiently.

[7] This number is based on the Revised PDP 7 target. However, it is important to note that the amount of power to be developed under the FIT is currently set at 17 GW, and it is difficult to know how many of these projects will be granted the FIT. Also, the Government is currently preparing Power System Development Plan 8 for which the solar targets will be updated and is expected that there will be an upward revision to the current 12 GW target by 2030.

8.3 Proposed Action Plan

- End 2018 – early 2019: Develop an overall solar development program and strategy to reach 12 GW of solar PV by 2030, which may need to be revised once the solar targets under PDP 8 are known;
- Early 2019: Explore options for solar park development, including giving EVN or selected provinces a strong leadership role.
- Mid-2019: Announce a deployment strategy to provide some certainty to developers and investors, with a regular schedule of progress checks and revisions.
- Mid-2019 – early 2020: Design and launch of a pilot solar auction (procedures for selection of winner, appropriate allocation of risk in PPA following international standards, criteria for sustainable integration into the grid, etc.), and consider expanding pilot to include additional standard and solar park auctions, either in parallel or in close sequence.
- Mid-2019: Develop a comprehensive VRE-integration strategy that (i) considers the longer-term potential of solar and wind to provide least-cost power, and (ii) includes plans for required grid upgrades and flexibility enhancements.

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