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FINANCING SOLAR PHOTOVOLTAIC TRANSITIONS: FROM UTILITY TO RESIDENTIAL MARKET ADOPTION IN EMERGING ECONOMIES

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Abstract

Solar photovoltaic (PV) technological leap-frogging greatly enhances energy accessibility, yet energy affordability remains a critical challenge. Traditional financing options, categorized as the solar-as-asset model, usually favor utility-scale PV projects, whereas the investment growth in smaller-scale PV systems is far behind, particularly in emerging countries. To further untapped PV potentials, we need to promote technological adoption in non-utility markets. That requires alternative financing approaches, such as the solar-as-service model. This paper examines the advantages and disadvantages of different financial schemes for introducing PV facilities in terms of the suitability of funding vehicles and investment mechanisms. Given the policy expense curtailment, owing to the gradual PV competitiveness, our analysis particularly focuses on the emerging market for PV installations for self-consumption. As the main obstacle is the high upfront cost of PV systems, we examine the new financial models in which customers buy the service rather than PV system per se. We consider what conditions would be necessary to facilitate the third-party ownership models and alternative financing schemes. Finally, this paper discusses what policy measures and instruments can be deployed to foster further PV adoption in the context of emerging economies. This study also provides implications for corporate strategy and financial institutions.

Keywords: PV investment models, PV price competitiveness, distributed PV system, solar-as-service, solar third-party ownership

JEL Classification: O16, O33, Q48

Contents

1. INTRODUCTION

Since the Industrial Revolution in the 19th century, fossil fuels—coals, oils, and natural gases—have come to account for around 80% of total primary energy supply (IPCC 2014). Besides the soaring anthropogenic greenhouse gas emissions, these resources are depleted and cannot solely secure increasing energy demand. A reduction in fossil fuels consumption and the promotion of renewable energy utilization will be a critical pathway toward a low carbon society (MacKay 2009). In order to achieve energy sustainability, each country faces different challenges due not only to geographic and climatic uniqueness, but also resource constraints and technological availability. As the soaring energy demand is directly related to the population growth, the issue will be more pronounced in emerging economies, where 85% of the 9.7 billion world population in 2050 is projected to be, compared to 15% in developed countries. In addition, the rapid growth of mega-cities is evident and urban areas will accommodate around 70% of inhabitants by 2050 (UN 2017). The term "energy trilemma" has been coined by the World Energy Council in reference to the three dimensions of energy security, energy equity, and environmental sustainability. The energy trilemma also addresses complex interactions between public and private actors, governments and regulators, economic and social factors, national resources, environmental concerns, and individual behaviors (World Energy Council 2013). Despite the dissimilar forms of energy contained in each resource, all renewable energy (RE) can be converted into electricity, which is the most convenient energy vector as it is easily transformed into other forms, such as light and heat, and can be conveniently transmitted and stored. It is widely considered to be a fundamental enabler of modern society. However, the high upfront cost and long payback periods of RE technologies are major impasses in clean technology adoption. Thus, this paper particularly addresses energy equity in terms of accessibility and affordability.

Solar photovoltaics (PV) are carefully selected as the subject of research. PV has shown the steepest learning curve (in terms of the sharpest PV panel cost reduction) amongst other renewable energy technologies (REN21 2016). In addition, thanks to the modular units, PV systems can be deployed on various scales, ranging from rooftop systems to ground-mounted systems in utility-scale solar farms, and are compatible as both grid-connected systems and off-grid/standalone systems suitable for remote areas. The initial high upfront cost of PV technology has justified the rationale of market intervention by the government, and PV-related policies truly signify the role of policy-induced technological change which, to some extent, disrupts the electric power industry worldwide. However, particularly in emerging economies, policy expense and policy discontinuity are often amongst the leading issues surrounding how further PV technology adoption can be deployed.

This paper consists of three sections. Firstly, it considers PV policy mechanisms and financing options based on three sectors: residential, commercial/industrial, and utility. The advantages and disadvantages of different financial schemes for introducing PV facilities in terms of the suitability of funding vehicles and investment mechanisms are reviewed. Secondly, policy implications are classified based on three stages of PV price competitiveness compared to retail electricity price. The analysis particularly focuses on the transition of PV system installation from utility-scale projects to distributed PV (DPV) systems in residential and commercial/industrial sectors. The last section will address what conditions would be necessary to facilitate the financing model and other third-party ownership models, and what policy measures and instruments can be deployed to foster further PV adoption in the context of emerging economies. The conclusion will also summarize the implications for corporate strategy and financial institutions.

2. PV POLICY AND INVESTMENT MODELS

While it is known that solar PV technology has been developing since the 1960s and a series of technological breakthroughs have been achieved, market adoption has nevertheless been sluggish and has directed attention particularly to silicon-based PV (Fraunhofer ISE 2018). Besides technogical challenges, the barrier to PV technology adoption in an existing fossil fuel-based electricity market typically revolves around the cost issue. The global solar PV market growth is well-aligned with the price reduction in solar modules. Besides the technological improvement aspect of the manufacturing, economic factors also influence the solar module pricing mechanism; the real interest rate has a positive correlation, whereas exchange rate, knowledge stock, and oil price have a negative correlation (Taghizadeh-Hesary, Yoshino, and Inagaki 2018). Hence, public policy intervention initially plays an important role. In terms of policy design for PV technological diffusion, the government intervention can be broadly divided into three categories (IET 2015) as follows.

2.1 Market-Based Support Mechanisms

Market-based support mechanisms consist of two main approaches. In the price-based market instruments, price is determined by the policymaker, while quantity is regulated by the market. In addition to price, the policy can be tailored to focus specifically on the investment (i.e., investment subsidies, tax incentives) and/or the generation (i.e., feed-in premium, feed-in tariff, net metering). In the quantity-based market instruments, quantity is determined by the policymaker, while price is determined by the market. Quota obligation (i.e., tradable green certificates or renewable portfolio standards), tender scheme, and auctions are amongst the policy choices. Some support mechanisms are listed in Table 1.

Table 1: Some Market-Based Support Mechanisms

	Price-based Instruments	Quantity-based Instruments
Investment-focused	Investment subsidies Tax incentives	
Generation-focused	Feed-in premium Feed-in tariff Net metering Net billing Tax incentives	Quota obligation Tender scheme Auctions

Source: Adapted from IET (2015).

2.2 Regulatory Policies

Grid connection capacity, adminstrative procedures, construction permit processes, utility interconnection rules, and technical standards are amongst policy design elements aiming to accommodate project establishment, streamline project execution, and ensure project operation.

2.3 Flanking Policies

Flanking policies include, but are not limited to, research and development (R&D) grants or funding, loans with no interest or a below-market rate of interest (a.k.a. soft loans) to enhance financial inclusion, education and knowledge dissemination for different stakeholders, and training programs for a skilled workforce.

Despite different degrees of PV policy deployment in different countries, both developed and emerging countries have adopted and promoted market-based support mechanisms to encourage early technology adoption. However, regulatory and flanking policies are of substantial importance and need more attention, particularly in emerging countries. Concerning PV segmentation, each country adopts its own classification based on PV system installation size and usage by different types of end consumer. Thus, this paper broadly identifies three sectors—residential, commercial/industrial, and utility—to reflect different PV investment models from PV developers' and project owners' perspectives, as well as policy influences and benefits which distinctively affect each sector. By definition, financing refers to the provision of financial resources (a.k.a. capital) which are required for project realization. Financing options can be distinguished by sources of capital: debt and equity. Debt capital providers consider solely interest and repayment of the principal loan. In contrast, project ownership is acquired by equity capital providers, and so full participation and a risk-return perspective are adopted. Besides typical debt and equity financing options, alternative options are capital leases and operating leases, which offer advantages of tax benefits and low transaction costs. Furthermore, financing options can be distinguished by the investment mechanism: corporate balance sheet and project financing. Although the balance sheet offers low transaction and capital costs, and a flexible financing structure, the project sponsor bears the default risk. For non- or limited recourse to a project sponsor, project financing (a.k.a. asset-specific financing), conducted as a legally independent project company, relies on a long-term contractual relationship between different entities; the stable and forecastable project cash flows are the main source of collateral and loan repayment. Hence, a reliable public support scheme or a long-term power purchasing agreement is preferred. Moreover, the multi-contacting and rich dynamics in various phases of project execution are key characteristics of project financing. Inevitably, the complexity embedded within project financing needs knowledge-intensive arrangements, and transaction costs can be high (RENAC 2016).

For a residential or commercial/industrial rooftop PV system, two investment options are self-financing, and retail debt or concessionary financing instruments, including mortgage-based loan, personal loan, and saving guarantee program. The practicality of solar crowdfunding (for loan or leasing) and the solar third-party ownership model (pay-as-you-go business model, which allows customers to pay for the power service and avoid the high upfront cost of the PV system) is yet to be demonstrated within the existing power market conditions, especially in emerging countries, where a new legal business structure and supporting policy have never been implemented.

For a utility-scale project, it is noteworthy to remark the different investment patterns despite less diversity in financing schemes. Even though all utility-scale projects are established as limited companies, the scrutiny of their shareholder structure often reveals parent companies that are responsible for the actual financial resource allocation. If the parent company is a listed company on the stock market, usually both debt and equity financing are utilized; but if the parent company is a non-listed company, it may depend on debt financing and/or corporate financing, and gain indirect benefits from a tax shield (as interest on debt is a tax-deductible expense). Concerning the cost of capital, debt financing can typically be obtained at a lower effective cost by a company that has performed according to expectations. However, the fixed cost of debt can be burdensome and can increase risk if the company fails to generate enough cash flow. Besides typical debt and equity financing options, alternative options are operating leases and capital leases. The comparison of each option is in Table 2 (RENAC 2016).

Table 2: Funding Vehicles

Structure	Potential advantages	Potential disadvantages
Debt	Fast, drawable options	Higher rates, on-balance sheet
Equity	No impact on debt profile	Potential future capital constraints
Capital leases	Tax benefits, low transaction costs	On-balance sheet
Operating leases	Tax benefits, low transaction costs	May require on-balance sheet

3. PV INSTALLATION TRANSITION FROM UTILITY SCALE TO DPV SYSTEM

A commonly used indicator to compare the costs of different types of electricity generation source is the levelized cost of electricity (LCOE). Three key drivers of LCOE of a PV system are: (1) the capital and installation costs of PV modules and the balance of the system, reflected in a unit of cost per watt (USD/W); (2) the average annual electricity yield (kWh/kW), which is a function of local solar radiation and solar cells' technical performance; and (3) the cost of finance for the entire PV system installation and operation (IRENA 2012). Grid parity refers to a point in time when the LCOE of an alternative energy source is less than or equal to the retail electricity price in a given country. In the context of PV, reaching grid parity determines PV technological competitiveness without subsidies or government support. Nonetheless, PV grid parity will not only stimulate PV technological diffusion, but also trigger the development of other PV-related businesses—e.g., solar inverters, energy storage technologies (chiefly mechanical and electrochemical storage), home energy management systems (HEMS), variable renewable energy grid integration support, weather forecasting technology, and an additional role of financiers in credit risk guarantee facility (Asia Clean Energy Forum 2016). Thanks to the economies of scale, utility PV is normally the first sector to reach grid parity, followed by the commercial/industrial sector; residential PV ranks last (Breyer and Gerlach 2013).

Regardless of PV sector, the same three stages of PV price competitiveness apply: uncompetitive, partially competitive, and fully competitive (IEA PVPS 2017). Valuation of the PV power output at each stage determines the monetary value of supporting schemes. In all three sectors, PV deployment has gradually shifted from installing a PV system as a power plant and selling all PV power output to the grid (as applied to both ground-mounted utility-scale projects, and solar rooftop with a long-term power purchase agreement), to installing a distributed PV system primarily for self-consumption purposes. An increase in DPV systems, particularly in the commercial/industrial and residential sectors, reflects a profound energy transition from supply-side to demand-side, where the consumer becomes the prosumer who is capable of self-generation and self-consumption of electricity.

During an initial uncompetitive PV stage, governments tend to use subsidies or levies as policy incentives (i.e., feed-in premium, feed-in tariff) to encourage technological uptake. It is worth noting that the feed-in premium (FiP) or the feed-in tariff (FiT) is typically financed through a levy on the electricity bill; thus, it is not a subsidy which is supported by public budgets or fiscal revenue. Subsequently, the rising retail electricity price, which affects all ratepayers, becomes a prevalent issue. Therefore, a series of tariff adjustments and dynamic degressions are implemented to accommodate appropriate changes with regard to the overall power industry and stakeholders.

In the partial competitiveness stage, PV installation gradually becomes economically viable. As the value of PV output is about the same as the retail electricity price, the DPV system benefits from a cost-saving basis and a risk reduction from future retail electricity price uncertainty. Additionally, there is the possibility to sell or store excess PV output. During this stage, the government can stimulate the market through a net-metering scheme. Net-metering allows customers to run the meter backward by exporting power back to the grid; in other words, the grid functions as a temporary power store. However, one argument from policymakers' perspective is that the value of DPV should not equal the retail electricity price; otherwise consumers will aim to sell electricity to the grid (given that the selling option is available). Thus, different policy tools are designed to allow the adjustable value of excess output from DPV; one policy choice is net-billing, wherein the purchasing price of the excess PV power portion can easily be regulated. However, policy implementation may face challenges, particularly in the retail sales market. Though DPV's primary goal is to fulfil the household electricity demand, the excess PV output does inherit financial opportunities, where institutional arrangements are required to optimize this potential.

In the full competitiveness stage, the value of the PV output can be lower than the average market price in order to remain competitive under the wholesale electricity market. Solar bidding—also referred to as auctioning or tendering—is a procurement mechanism by which the PV electricity supply is competitively solicited from sellers, who offer bids at the lowest acceptable price. Bids may be evaluated on both price and non-price factors (REN21 2016). The DPV system still benefits from a cost-saving basis and a risk reduction from future retail electricity price uncertainty, based on an assumption that the PV system owner is the same as the consumer (a.k.a. solar-as-asset model). But the innovative business model can enhance DPV system deployment by considering the solar-as-service model, in which the PV system owner need not be the same as the consumer. The third-party ownership model is discussed in the following section.

Besides the common benefits associated with other RE technologies (e.g., reduced or avoided greenhouse gases emission, green economy growth, and job creation), specific benefits from DPV deployment are as follows.

- Avoided electricity generating costs and peak demand saving. PV output yields maximum capacity during daytime which matches the highest electricity demand in many countries. Hence, DPV can substitute or reduce the usage of expansive standby power plants.
- Avoided transmission and distribution (T&D) costs and losses. DPV is installed on-site and its output is used locally. Therefore, a centralized T&D network is not required for an off-grid PV system, or becomes secondary for a grid-tied PV system.

- Avoided investment in new power plant capacity in a centralized power system. Despite intermittency issues, DPV can serve the additional power demand, which tends to increase with economic growth, especially in emerging countries.
- Supporting grid stability as an ancillary service. DPV can provide reactive power which then supports the medium and high voltage grid in times of voltage dip (voltage ride-through capability) (RENAC 2016).

However, DPV can have negative impacts on some stakeholders and raise some debatable issues, as follows.

- Utility opportunity and revenue lost. When consumers possess self-generating capability, demand from the grid become secondary. In other words, the lower electricity demand from the grid system will certainly reduce electricity sales (assuming a business-as-usual constant electricity demand).
- System integration costs. DPV system deployment indicates one issue in the fixed cost of a standby grid system—that PV adopters tend to be the free-riders. One possible countermeasure is to levy grid (accessibility and/or usage) fees.
- The interdependence of utility revenue and rate impacts of the future government supporting a PV monetary scheme (e.g., net-metering, net-billing) requires delicate analysis to minimize possible negative effects on retail electricity prices (Barbose 2017).
- Decreased tax revenues. Tax authorities may face decreasing tax revenues due to the decreasing retail sales from the electricity grid.
- Though a prosumer—the concepts of self-generation and self-consumption—will strengthen the notion of energy security, particularly on a household level, a broader perspective of national grid system security may not be positive. So far, no study has been done to forecast a threshold of PV penetration level which will have an adverse effect on the grid system due to either grid-connected or grid-tied PV systems. By the end of 2016, the PV penetration level in national electricity demand showed the progressive PV shares in three European countries—Greece (7.4%), Italy (7.3%), and Germany (7.0%)—while the next top ten countries in terms of cumulative PV installed capacity had less than 4% (REN21 2016; IEA PVPS 2017).

4. FINANCING INNOVATIONS

Traditional financing options regard a PV system as an asset, seeking to invest and acquire full ownership of the PV system. The initial investment includes the PV module cost, balance of system (BOS) cost, and power electronics. Besides a high upfront cost, the operations and maintenance (O&M) cost is marginal. Still, O&M is required to optimize the PV system. Benefitting from economies of scale, the utility-scale project dominates the PV market, especially in emerging countries. The People's Republic of China has surpassed Germany to become the world's largest country in terms of PV cumulative installed capacity since 2015, with utility-scale PV projects accounting for 85.6% of the 43.3GWp capacity in 2015 (IEA PVPS, CPVS 2016). PRC cumulative installed capacity reached 78.07GWp in 2016; India, the second most populous country, has demonstrated the most rapid PV market growth recently, doubling its installed capacity during 2015–2016. Indian cumulative installed capacity reached 9.01GWp in 2016 (IEA PVPS 2017) and 12.28GWp by the end of April 2017 (CEA

2017). However, India still struggles with two major issues: deficit in electricity supply, and huge losses in the transmission and distribution (T&D) network. In 2014, electric power coverage was estimated at 79.2% of the total 1.3 billion population, and T&D losses were reported to be 19% of the electricity output (World Bank 2017).

If the Association of Southeast Asian Nations (ASEAN) were a single country, it would have the third largest population in the world. According to the 4th ASEAN Energy Outlook (ACE 2015a), ASEAN accounted for approximately 8.5% of the world's population in 2013, consumed around 4.5% of the world's primary energy, and was accountable for about 5.7% of total global energy production. However, the regional supply is less likely to meet the growing demand based on the assumed GDP growth rate of 6.1%. The future demand is expected to increase by 2.7 times in 2035 (1,685 Mtoe of total primary energy supply (TPES) in 2035, compared to 619 Mtoe in 2013), or roughly 4.7% of the compounded annual growth rate (CAGR). Therefore, the efficiency standards, demand-side management, and deployment of RE are amongst the top priories in ASEAN member states (ACE 2015a). Thanks to the geographical locations, ASEAN countries have great potential for solar PV in terms of their annual solar insolation levels, which range from 1460 to 1892 kWh/m^2 per year (Ismail et al. 2015). Some key statistics of ASEAN energy infrastructure are displayed in Table 3.

Table 3: ASEAN Key Statistics in Energy Infrastructure

Country	**Population**	**Electrification Rates**	**Installed Capacity** (MW)	**Electricity Generation** (GWh)	**T&D Losses** (%)	**RE Electricity Output** (%)
Brunei Darussalam	434,448	100%	805.00	3,775.72	14.00	0.04
Cambodia	16,076,370	66%	1,899.00	5,698.00	4.27	61.10
Indonesia	263,510,146	88%	52,889.22	233,982.00	9.77	11.44
Lao PDR	7,037,521	88%	6,290.00	33,590.00	7.12	93.15
Malaysia	31,164,177	100%	30,875.23	143,826.00	1.63	9.71
Myanmar	54,836,483	32%	4,805.00	14,156.00	19.00	62.36
Philippines	103,796,832	90%	18,765.00	82,413.00	3.69	25.60
Singapore	5,784,538	100%	13,009.00	50,272.00	3.00	1.66
Thailand	68,297,547	100%	38,839.00	183,466.84	1.61	9.08
Viet Nam	95,414,640	99%	38,642.00	164,400.00	8.30	41.65
ASEAN	646,352,702	78.70%	206,818.45	915,579.56	7.24	31.58

Notes:

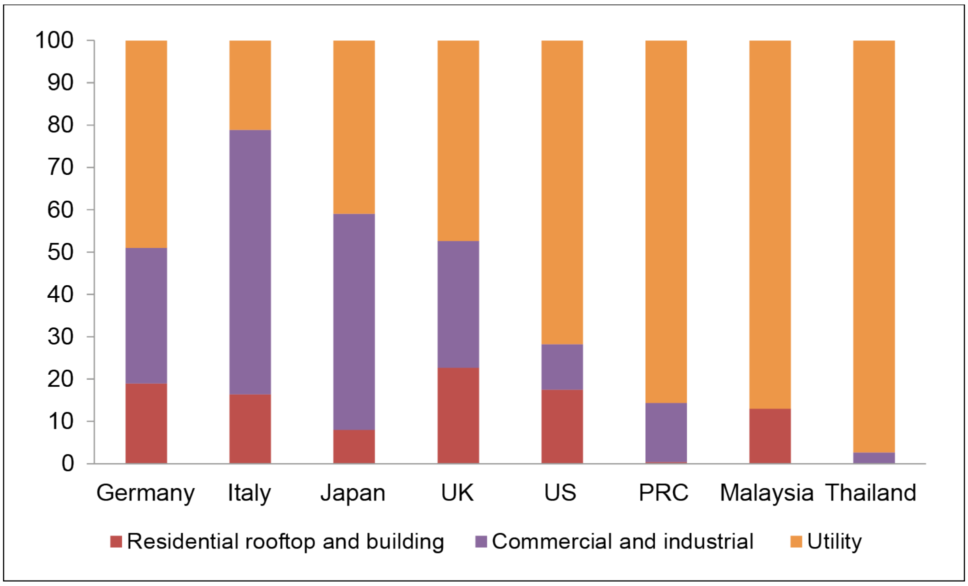
Population data as of March 2017 (UN 2017).

Electrification rates, installed capacity, electricity generation, and T&D losses data as of 2015 (ACE 2015b).

Renewable energy (RE) includes wind, solar PV, solar thermal, hydro, marine, geothermal, biomass, renewable municipal waste, liquid biofuels and biogas. RE electricity output (% of total electricity output) data from 2014 (World Bank 2017).

Compared with the historical regional power consumption amongst 10 ASEAN countries, Thailand's electricity consumption has increased drastically, ranked second to Indonesia (EIA 2014), even though Thailand's population is about a quarter of Indonesia's. In addition, Thailand is a leader in PV technological diffusion and the uncommonly over-dominant utility-scale project, which accounted for 97.3% of 2.1GWp capacity in 2016 (IEA PVPS, DEDE 2016). Because of a unique PV installation pattern in emerging economies, as shown in Figure 1, especially in Thailand (Tantiwechwuttikul, Yarime and Ito 2018), PV policy has been designed to encourage PV market growth in the non-utility market by means of subsidy, feed-in premium, or feed-in tariff for a specific installation size of PV system, which is applicable for commercial/industrial and residential sectors. However, investment mechanisms remain similar and can generally be categorized as the solar-as-asset model.

Figure 1: PV System Installation by Segment in Selected Countries (End of 2016)
(%)



PRC = People’s Republic of China, UK = United Kingdom, US = United States.

Source: Adapted from Tantiwechwuttikul, Yarime, and Ito (2018).

Among the two main types of investment mechanism—corporate financing and project financing—utilized particularly for utility-scale projects, project financing is predominant and has some advantages thanks to its non-recourse or limited-recourse nature from the established project company (a.k.a. special purpose vehicle, or SPV). An SPV is an intermediary acting as a debtor and is responsible for the financing arrangement. Thus, the project owner’s assets (i.e., the parent company) and general creditworthiness are not affected. However, the costs for the arrangements can be high in terms of both transaction costs and legal fees. Applying the system approach and value flow mapping (Cameron et al. 2008; Crawley, Cameron and Selva 2016) to a typical project financing, key stakeholders have been identified through their roles and specific needs as value flows. There are four types of value flow: financial, goods/services, information, and political. Due to various stages in the project value chain (from project development to construction and operation), each stakeholder has a different timeline and depth of engagement at each stage. A temporal aspect of project financing execution is beyond the scope of this study. However, Figure 2 illustrates how key stakeholders and flows of value interrelate, with detailed descriptions provided in Tables 4 and 5, respectively. The project sponsor and EPC contractor typically engage early in the project investment agreements, while technical/commercial services, long-term offtakers, and the local community are involved in the operating and financing agreements.

Figure 2: Stakeholder Map and Value Flow in Project Financing Mechanism

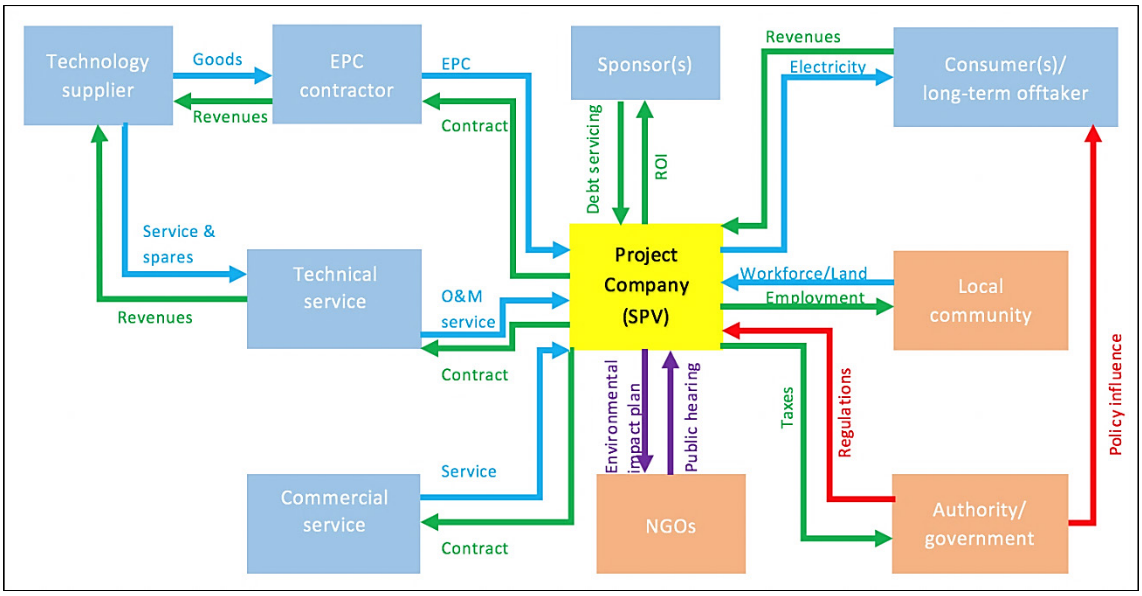


Table 4: Description of Stakeholders in Project Financing

Stakeholder Type	Description
Project company (SPV)	Owns and operates project; partner for different agreements
Sponsor(s)	Provides financial resources
Consumer(s)/Long-term offtaker	Purchases project output
Authority/Government	Provides law, regulation, and/or financial incentive
Local community	Provides resources—e.g., workforce, land
EPC contractor	Provides engineering, procurement, and construction of project
Commercial service provider	Operates general management contracts
Technical service provider	Provides operations and maintenance through service contract/insurance
Technology supplier	Deliver devices (i.e., solar panel)
NGOs	Serving as non-government organizations in interests of the public

As PV price competitiveness is approaching grid parity, government incentives are subsided and will eventually be eliminated. Hence, the trend of PV system installation is shifting from centralized grid-connected systems to distributed systems (e.g., rooftop for self-consumption purposes, off-grid or standalone PV system). Even though the solar-as-asset model allows the PV system owner to hedge the electricity cost and reduce market risk, a high upfront cost and O&M requirement hinder PV system installation. In order to ease the burden of purchasing a PV system, low-interest loan programs help finance the installation of a PV system; yet access to these financial services is another issue of financial inclusion, particularly in low-income households. Therefore, financing innovations can provide alternative solutions to further PV system installation and financial inclusion, which can be achieved through at least two approaches: the solar-as-service model and alternative financing schemes.

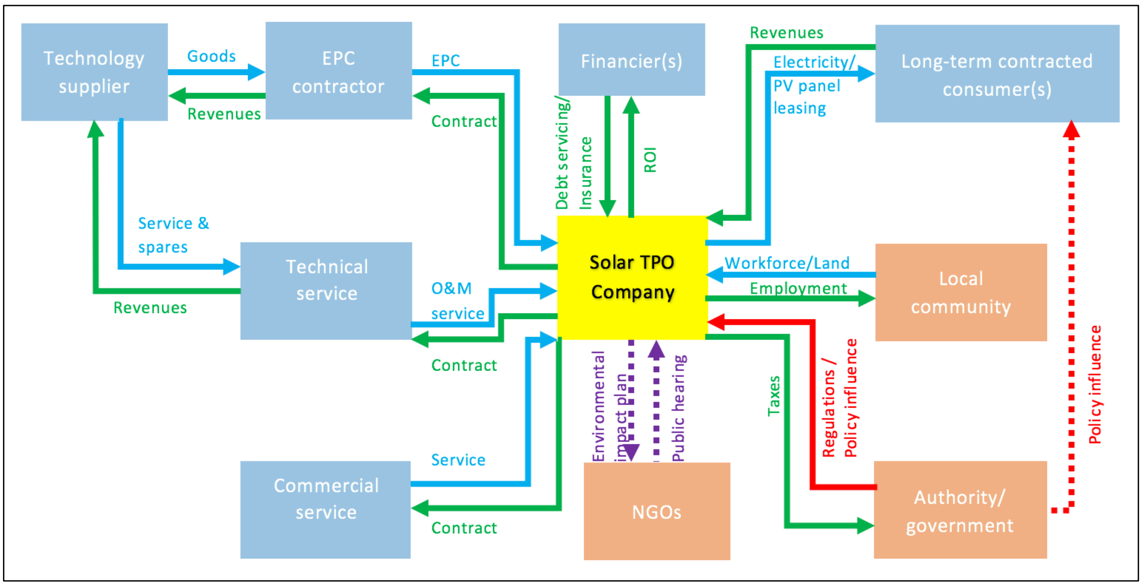
Table 5: Value Flow across Stakeholders in Project Financing

To Stakeholder	Value Flow	From Stakeholder
Project company (SPV)	Debt servicing	Sponsor(s)
	Revenues	Consumer(s)/long-term offtaker
	Workforce/land use	Local communities
	Regulations/approval	Authority/government
	Services	EPC contractors, technical service provider, commercial service provider
	Information	NGOs
Sponsor(s)	Return of investment	SPV
Consumer(s)/Long-term offtaker	Electricity (goods)	SPV
	Policy influence	Authority/government
Authority/ Government	Taxes	SPV
Local community	Employment	SPV
EPC contractor	Contract	SPV
	Solar system (goods)	Technology supplier
Commercial service provider	Contract	SPV
Technical service provider	Contract	SPV
Technology supplier	Revenues	EPC contractor, technical service provider
NGOs	Project information	SPV

The solar-as-service model identifies different value propositions and distinguishes between the PV system owner and user. In general, the third-party ownership (TPO) model can lease the PV system (solar leasing model) or sell PV electricity under a solar power purchase agreement (solar PPA model) (Bolinger , Barbose and Wiser 2009). The PV user can be benefit immediately from day one with no or little initial investment, and O&M is included in the service contract (Överholm 2015a). Several barriers to PV technology adoption—including technology risk and complexity, financing needs, high transaction costs in handling financial negotiations with banks, and learning costs—have entirely been transferred to the PV system owner (Drury et al. 2012; Hobbs et al. 2013). For the PV system owner (a.k.a. solar TPO company) to get profit and sustain its solar-as-service business, a long-term contract and creditworthy customers and financial partners are essential.

The working principle of a solar TPO company operates similarly to SPV in terms of project financing. The planning, financing, installation, ownership, and maintenance of PV systems are borne by the TPO company with the premises of end customers with long-term contracts either for PV panel leasing or electricity PPA. Figure 3 illustrates key stakeholders and flows of value within the solar TPO model, and provides more details of the solar TPO ecosystem, including key stakeholders and their interactions, which is simplified in other literatures (Överholm 2015b; Strupeit and Palm 2016). In comparison to the project financing shown in Figure 2, three key components in the solar TPO model have been altered. Firstly, the end customer value proposition is on a par with or superior to the existing retail electricity price from the grid—hence less policy influence from the government, which is coherent with policy transition in a solar PV competitive stage. Secondly, financial sponsors tend to be financiers providing not only debt servicing, but also the additional role of a credit risk guarantee or insurance service, because a prime determinant of business survivability is creditworthiness across all stakeholders. Last, the solar TPO model is usually deployed in the commercial/industrial and residential sectors; therefore, the smaller PV scale of the distributed PV system, and mainly rooftop installations, are less likely to exhibit major environmental concerns (e.g., land use and land cover change, soil erosion, water resources, and human health) as apply to the utility-scale PV project.

Figure 3: Stakeholder Map and Value Flow in Solar Third-Party Ownership Model



The United States, especially in the state of California, has since 2005 shown a proliferation of solar TPO business models, which are suitable for commercial/industrial and residential applications (Överholm 2013). The solar TPO model offers an immediate reduction of customers' electricity bills of around 10–20% via monthly customer savings on grid electricity bills over the course of 15–25 years (a hedge against future electricity price increases) and no upfront payment is needed (Hobbs et al. 2013). To compare solar PV purchasing and leasing options, a benefit-cost analysis of PV 4kWp installation size revealed that a cash purchase of a PV system resulted in a higher net electricity price relative to a home equity loan purchase due to tax deductions from interest paid on a home equity loan. In addition, a leasing option gains benefits from solar equipment depreciation. A sensitivity analysis displayed the more competitive conditions of a home equity loan purchase with capital depreciation over a leasing option when the discount rate is lowered from 10% to 5% or the cost of PV system decreased by 15%. Hence, combined tax breaks from capital depreciation, equipment depreciation, and interest deductions were key variables which emphasized the role of the federal and state-wide subsidies and tax credits to stimulate PV market growth in the residential sector (Liu et al. 2014). Interestingly, a self-financed commercial PV system with 500kWp installation size in California provided around 30% lower LCOE than a solar PPA option. Considering a payback period and project timeline, the self-financer would have a negative net cash flow for about 5–11 years, whereas the solar PPA offered a quicker positive cash flow, economically more attractive during the first 6–14 years (Feldman and Margolis 2014). In Thailand, where the utility-scale PV project dominates, solar PPA in the commercial/industrial sector emerged as one potential business model. A benefit-cost analysis of PV 120kWp installation size revealed that LCOE from solar PPA is around 10% lower than a self-financed option. The lower initial costs in solar PPA and retail electricity price escalation were key attributes. The self-financed option was highly sensitive to the discount rate; thus, a favorable condition occurred under the lower discount rate (Potisat et al. 2017). It is noteworthy that the underlying assumptions in financial modelling, market conditions, and policy supports are some variable, which have profound impacts on country-based analysis.

The paradigm shift of energy business models from the energy access company to the energy service company (ESCO) is transforming the power industry worldwide. The solar TPO model is disrupting not only the traditional utility ESCO model, but also the minuscule and distributed characteristics of the PV system from asset to service. Value creation of solar TPO is established through the solution providers, structuring the large number of situations and opportunities into standardized and fast-to-implement solutions. So, from PV users' perspective, DPV adoption needs to be low-risk, affordable, and uncomplicated (Schleicher-Tappeser 2012). TPO business opportunities achieve an inadequate financial capacity, particularly in the residential sector, while the commercial/industrial sector may strategically seek to outsource non-core business. Environmental consideration and partial grid independence are additional attributes of solar TPO attractiveness.

A relatively new business model, solar TPO, is mainly dominant in the US residential sector. As of April 2017, 26 states allow third-party solar PPA, including some states that limit or prohibit solar PPA explicitly allow it for residential solar leasing arrangements (DSIRE 2017). The solar TPO implications in the European and Asian markets are yet to be demonstrated. Nonetheless, some policy considerations can be applied for broader policy design principles (Överholm 2015b):

1. Legality of solar TPO model. Legal authorization for both solar PPA and leasing usually lies in the definition of a "utility" in national/state statutes, regulations or case law; in state regulatory commission decisions or orders; and/or in rules and guidelines for state incentive programs. Rather than traditional utility activity, which is usually mandated to be regulated, a business pursuit requires legitimate and administrative validation as a prerequisite for business establishment.
2. Policy consistency and stability. The solar TPO model relies on a long-term contractual relationship between different entities, similar to project financing. Stable and forecastable project cash flows are the main source of collateral and loan repayment. Hence, a reliable public support scheme or a long-term PPA is preferred. Moreover, the multi-contacting and rich dynamics of key stakeholders, including a variety of end customers' demands, address the important of creditworthiness, which can be problematic and determine business survivability.
3. Support for solar TPO financing. Given the policy expense curtailment owing to the gradual PV competitiveness, the primary agents of PV market growth are entrepreneurs and their ecosystems rather than individual customers. Hence, the influence of government policy can be directly applied through market-based support mechanisms with an investment focus, such as Investment Tax Credits (ITC) and other tax breaks from capital depreciation, equipment depreciation, and interest deductions. Policy incentives should be crafted to be easily claimed. Furthermore, flanking policies can lower financing costs through education and knowledge dissemination for financing institutions. The avoided information asymmetries can yield more accurate project risk assessment, and subsequently better project bankability analysis and appropriate financing agreements (RENAC 2016).

4. Facilitate solar installation processes. Solar TPO is a solution from providers for PV end users, which includes all aspects of regulatory issues, ranging from multi-stakeholders' legally binding contract preparation and permit processes to technology selection and utility interconnections. Solar TPO may seek operational integration with regulators and utilities so as to ensure swift, transparent processes and to help improve necessary regulatory policy.

Besides solar leasing or solar PPA, many innovative technology platforms have demonstrated business viability in emerging countries where the grid infrastructure is inadequate. Pico solar lanterns and pico solar PV systems for remote homes allow energy accessibility at an affordable price (IEA PVPS 2013). One leading global initiative, Lighting A Billion Lives, offers lighting solutions and operates as a pay-as-you-go business model. So far, solar lanterns have been disseminated globally, together with solar charging stations, solar micro grids, solar home lighting systems, and integrated domestic energy systems and over 5.65 million people and 3,300 villages have better access to the clean energy option (Lighting a Billion Lives 2017). In Japan, cross-selling of a DPV system with prefabricated homes is generally approximately 10% cheaper that a retrofit PV option. DPV financing, which is marginal compared to the total housing price, is bundled within the home mortgage, so transaction costs and loan interest rates are reduced (Strupeit and Palm 2016).

Alternative financing schemes such as solar crowdfunding aim to utilize lateral financing capability (e.g., peer-to-peer social loaning) through loan or leasing. Individual investments are pooled through solar crowdfunding platforms and are paid back in full within the agreed period. Typical crowdfunding platforms are: (1) donate sites, simply asking for a donation with no legal bidding and offering no incentive; (2) reward or pre-purchase sites, such as Indiegogo and Kickstarter platforms (Indiegogo 2018; Kickstarter 2018); (3) lending sites, where an intermediary company helps facilitate person-to-person lending, such as Mosaic and Zopa loan platforms (Mosaic 2018; Zopa 2018); and (4) equity sites, where an investment is made in an early stage of an unlisted company in exchange for shares of that company. Laws and regulations of crowdfunding schemes depend very much on national contexts, and accredited investors are desired, or sometimes required, for specific high value crowdfunding projects (Moungchareon 2015). In addition, power utilities can help facilitate DPV system installation, taking advantage of existing customers through the on-grid system and on-bill financing model. Customers' pooled PV demands—either PV system or PV electricity—can certainly extend the current power utility business (Barbose et al. 2016).

5. CONCLUSION AND POLICY RECOMMENDATIONS

Key challenges in PV financing can be intrinsic factors such as PV project uncertainties, and extrinsic factors of PV prospects. A PPA contract for PV projects under a feed-in premium or feed-in tariff is granted on specific terms. If the cost of electricity from the PV project is not competitive with conventional power plants by the time of contact expiration, PV project owners may discontinue PV projects at the end of their contracts. Market conditions are thus likely to play a key role in the development of the PV market. The national strategic development plan also plays a crucial role in PV technological diffusion and industry development. Key drivers include proactive consumers, institutional arrangements, and strategic repositioning of policy and industrial competitiveness. The co-existence and further market growth of both rooftop PV in residential and commercial/industrial sectors, and ground-mounted utility-scale PV systems are attainable but do require different policy instruments and supporting systems.

Concerning the risks associated with PV project investment, risks differ from development to construction and to operation stages. Risk consideration in four dimensions can provide a workable guideline for risk assessment. Firstly, political and regulatory risk covers country, permit, regulatory, fiscal, legal, and financial risks. Secondly, economic risk involves contractual, price, and volume risks. Thirdly, technical risk includes construction, O&M, performance, and availability factor risks. Finally, environmental and social risk covers public acceptance, labor, safety, and environmental issues.

Policy-induced technological change plays a crucial role in the PV industry through the national strategic development plan, in which institutional establishment and arrangements are essential. Initial market-based support mechanisms have thus far encouraged early technology adoption. Since PV price competitiveness is approaching grid parity, the role of the government is shifting from market intervention to the regulation and facilitation of investment mobilisation. With regard to PV system installation transition from utility-scale projects to distributed PV systems in residential and commercial/industrial sectors, variation of financing innovations is a key enabler. Traditional financing options consider the solar-as-asset model, and the high upfront cost and long payback periods hinder PV market growth, especially in low-income households. By contrast, the solar-as-service model unlocks financial constraint from the initial PV system investment and provides benefits to both investor and user through the solar TPO business model. Dependent upon different national contexts and market conditions, solar leasing, solar PPA, pay-as-you-go, and cross-selling business strategies are some practical financial innovations which require timely policy actions to fundamentally enable project feasibility. In addition, alternative financing schemes such as solar crowdfunding and the utility on-bill financing model can utilize the lateral financing capability and provide a business opportunity for the existing power utility. The essentials in the solar TPO model are long-term contractual agreements and a supportive policy landscape to accommodate novel business models.

Based on the findings, key solar energy policy recommendations, especially for the emerging economies, are: (1) legality of novel business models, which is a prerequisite for business establishment; (2) policy consistency and stability, which determines business survivability; (3) market-based support mechanisms which are investment-focused, addressing entrepreneurs and their ecosystems as primary agents of the current PV market growth; and (4) regulatory policies, which encourage and accelerate such financial arrangements and technological adoption, and substantially secure project sustainability.

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