Financing Renewable Energy Development in East Asia Summit Countries

A Primer of Effective Policy Instruments

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List of Abbreviations

ACE	ASEAN Centre for Energy
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
ASrIA	Association for Sustainable & Responsible Investment in Asia
BOI	Board of Investment
CBI	Climate Bonds Initiative
CDB	China Development Bank
CODI	Community Organizations Development Institute
CSG	China Southern Grid
DPSV	distributed solar photovoltaic
EAS	East Asia Summit
EE	energy efficiency
EPC	engineering, procurement, and construction
ERC	Energy Regulatory Commission (Thailand)
ESCO	energy service companies
ESG	environmental social governance
EU	European Union
FIP	feed-in premium
FIT	feed-in tariff
GBPs	Green Bond Principles
GHI	global horizontal irradiance
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	internal rate of return
Lao PDR	Lao People's Democratic Republic
LCOE	levelised cost of electricity
LSPV	large-scale photovoltaic
MCP	measure-correlate-predict
MG	mini-grid
NASA	National Aeronautics and Space Administration
NDRC	National Development and Reform Commission (China)
NEC	National Energy Administration
NGO	nongovernment organisation
NPV	net present value
O&M	operations and maintenance
OECD	Organisation for Economic Co-operation and Development
OGRE	off-grid energy project
PESCO	provincial electrification service company
PPA	power purchase agreement
PPP	public–private partnership

PV	photovoltaic
R&D	research and development
RE	renewable energy
REC	renewable energy certificate
RECAI	Renewable Energy Country Attractiveness Index
REN21	Renewable Energy Policy Network for the 21st Century
RET	renewable energy target
RPS	renewable portfolio standards
SGCC	State Grid Corporation of China
SHS	solar home system
SME	small and medium-sized enterprises
SRI	socially responsible investment
SSA	Supranational, sub-sovereigns, and agencies
SSE	Surface Meteorology and Solar Energy
SWOT	Strength, Weakness, Opportunities, and Threats
TSB	Tenaga Suria Brunei
UN	United Nations
US	United States
VAT	value-added tax
VC	venture capital
VEM	village electricity manager
VOP	village off-grid promotion scheme
WACC	weighted average cost of capital

Measurements

GW	gigawatt
GWh	gigawatt hour
km	kilometre
kWh	kilowatt hour
kWp	kilowatt peak
m2	square metre
MCp	megawatt peak
MW	megawatt
MWh	megawatt hour
W	watt

Currencies

B	baht
CNY	yuan
$	US dollar

Executive Summary

Background and objectives

The research aims to identify and update the most effective policies in the Asian context, especially for the Association of Southeast Asian Nations (ASEAN) countries, China and India. Specifically, it addresses what policies could effectively mitigate the most prominent risks related to renewable energy investments and therefore facilitate the application of the most promising financial mechanism in the region.

The project invited field experts to contribute research papers to give a timely update on the most important policy issues related to the financing of renewable energy development in the developing East Asian countries. The working group of authors consists of field experts in renewable energy financing issues from top energy research institutes such as the Brunei National Energy Research Institute, the Chinese Academy of Social Sciences, the Energy Research Institute of Chulalongkorn University, the Energy Studies Institute of National University of Singapore, North China Electric Power University, and ERIA; and international financial institutes such as the Asian Development Bank; as well as universities such as Nanyang Technological University in Singapore, Ohio State University, and Southwestern University of Finance and Economics in China.

The following financing issues are highlighted for the customised studies on the policy options for these countries:

❖ Financing mechanisms, including debts, equity, hybrid structures, and risk-sharing and mitigation, for the projects of different technologies – wind, solar, biomass, etc. A greater emphasis is given to the following in the Asian context:
    - Financing small-scale distributed renewable energy projects in urban areas as well as rural areas
    - The feasibility of smaller-scale lending through micro-credit, the fees for the service model, the revolving funds model, and the cooperatives model in rural areas
    - The feasibility of equity financing, such as joint ventures, specialised investment funds, and venture capital

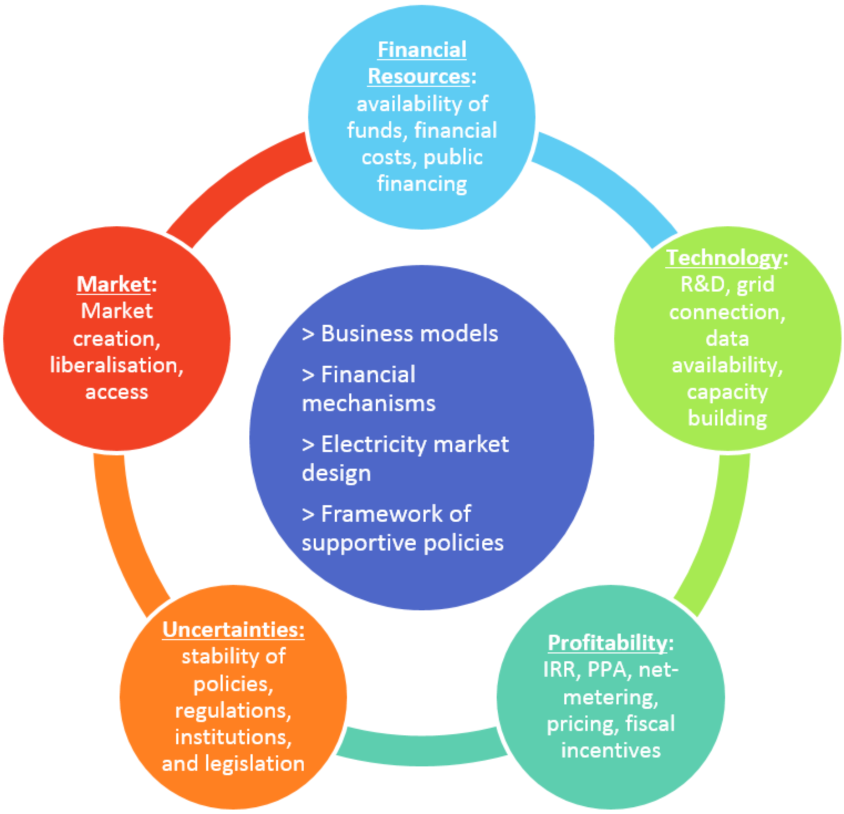
❖Other innovative financial mechanisms such as loan guarantees and political risk insurances

❖Liberalising energy markets, removing subsidies on fossil fuels and internalising the negative externalities of fossil fuel usage, and opening up of renewable energy markets

Methodology and organisation of the project

Specifically, all studies chosen highlight one or a few of the key issues in the following five dimensions as shown in Figure 1.1. The focal points which link these five dimensions of issues in financing renewable energy are: the business models, the financial mechanisms, the electricity market design, and the framework of supportive policies.

Figure 1.1: Five Dimensions of Issues to Promote the Financing of Renewable Energy



Note: IRR = internal rate of return; PPA = power purchase agreement.
Source: Prepared by the authors.

Policies pertaining to the five dimensions include: 1) market creation policies such as the renewable portfolio standard, the renewable energy certificate (REC), and carbon credit and trading; 2) reducing uncertainties of investment in renewable energy through the provision of stability of policies, regulations, institutions, and legislation; 3) improving profitability of renewable energy projects through the provision of power purchase agreements (PPA), net-metering, proper retail pricing, and even fiscal incentives; 4) regarding the barriers related to technologies, support should be given on R&D, grid-connection, data of renewable energy resources, and capacity building for all stakeholders of renewable energy projects; and 5) widening the sources of funds dedicated to renewable energy and lowering the financial costs for renewable energy projects. For both purposes, the involvement of public financing would be necessary to eventually leverage on private investments.

However, a country must be selective in choosing among these policy tools to build up its own framework and mechanisms of support for renewable energy, as the characteristics of renewable energy resources, technological capacities, maturity of the domestic electricity market, financial market readiness, and availability of public financing are all different. We thus emphasise the studies on the experience and lessons learned from each country in this region, and highlight the importance of integrating the design of policies from all five dimensions into a rational mesh of incentives for renewable energy investment. The selected studies are as follows:

No.	Studies
1	Renewable Energy Policies in Promoting Financing and Investment among the East Asia Summit Countries: Quantitative Assessment and Policy Implications
2	Assessment of Instruments in Facilitating Investment in Off-grid Renewable Energy Projects – Global Experience and Implications for ASEAN Countries
3	Business Models and Financing Options for a Rapid Scale-up of Rooftop Solar Power Systems in Thailand
4	Analysis of Distributed Solar PV (DSPV) Power Policy in China
5	Innovative Business Models and Financing Mechanisms for Distributed

	Solar PV (DSPV) Deployment in China
6	Exuberance in China's Renewable Energy Investment: Rationality, Capital Structure, and Implications with Firm-level Evidence
7	The Impacts and Interaction of Upstream and Downstream Policies for the Solar Photovoltaic Industries of China
8	Retail Electricity Tariff and Mechanism Design to Incentivise Distributed Generation
9	Financing Solar PV Projects: Energy Production Risk Reduction and Debt Capacity Improvement
10	Bond Financing for Renewable Energy in Asia
11	Utilising Green Bonds for Financing Renewable Energy Projects in Developing Asian Countries
12	Renewable Energy Policies and the Solar Home System in Cambodia

For each topic chosen, a comprehensive review of the issues in these countries is required, followed by an analysis of how specific policies should be applied to address the issues. A clear, solid, and consistent analytical framework is applied within each study. The highest academic standards are also applied to each study for publication purposes.

Policy implications

In general, the developing economies of the East Asia region, especially the ASEAN countries, have to work in all five policy dimensions with the following issues highlighted: 1) A weaker form of renewable energy market exists. In other words, market-based policies such as REC and net-metering should be implemented further. 2) Renewable energy acts are to be established in many countries in the region, although renewable energy targets widely exist. 3) Insufficient emphasis has been given to technological factors, such as the availability of accurate and comprehensive data of renewable energy resources, smart grid capability, and capacity building for technicians, engineers, financiers, entrepreneurs, and other stakeholders. 4) Although policies to improve profitability of renewable energy projects and efforts to enhance the availability of financial resources are already prevalent in the region, policy stability and predictability should be emphasised.

For off-grid renewable energy and mini-hybrid systems, especially regarding rural areas: 1) A clear electrification plan should be provided to reduce the risks of investing in renewable energy off-grid systems. 2) Public financing is still to a large extent needed in rural areas considering the low-income levels and the high upfront cost of renewable energy systems. 3) For business models, which provide electricity from renewable energy as a service to rural residents, information technology tools for remote metering, monitoring, fee collection, and regulating consumption are needed. 4) Engagement with and capacity building for the local communities, in designing, installation, operation, and maintenance, are key to the successful adoption of renewable energy systems. 5) Training of local engineers and setting up of local service networks need to be developed with government support. 6) Capacity building for local small business entrepreneurs to develop viable business models is important for the adoption and operation of renewable energy in rural areas on a commercial basis. 7) Governments can significantly cut the upfront cost of investment if measures are taken along the whole supply chain from procurement of equipment to installation, to minimise transaction costs.

Distributed generation (for example, solar rooftop), requires different types of support from large-scale renewable energy stations and farms. 1) Net-metering, which works more efficiently than feed-in tariffs (FIT) in promoting distributed generation from renewable energy. 2) An innovative grid connection mechanism similar to the network access mechanism for the mobile phone industry, to shift the grid connection procedure from end users of distributed generation systems to the product manufacturers and installation and maintenance service providers. 3) Proper retail electricity pricing to provide incentives for distributed generation, together with a cost allocation mechanism to avoid impacts on the utility's ability to recover investment costs on the grid and conventional power generation assets. 4) Simplifying permit processes and reducing transaction costs. 5) Providing tax credit, which will especially help residential solar leasing models to be financially feasible. 6) Building a qualified installation workforce with certification systems as well as standard systems for equipment and services. 7) Defining and regulating innovative financing mechanisms such as internet financing to raise small funds for small investment projects such as distributed generation systems.

The availability of financial resources and a dedicated financial market for renewable energy is especially important for developing economies, as they do not typically have deep capital markets. This report highlights the potential of bond financing, which could help attract a new class of investors in this region, for financing renewable energy projects. To accelerate the development of a green bond market in the region, various policies could contribute, including the following: 1) Develop a pool of long-term investors that can invest in long-term green bonds. 2) Encourage and facilitate the issuance of retail bonds to attract small investors and enable small to medium-sized renewable energy companies to tap the bond market for financing. 3) Make historical data about the performance of renewable energy projects available to reduce investors' perceived risks of renewable energy projects. 4) Create national regulation rules, standards, and classification systems for green bonds. 5) Create incentives for the issuance of green bonds. 6) Develop a regional financial market for fixed-income instruments, which helps increase the liquidity of green bonds.

Policymakers should also keep the spill-over effects of policies and overinvestment issues in mind. 1) Supportive policies for downstream renewable energy industries, namely the adoption and application of renewable energy, have strong feedback effect and help the upstream industries reducing the costs of the products. 2) Supportive policies for upstream renewable energy industries, namely the manufacturing of materials and equipment, have smaller spill-over effects on downstream industries to help reduce the cost of investment. 3) Typical firm-level investment decisions may overreact to policy stimulus in the form of 'free cash'. However, this would not necessarily lead to overinvestment, as many firms may have limited access to debt financing.

Chapter 1

Financing Renewable Energy in the Developing Countries of the EAS Region

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1. Background

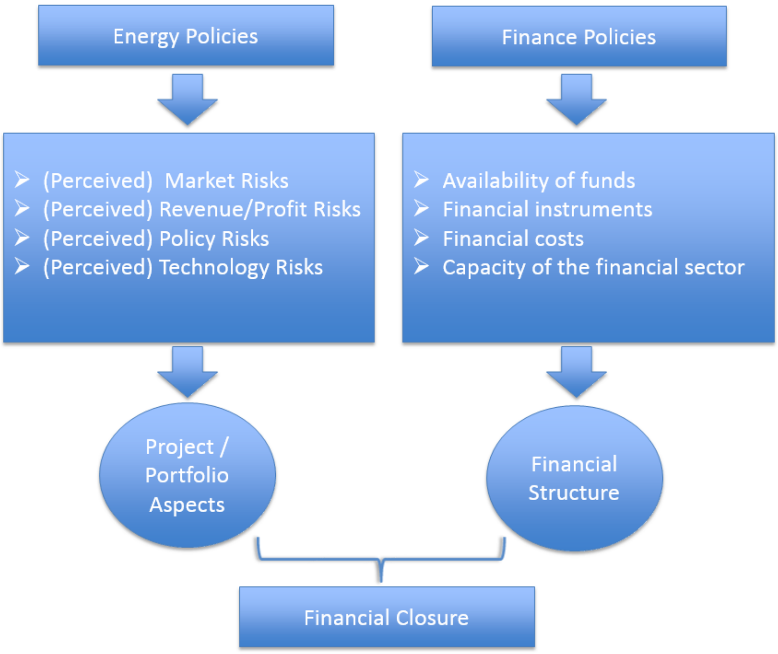
The East Asia Summit (EAS) region is still experiencing significant growth in energy demand, especially in the form of electricity, at faster rates than the world average. This is mainly driven by industrialisation, urbanisation, motorisation, and increases in per capita income (ERIA, 2015). Investment in energy infrastructure in this region is not likely to be satiated in the coming decades (IEA, 2014). When it comes to investment in clean energy, especially new and renewable energy, the challenge is that it not only has to compete for financial resources with conventional thermal energy, but also with other infrastructure projects such as highways, airports, ports, railways, utilities for water and gas. Renewable energy projects typically come with a relatively low internal rate of return (IRR), which is a financial measure of the feasibility and profitability, due to current renewable energy technologies and costs of production.

How to promote investment in new and renewable energy in the region therefore has different policy implications here from elsewhere for the following reasons: (1) economic development needs massive amounts of additional energy supply; (2) newly developed energy supplies should be as clean as possible; and (3) public financing is already tight and private financing prioritises other high-IRR projects. So what can be done in this respect? Besides the well-known policy tools and financial tools for renewable energy adoption, a new and different strategy might be needed to promote renewable energy as much as possible in the region.

2. Supportive policies for renewable energy

Figure 1.1 is a summary of policy tools identified in the literature (IRENA, 2014; REN21, 2014). Basically, investors make the final investment decision based on the risk-return prospects of a project or a portfolio of projects. On the one hand, energy policies, by reducing the risks and improving the expected revenue, help improve such aspects to incentivise commercial and private investors. On the other hand, a lucrative project cannot be undertaken if there is a shortage of financial means to mobilise and secure the financing at reasonable cost. Therefore, policies to enhance the availability and affordability of financial resources are also needed.

Figure 1.1: Supportive Policy Framework for Renewable Energy Investment



Source: Prepared by the authors.

Table 1.1 summarises the full list of energy and finance policies.

Table 1.1: Energy Policies and Finance Policies

Energy Policies	Financial Policies
FIT / FIP	Banking regulations (sustainability requirements)
RPS / utility's obligations	
REC	Public financing scheme
Auctions / Tendering	
Self-supply regulations	Carbon financing
R&D Investment	
Net-metering	Technical assistance and capacity building to the financial sector
Grid connection and access to transmission	
Competitive energy market pricing	Competitive and transparent financial markets, especially bond markets and stock markets
Carbon tax / carbon cap and trade	
Regional energy market integration and grid interconnectivity	Financial instrument innovations
Licensing	
Construction risks related regulations	
RE targets	
Long-term policy (Policy uncertainty)	
PPA and supportive customers	
RE resource data	
Technical assistance and capacity building	

Note: FIT = feed-in tariff; FIP = feed-in premium; PPA = power purchase agreement; R&D = research and development; RE = renewable energy; REC = renewable energy certificate; RPS = renewable portfolio standard.
Source: Prepared by the authors.

Energy policies are mainly concerned with the siting, planning, construction, grid access, operation, pricing, sales, and internalisation of environmental impacts of renewable energy projects. Finance policies ranges from providing public finance to incentivising private sector financing. As the key obstacle to financing is the reducing and sharing of risks involved in a renewable energy investment, various financial tools, supported by corresponding policies, could be devised, as summarised in Table 1.2.

Table 1.2: Financial Tools for Renewable Energy Investment

Private / Commercial	Public Financing
Equity / Balance sheet financing	R&D support
Debt / loans	Grants
Bonds	Soft loans
Credit facilities	Loan facilities
Insurance	Credit enhancement
Project finance	Credit lines
Lease finance	Guarantees
Refinancing	Incubators
Angel investor	Public VC funds
Venture capital	Public equity funds
Private equity	
Mezzanine finance (tax equity, passive equity, preferred equity, convertible debt)	
Development banks / Import-export banks	
Carbon financing	

R&D = research and development; VC = venture capital.
Source: Prepared by the authors.

3. Challenges for developing countries in the East Asia Summit region

While the common methods and policy framework to promote renewable energy investment have been well-established and are well known, the developing countries in the East Asia Summit (EAS) region face specific challenges due to their unique economic, demographic, geographical, and technological characteristics. This project aims to study these challenges in depth.

One unique challenge for the developing countries in this region is the need for electricity in the rural and remote (island) areas for relatively small communities, especially those that have not been electrified and have no grid access. Other challenges include the lack of local capacity for installation, operation, and maintenance; the lack of experience with renewable energy projects in both the utility sector and the financial sector; the lack of reliable data on renewable energy resources; the lack of mature and flexible financial markets as well as financial tools; a vertically integrated electricity market; and the lack of markets for renewable energy and its environmental products such as carbon credits, renewable tax credits, and renewable energy certificates (APEC, 1998).

With significant policy support, especially feed-in tariffs (FIT) and/or feed-in premiums (FIP), together with fast decline in the costs of solar photovoltaic (PV) power and wind turbines, utility scale solar and wind projects have already seen massive installation in developing countries, especially China and India. The Association of Southeast Asian Nations (ASEAN) countries are making steady progress in this regard too, but their FIT and/or FIP programmes face greater challenges from the existence of fossil fuel and electricity subsidies, the lack of infrastructure, the lack of regulatory frameworks (especially connection rules and pricing mechanisms), the lack of experience and capacity, the lack of coordination amongst stakeholders, and vested interest in the energy market structure (IEA, 2010; ERIA, 2015; IRENA, 2014; Kumar and Shretha, 2012).

At the same time, when it comes to the distributed generation of renewable energy, commercially viable business models and financial structure are largely missing in all these developing countries. Even though supportive policies have been devised, progress in this sub-sector is much more limited compared with utility scale projects. One key barrier stems from the various difficulties faced by the financial sector in financing small-scale projects with long payback periods (REN21, 2014).

Above all, although advanced renewable energy technologies, such as high-altitude wind power (kinetic energy), wave and tidal energy, advanced solar PV, advanced energy storage (lithium-based graphene and fuel cell), liquid hydrogen production and supply (including solar chemical–artificial photosynthesis), and advanced bio-fuel are still being developed, mostly in developed economies, the developing Asian countries stand a chance to make the best use of the existing mature renewable technologies. Wider adoption of these technologies as well as the development of relevant industries could be done for the good of clean energy development and also for the good of economic growth and moving up the industrial value chain. China and India set up examples in commoditising solar PV and wind turbine technologies (World Bank, 2014).

Such issues concerning renewable energy development in the developing countries of the EAS region justify our research project to explore a suitable policy portfolio for these countries to maximise the benefits and seize the opportunities offered by renewable energy technologies. In the following section, we summarise the studies in this project to address the most pressing issues of renewable energy investment in this region and we explore how policies should be chosen to work together optimally.

4. Studies

The first two chapters first provide an overview of policy options to promote the financing and investment of renewable energy. This is followed by a comprehensive scan of the adoption of these policies in each developing country in the region, as well as an assessment of the effectiveness of these policies.

Chapter 2, titled 'Renewable Energy Policies in Promoting Financing and Investment among the East Asia Summit Countries: Quantitative Assessment and Policy Implications' presents a renewable energy policy index study led by Prof Youngho Chang of Nanyang Technological University. From a project investor's point of view, all policy options to support the investment of renewable energy are categorised into five groups based on their main objectives: market, uncertainty, profitability, technology, and finance. It subsequently applies this framework to assess what policies from each group have been used in each country to help create a market for renewable energy, reduce risks relating to the investment, maximise potential profits, develop and adopt new technologies, and provide access to financial resources. It then compares the scoring of each country's policies against a selected benchmark, which is whether a country has been considered successful in implementing policies to promote renewable energy investment and financing.

Chapter 3, titled 'Assessment of Instruments in Facilitating Investment in Off-grid Renewable Energy Projects – Global Experience and Implications for ASEAN Countries', is a study lead by Dr Xunpeng Shi of the Energy Studies Institute, National University of Singapore. This study focuses on the effectiveness of policies to promote the investment in and facilitate the financing of off-grid renewable energy projects. Specifically, it quantifies the feasibility, sustainability, and replicability of these policies to assess their effectiveness. Each instrument was evaluated in terms of the three dimensions by experts from ASEAN countries with various backgrounds, including policymakers, industrial players, and other relevant stakeholders in renewable energy investment.

The next four chapters look into the micro-structure of projects or firms for the investment and financing of renewable energy. Both Thailand and China, as the leading countries in the adoption of renewable energy in the region, provide ample cases and data to identify factors for the financial success of renewable energy businesses in this region.

Chapter 4, titled ‘Business Models and Financing Structures for a Rapid Scale-up of Rooftop Solar Power Systems in Thailand’, is a study contributed by a research team led by Prof Sopitsuda Tongsopit of the Energy Research Institute, Chulalongkorn University. Thailand is a leading country in solar energy development in Southeast Asia. But despite policies that have successfully promoted utility-scale solar energy projects, rooftop systems have made limited progress. This study examines how policies could facilitate the innovative business models and financing options of the rooftop systems in Thailand, including the roof rental model, the PPA model, the leasing model, the community solar model, and the solar loan model. The internal rate of return (IRR) and levelised cost of electricity (LCOE) of these models are compared with the existing buying model for rooftop solar in Thailand.

Chapter 5, titled ‘Analysis of Distributed Solar Photovoltaic (DSPV) Power Policy in China’ and Chapter 6, titled ‘Innovative Business Models and Financing Mechanisms for Distributed Solar PV (DSPV) Deployment in China’ are studies contributed by the team led by Prof Sufang Zhang of the North China Electric Power University. Chapter 5 reviews the history of DSPV policies and identifies the key constraints in China. Chapter 6 subsequently zooms in on the micro-level structures for DSPV investment in China – the business models and the financing mechanisms. It provides a comprehensive review and analysis of the advantages and disadvantages of each business model under the current policy framework and proposes improvements and enhancement of these policies to better support innovations in both business models and financing mechanisms in the context of China.

Chapter 7, titled ‘Exuberance in China's Renewable Energy Investment: Rationality, Capital Structure, and Implications with Firm-level Evidence’, is a contribution from a team led by Prof Dayong Zhang of Southwestern University of Finance and Economics. The authors examine the efficiency of renewable energy policies in general and in China and quantitatively assess if firms responded to the policies with overinvestment at the current stage of market and technology development, based on the economics of finance – the Q-model. It turns out that firms’ investment decisions in response to policies depend on their own capital structure and thus some firms do overinvest or irrationally expand in renewable energy.

The readiness of technologies, industries, markets, and the availability of comprehensive data on renewable energy resources are critical technical factors for the economic and financial performance of renewable energy projects. Accordingly, policies should provide support in terms of these aspects as well. In the following two chapters, one study is devoted to the impacts of upstream policies on renewable energy technologies and manufacturing of renewable energy equipment; the other study presents evidence on the importance of high-accuracy data on renewable energy resources in real projects.

Chapter 8, titled 'The Impacts and Interaction of Upstream and Downstream Polices for the Solar Photovoltaic Industries of China' is a study conducted by a team led by Prof Hongwei Wang of the Chinese Academy of Social Sciences. This study provides a comprehensive review of the supportive policies for both the upstream and downstream solar PV industry. It then conducts a quantitative assessment of the impacts and interactions of these policies. The study confirms the intuition that downstream policies are in fact effective in bringing down the cost of solar PV production upstream and subsidies provided upstream are not equally effective in lowering the cost of electricity generated from solar PV.

Chapter 9, titled 'Retail Electricity Tariff and Mechanism Design to Incentivise Distributed Generation', is a study conducted by Prof Ramteen Sioshansi of Ohio State University. Building on an in-depth review of international experiences with distributed renewable power generation, this study addresses the market design issues related to existing incentive schemes to promote renewable energy adoption. The key issue is the system cost allocation and potential cross-subsidies between grid customers with and without distributed renewable energy systems. The problem becomes more visible when the penetration rate of distributed renewable power generation increases – a medium- to long-term policy issue. Real time pricing and two-part tariffs with demand charges are proposed to resolve the issue and work together with existing incentive mechanisms such as FIT and quota-based obligations.

Chapter 10, titled 'Financing Solar PV Projects: Energy Production Risk Reduction and Debt Capacity Improvement', is a study conducted by Dr Pacudan Romeo of the Brunei National Energy Research Institute. This study, using a Brunei Darussalam case, reveals the financial implications of high-quality solar energy resource data for renewable energy projects. Ground-measured solar energy resources of the project site turn out to significantly reduce the estimated uncertainty of energy production of a solar PV facility.

The reduced uncertainty results in a high debt coverage ratio of a solar PV project, reducing the overall financial costs.

The readiness of financial markets and the availability of financial resources remove the final constraints on the investment and financing of renewable energy, when the energy market policies are put in place and are in good shape. Our project this year especially emphasises the relevance and importance of an established bond market for renewable energy in the region, considering the need for large-scale, long-term financing as well as the features of bonds such as flexibility and low costs.

Chapter 11, titled 'Bond Financing for Renewable Energy in Asia', is a contribution from Dr Thiam Hee Ng of the Asian Development Bank. This study emphasises that the importance of bond financing increased after the Basel III rules were announced. The private investors in this region especially need the bond market as a tool to package renewable energy investment into asset packages they are familiar with, considering the fact that a large portion of the surplus capital from this region is invested in low-yield assets in the developed world. Specially, a market for green bonds should be developed in the region, as a dedicated financing tool for renewable energy investment.

Chapter 12, titled 'Utilising Green Bonds for Financing Renewable Energy Projects in Developing Asian Countries', is a study contributed by a team led by Ms Jacqueline Tao of the Energy Studies Institute, National University of Singapore. This study provides an in-depth review of the development process of green bonds in deriving a roadmap for this region. A Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis is also conducted to analyse the advantages and viability of green bonds in the region.

Chapter 13 titled 'Renewable Energy Policies and the Solar Home System in Cambodia', is a contribution from Dr Phoumin Han of the Economic Research Institute for ASEAN and East Asia. Solar home systems (SHS) are found to be competitive in the rural and remote areas of Cambodia where the grid has not reached. SHS is already half as cheap as other means of electricity supply in these areas, and two-thirds cheaper if government subsidies are considered. However, a lack of availability of equipment at competitive market prices, high upfront costs, a lack of capacity building especially training of technicians for installation and maintenance, and a lack of small entrepreneur business models, are barriers to the wider adoption of SHS in rural Cambodia. The experiences from Cambodia are especially relevant to how low-income economies could promote the adoption of renewable energy technologies.

5. Policy implications in brief

To summarise, this ERIA report highlights policies that address the following issues regarding more effective promotion of renewable energy investment in the region.

1. Viable and innovative business models and financial mechanisms/structures, especially for distributed generation from renewable sources
2. Market creation through the implementation of market-based mechanisms
3. Stability of policies and the need for renewable energy legislation
4. Availability of high-quality and high-accuracy renewable energy resource data and other technical assistance to reduce the uncertainty of renewable energy production
5. Electricity market design which internalises not only the positive externality of renewable energy but also its negative externality (especially the impact on the grid capacity and grid balancing)
6. Improvement in the availability of financial resources in the region through market creation and enhancement of innovative financial instruments, such as green bonds, which may be familiar and attractive to Asian investors.

It should be noted that this report does not claim to be comprehensive in its coverage of the issues related to policies on the financing and investment of renewable energy, but to highlight the currently most critical and imminent issues in the region. This study is thus meant to complement the existing literature in this area.

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Chapter 2

Renewable Energy Policies in Promoting Financing and Investment among the East Asia Summit Countries: Quantitative Assessment and Policy Implications[1]

Youngho Chang[2], Zheng Fang, Yanfei Li

Abstract

Many countries have implemented policies for renewable energy development ranging from setting power purchase agreements and the legislation of renewable energy requirements to providing incentives and imposing carbon taxes. The evaluation of the effectiveness of such policies, however, is fragmented, which raises a need for a comprehensive analysis. This chapter aims to assess whether and how policies promoting renewable energy investment have achieved the intended goals. It employs five broadly defined criteria – market, uncertainty, profitability, technology, and financial resources – to build an index to assess respectively if such policies have helped create a market for renewable energy, maximise potential profits, reduce risks relating to the investment, develop and adopt new technologies, and provide access to financial resources. Each criterion is reflected by three indicators. Values of each indicator are converted into ordinal values for analysis. The index not only scans comprehensively all relevant renewable energy investment policies in the developing East Asian countries, but also provides systematic and quantitative measures to compare the effectiveness of policies in these countries with respect to the creation of market, the degree of uncertainty, the potential of profitability, the development and adoption of technology, and the accessibility of financial resources.

Keywords: Renewable energy investment, financing, profitability, risks, policies

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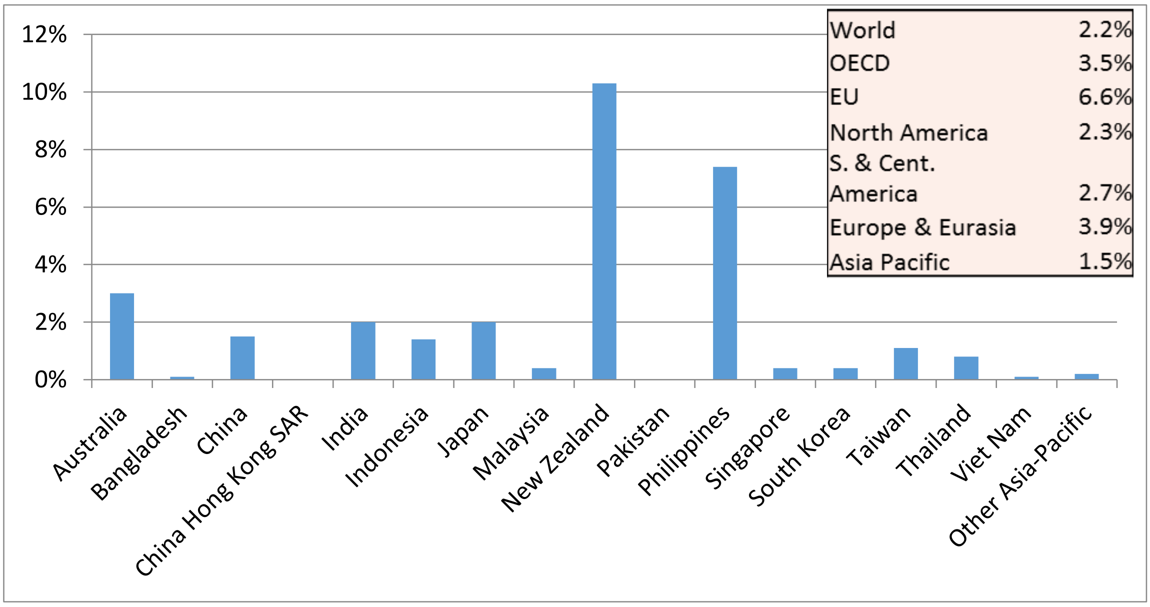
1. Introduction

Many countries have implemented policies for renewable energy development ranging from setting power purchase agreements (PPA) and the legislation of renewable energy requirements to providing incentives and imposing carbon taxes on fossil energy sources (see renewable energy policy reviews conducted by Shen and Luo, 2015 for China; Mekhilef et al., 2014 for Malaysia; Chen et al., 2014 for Japan, South Korea, and Taiwan; Lidula et al., 2007 for the Association of Southeast Asian Nations (ASEAN); Sarraf et al., 2013 for Cambodia; Schmid, 2012 for India; Blok, 2006 and Klessmann et al., 2011 for the European Union). However, the share of renewable energy in the total primary energy consumption in 2013 averages 2.2% across the world, and it is even smaller at 1.5% for the Asia-Pacific region. Within the Asia-Pacific region, New Zealand tops at 10.3%, followed by the Philippines at 7.4%, and Australia at 3% (Figure 2.1).

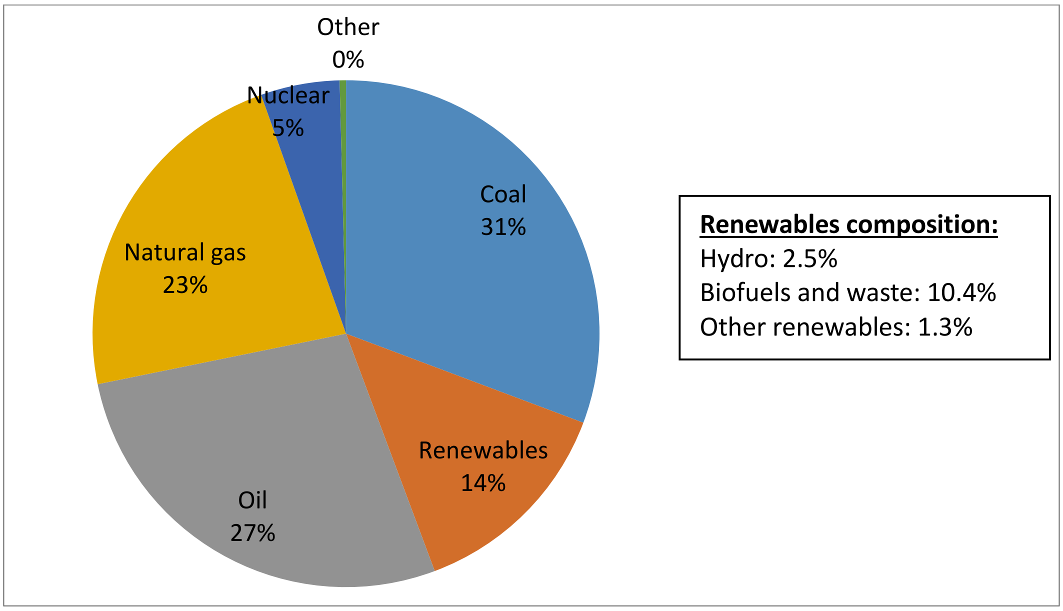
Figure 2.1: Share of Renewable Energy in Total Primary Energy Consumption, 2013



EU = European Union; OECD = Organisation for Economic Co-operation and Development; SAR = Special Administrative Region.
Source: BP Statistical Review of World Energy June 2014. Available at: http://www.bp.com/content/dam/bp-country/de_de/PDFs/brochures/BP-statistical-review-of-world-energy-2014-full-report.pdf

For the rest of the countries, the renewable energy share is no more than 2%. Looking from the supply perspective, only 14% of global total primary energy supply is from renewable energy, among which biofuels and renewable waste account for more than 10% and other renewable sources such as solar, geothermal, wind, and tide account for only 1.3% (Figure 2.2).

Figure 2.2: Fuel Shares in World Total Primary Energy Supply, 2013

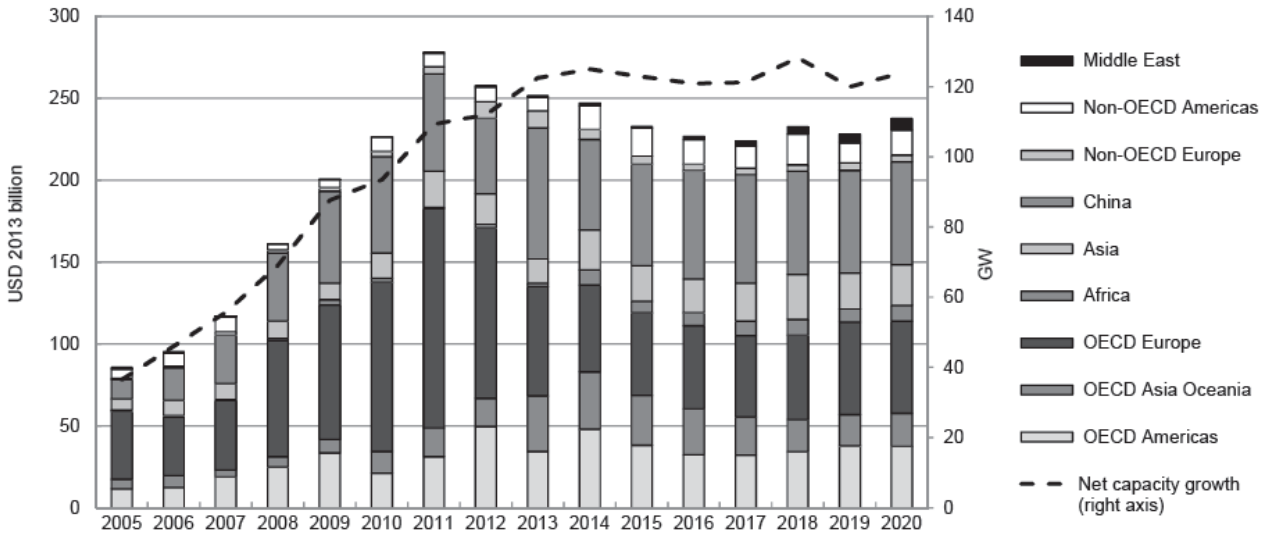


Source: International Energy Agency (2015).

Many countries invest heavily in renewable energy capacity. According to the International Energy Agency, since 2005 the global annual investment on renewable energy-based electricity generation has almost tripled, and in 2013, renewable energy accounted for about 60% of $400 billion investment in new power generation. As shown in Figure 2.3, Asia (including China) contributes to almost half of the world investment in new renewable power capacity. Figure 2.4 further shows that the growth of non-hydro renewable energy capacity in Asia in 2014 is mainly driven by big economies such as China, India, and Japan. All developing countries in this region, except for China, have a growth rate lower than the Asian average. In the meantime, it is noted that although some countries in Southeast Asia, such as Cambodia, Malaysia, the Philippines, and Viet Nam, had more than 10% growth rate, the accumulated capacities in these countries are still very small. Thailand is the leading country in Southeast Asia when measured by both growth rate and accumulated capacity. However, the growth rate in Thailand is still far behind the Asian average.

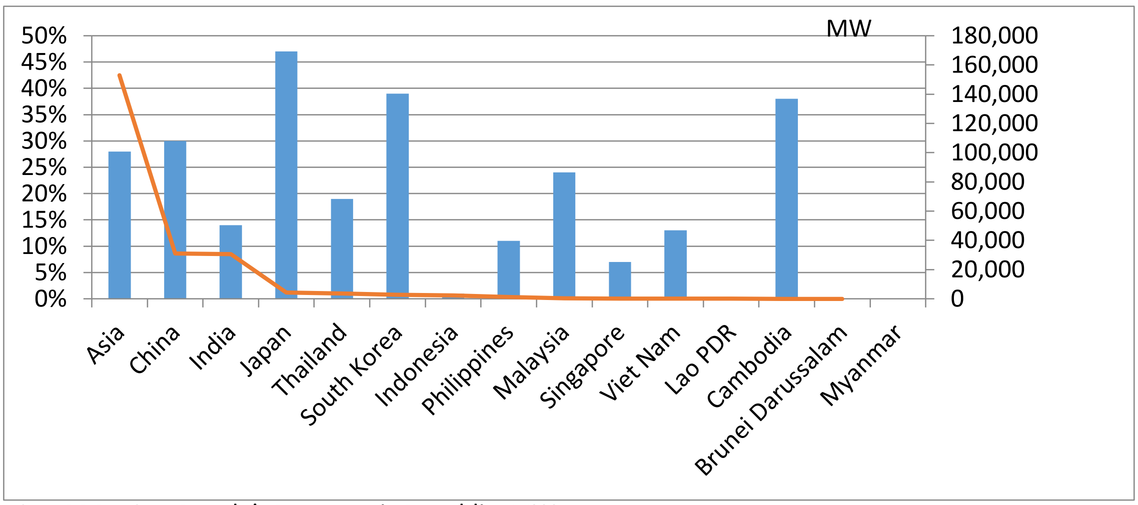
It is thus interesting to ask what the countries in East Asia have done right and what policy gaps are remaining in incentivising investment and financing of renewable energy projects. Specially, the evaluation of the effectiveness of such policies is so far mostly fragmented in the literature to our knowledge. This also raises a need for a comprehensive analytical framework for policy evaluation.

Figure 2.3: World Investment in New Renewable Power Capacity, Historical and Projected



GW = gigawatt; OECD = Organisation for Economic Co-operation and Development.
Source: International Energy Agency (2015).

Figure 2.4: Growth Rate and Total Capacity of Non-hydro Renewable Energy, 2014*



Lao PDR = Lao People's Democratic Republic; MW = megawatt.
*Note: the bar shows the growth rate and the line indicates the total existing capacity.
Source: IRENA (2015).

This chapter assesses whether and how policies, which are supposed to promote renewable energy investment, have achieved the intended goals. It employs five broadly defined criteria – market, profitability, legislative uncertainty, technology, and financial resources – to build an index of policies to assess if such policies have helped create a market for renewable energy, maximise potential profits, reduce risks relating to the investment, and develop and adopt new technologies, as well as provide more financing channels.

Each of the five aspects – market, profitability, legislative uncertainty, technology, and financial resources has several indicators. The market aspect examines whether policies helped create and extend a market for renewable energy. The profitability aspect presents whether policies provided the environment in which potential profits from renewable energy investment can be improved. The uncertainty aspect examines whether there are mechanisms, legislation, and regulations that reduce risks relating to the investment in renewable energy. The technology aspect shows whether and how policies helped develop and adopt renewable energy technologies. The financial resources aspect presents policies that could improve the availability of funds by addressing issues on the supply side, including public financing, financial institutions, financial markets, financial tools, and business models. The values of each indicator are collated and the cardinal values are converted into ordinal values for analysis. As the outcome, this research not only comprehensively scans all relevant renewable energy investment policies in the East Asia Summit (EAS) countries, but also provides systematic and quantitative measures to compare the effectiveness of policies in these countries with respect to the creation of market, the degree of uncertainty, the potential of profitability, the development and adoption of technology, and the accessibility of financial resources.

This chapter is structured as follows. Section 2 reviews relevant literature to lay down the theoretical background of our analytical framework and presents how the evaluation index is constructed. Sub-indices of the five aspects – market, profitability, legislative uncertainty, technology, and financial resources are explained in detail with examples. Section 3 analyses the index of 16 EAS countries and discusses results first by the region as a whole and then by individual countries separately. Section 4 concludes this study with policy implications.

2. Methodology

In this section, we first survey relevant literature and subsequently describe in detail how the evaluation index is constructed by explaining the sub-indices with examples.

2.1. Index of renewable energy policies

Previous studies that have used an index to assess the performance of renewable energy policies include the International Renewable Energy Agency (IRENA) reports and the Renewable Energy Country Attractiveness Index (RECAI). IRENA (2012) produced an index that covers the effectiveness, efficiency, equity, institutional feasibility, and replicability of these policies. IRENA (2012) provided a comprehensive review on the policies that could effectively reduce the risks involved in renewable energy investment and the major barriers in financing renewable energy. Compared to the IRENA report, our study focuses specifically on how policies could improve financial attractiveness and feasibility of renewable energy projects and thus facilitate investment on renewable energy, more from the investors' perspective. With this purpose, our study develops a consistent framework index to quantitatively evaluate the effectiveness of policies and thus provide policymakers with a tool for the assessment and identification of policy gaps.

RECAI is an indicator measuring each country's attractiveness in renewable energy business. It comprises three drivers: macro, energy market, and technology-specific drivers. The macro driver includes two aspects: macro stability and investor climate. The energy market driver includes the prioritisation and bankability of renewable energy projects. The technology-specific driver refers to project attractiveness. Sixteen parameters are used to measure each of these five sub-drivers. While conceptually well designed, the implications of RECAI are not policy-oriented and thus not clear regarding what policies could help and should be strengthened. Besides, attractive renewable energy investment opportunities exist to a different extent in almost every country. A country that appears to be less attractive in renewable energy development in general may still have some renewable energy projects with good potential. The question is how to mobilise funds from various sources into such businesses; how could policies make those projects that are not so financially attractive become bankable so that they are attractive to private investors. Our study indicates clearly projects in which country are more attractive or financially viable due to its policies.

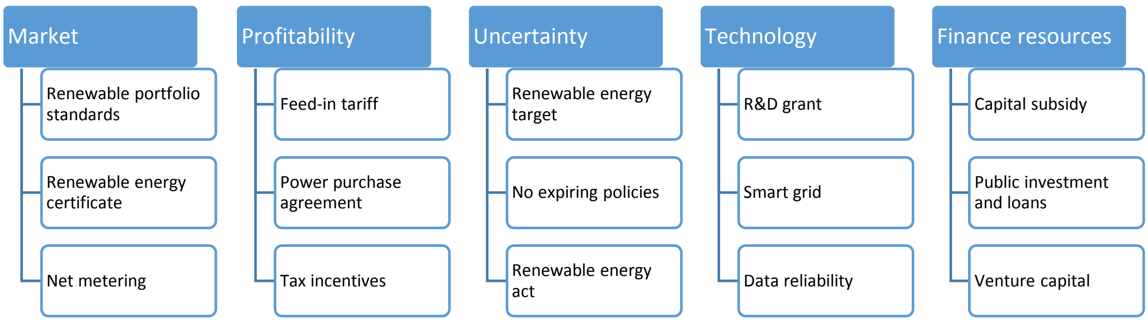
2.2. Index construction

This study chooses three most relevant indicators for each of the five criteria, so as to give balanced weight to each criterion when we evaluate the existing policies of a country. Specifically, we examine the following renewable energy policies (Figure 2.5):

- Market: Renewable portfolio standards (RPS), renewable energy certificate (REC), net metering
- Profitability: Feed-in tariff and/or feed-in premium, power purchase agreement (PPA), tax incentives
- Uncertainty: Renewable energy target, near expiry or frequent policy revisions, renewable energy act
- Technology: research and development (R&D) grant, smart grid, data reliability
- Finance resources: capital subsidy and/or rebate, pubic investment and loans, venture capital

In the following, the scoring process is explained for each of the indicators.

Figure 2.5: Index Construction



R&D = research and development.
Source: Prepared by the authors.

Market

Renewable portfolio standards (RPS), 'renewable obligations', or 'mandated market shares', are a statutory obligation where a utility company or consumers must provide a percentage of installed capacity from renewable energy sources. RPS were in place in 25 countries in 2013 (REN21, 2014). Since the regulation to some extent ensures the existence of the renewable energy market, it is used as a market indicator. The indicator equals 1 if RPS exist, otherwise equals 0.

A renewable energy certificate (REC), a certificate given to the generation of one unit (typically 1 megawatt hour [MWh]) of renewable energy, is associated with RPS programmes. The REC market exists mainly because of the obligation with which power supply companies have to abide, while some RECs are used to meet the voluntary renewable energy targets. For instance, the Australian government has implemented a target of 20% electricity generated from renewable energy sources by 2020. The target is estimated to require 45,000 gigawatt hours (GWh). As 1 MWh of energy equals one REC, 45 million RECs will be generated to meet the 2020 target. Since the demand for and supply of REC indicates the existence of the renewable energy market, it is taken as an indicator of the maturity of renewable energy market. The indicator equals 1 if a REC exists, otherwise equals 0.

Net metering is widely used in the United States (US) and Europe. It is a regulated arrangement in which electricity customers only need to pay for the amount of total electricity consumption minus self-generated electricity. The net metering policies vary across states and countries, that is, whether excess power is allowed to feed into the grid, which price is applicable to excess power, how long one can keep the banked credits, among others. Unlike the US, the electricity meter in Singapore cannot spin backwards, so they have separate meters to record exported and imported electricity. Besides, electricity exported to the grid is compensated at a lower price than the electricity consumed in Singapore. According to REN21 (2014), up to 2013, there were 43 countries worldwide adopting net metering policies. The Philippines recently brought into effect the net metering policy legally established in 2008 and there is now a new set of interconnection standards. Net metering indicates the existence of a market for distributed renewable energy generation. The indicator equals 1 if net metering exists, otherwise it equals 0.

Profitability

Feed-in tariff (FIT) specifies a guaranteed price for every kilowatt hour (kWh) of electricity produced from renewable energy sources sold to the grid over a fixed period of time. It has been increasingly considered the most effective policy to encourage the development of renewable energy among academics and policy makers (Couture and Gagnon, 2010). Investors also have the same perception according to a survey of 60 professionals from European and North American venture capital and private equity funds (Bürer and Wüstenhagen, 2009). By offering long-term contracts and guaranteed pricing, FITs can significantly reduce the risks of investment in renewable energy technologies and renewable energy production, and provide a high degree of security to the investors on future cash flows. Most of the FIT policies are market independent, meaning there is a fixed or minimum price, while some of the FIT policies are market dependent, which are also known as feed-in premiums, as a premium is paid above the market rate. The indicator equals 1 if the country has a FIT policy, otherwise it equals 0. For instance, on 20 June 2014 the government of Viet Nam implemented the regulation on feed-in tariff support for waste-to-energy power plants; the tariff level is set to D2,114/kWh for power projects using solid waste for a period of 20 years. Therefore, the indicator for Viet Nam equals 1.

Power purchase agreements (PPAs) are legal contracts between power generating parties (the seller) and power purchase parties (the buyer) in which all of the commercial terms including schedules for delivery of electricity, payment terms, penalties for under delivery, and termination are well defined. Since a PPA can determine the revenue of a generating project, it is considered a sub-index for the profitability. The indicator equals 1 if the country has some form of PPAs in use, otherwise it equals 0.

Tax incentives could be in various formats, for example, investment tax credit, production tax credit, and value-added tax rebate, among others. Investment tax credit allows the deduction of tax obligations of firms that have invested in renewable energy, while production tax credit provides an annual tax credit to the qualified investor based on the amount of renewable energy used. Both tax credit schemes could help reduce the cost of investment and/or production and encourage the deployment of renewable energy projects. Besides these two, other tax incentives could also boost investment and attract investors in the renewable energy sector. For example, China in 2013 introduced a 50%

value-added tax (VAT) rebate for solar power plant operators and also put in place tax incentives for hydropower investors.[3] In India, the government allowed for accelerated depreciation at 80% for renewable energy investment in windmills installed before end March 2012 and accelerated depreciation at 15% afterwards. The indicator equals 1 if there exists any kind of tax incentive, otherwise it equals 0.

Uncertainty

A renewable energy target is a goal set by a state or national government to achieve a certain amount of renewable energy by a future date. China, for example, aims to increase the proportion of renewable energy in the total energy consumption from 5% in 2005 to 20% in 2020. The New Zealand government has identified clear goals for increasing renewable electricity generation through the *New Zealand Energy Strategy 2011–2021*, which specifies a target that '90% of electricity generation from renewable sources by 2025 providing this does not affect security of supply' (Ministry of Business, Innovation and Employment, 2011). The existence of a renewable energy target could give investors' confidence in the prospect of the renewable energy market, where it typically takes a longer time to reap the return of investment. The indicator equals 1 if any form of renewable energy target exists, otherwise it equals 0.

As argued by Shen and Luo (2015), subsidy policies have positive effects only for a short term. To account for the uncertainty of such policies, we take expiring dates into consideration. Expiring policies indicate the uncertainty of renewable energy policies ahead; while policy revisions, especially frequent and unfavourable revisions, suggest the inconsistency of the renewable energy policies. Investors would like to avoid both these situations during decision-making. Evidence shows that investors react to these uncertainties negatively. For example, repeated expiration and renewal of the federal production tax credit in the United States have caused a boom–bust cycle in the wind power industry (Barradale, 2010). In 2012, in particular, before its expiration, many wind power developers were found to close projects in a hurry and as a result there was 13.1 GW installed wind power in that year, but 1 year later, the US ended with just over 1 GW

[3] See the Announcement of Value-added Policies for PV Generated Electricity declared by the Ministry of Finance in China, 23 September 2013. Available at:
http://www.chinatax.gov.cn/n810341/n810765/n812146/n812323/c1080750/content.html

installed wind power in that year. If the legislation such as FIT, net metering, and tax incentives are to expire within the next 3 years (beyond which investors have time to react), or there are unfavourable revisions of unexpired legislations within 1 year, the indicator is set to 0, otherwise is set to 1 (so that 0 represents a bad situation, and 1 represents a good situation). For example, the 50% VAT rebate in China, with effect from 1 October 2013 will terminate on 31 December 2015. Therefore, the score for this indicator is 0 in China.

A renewable energy act is usually a part of energy law that relates primarily to the legal and policy issues at the development, implementation, and commercialisation stages of renewable energy, such as land use, siting, and finance issues encountered by project developers. The existence of a renewable energy act may help reduce the uncertainty of policies, protect the interests of stakeholders legally, and boost the confidence of investors. The Renewable Energy Law was enacted on 28 February 2005 in China. Following that, renewable energy investment and development sped up (Wang et al., 2010). According to REN21 (2014), China's investment in renewable energy increased from $2.4 billion in 2004 to $56.3 billion in 2013, more than the total investment in all Europe. As such, China has become the top investor in the renewable energy sector. The indicator equals 1 if any form of renewable energy act exists, otherwise it equals 0.

Technology

An R&D grant is a grant that is used specifically for the research and development of renewable energy-related technologies. For example, to foster a domestic market, South Korea is investing $20,000 per technology per year in R&D, which will amount to $100 million by 2030. Globally, according to Renewable Energy Policy Network for the 21st Century (REN21, 2014), R&D expenditure on solar energy has declined by 2% to $4.7 billion in 2013; wind and ocean power R&D investment also declined slightly, while investment in other renewable energy sources such as biopower, geothermal, and small-scale hydropower went up slightly, and R&D investment in biofuels was stable. The indicator equals 1 if any form of R&D grant for renewable energy technologies and their adoption exist, otherwise it equals 0.

As mentioned in Nature News 2010 (Lindley, 2010), 'renewable energy is not a viable option unless energy can be stored on a large scale', and the smart grid technology could be one way of 'evening out the usual peaks and troughs in grid load'. A smart grid is an 'electrical grid that uses information and communications technology to coordinate the needs and capabilities of the generators, grid operators, end-users, and electricity market stakeholders in a system' with the aim 'to improve the efficiency, resilience, reliability, economics and sustainability of the production and distribution of electricity' (Santhosh et al., 2013). The indicator equals 1 if any smart grid initiatives exist, otherwise it equals 0. The South Korean government, for example, together with major players in the industry, has launched a $65 million pilot programme on Jeju Island, which includes a fully integrated smart grid system for 6000 households, several wind farms, and four distribution lines. Therefore, the indicator in South Korea is 1.

Reliable and easy access to data regarding detailed resource assessment for renewable energy is important in the decision-making of investors. The indicator equals 1 if reliable data or capacity building support exists, otherwise it equals 0.

Finance resources

Project developers raise as much capital as possible from the cheapest source before moving up to the next cheapest tiers. Capital subsidy is a kind of 'free money'. For example, in India, 90% of the project cost is provided to the implementing agency for eligible projects separating agricultural and non-agricultural feeders or strengthening and augmenting sub-transmission and distribution infrastructure. The indicator equals 1 if any capital subsidy exists, otherwise it equals 0.

Public loans, usually at low interest rates, could be used specifically for deployment of renewable energy projects. For example, in the Yokohama Smart City Project of Japan, there is a provision of low-interest loans for renewable energy and energy efficiency investments. The indicator equals 1 if any form of public loans exist, otherwise it equals 0.

Venture capital or private equity investment facilitates the provision of funding to firms in the industry with unproven and high-risk technologies (Gompers and Lerner, 1999). In the last decade, venture capital investment in clean energy has grown dramatically from $230 million in 2002 to $4.1 billion in 2008 in the US (Ghosh and Nanda, 2010). In Asia excluding China and India, it grew from almost nothing to $201 million in 2014 mainly due to two deals with Lanzatech and Sunseap Leasing (Bloomberg New Energy Finance, 2015). In China, venture capital investment in renewable energy technologies reached $403 million in 2006 (Huang, 2009). The indicator equals 1 if venture capital investment exists, otherwise it equals 0. Recent developments in investment channels include project bonds, green bonds, yield companies, and asset-backed securities (Table 2.1). Examples and critical reviews can be found in Eckhart (2014).

Table 2.1: Emerging Investment Vehicles for Renewable Energy

	Description
Project bonds	Debt securities issued on an individual project
Green bonds	Debt securities issued by corporations to support green investments
Yield companies	Listed investment companies with equities that pay dividends based on underlying assets
Asset-backed securities	Debt securities that pool assets such as mortgages or auto loans

Source: International Energy Agency (2015).

3. Results and discussions

3.1. Overall analysis

Table 2.2 shows the scores of 15 indicators across 16 EAS countries. Looking at Table 2.2 vertically, we find that in the whole EAS region, eight countries have set RPS, while REC and net metering exist in only five or six countries. This indicates that the renewable energy market exists in the region, but could be developed further. Incentives such as FIT or tax reductions are prevalent, while PPAs are rare. As to legislation related with renewable energy, the establishment of renewable energy acts is one of many areas that the EAS region could work on. Besides, policies that may advance technologies are scarcely seen. Financing resources, on the other hand, seem to be in place; but emerging and innovative investment vehicles are to be explored. Overall, it seems that the renewable energy market exists, while legislation, financing resources, and profitability considerations when making renewable energy investment decisions are also not major concerns, but technology advancement and reliability is a critical area where policies should pay attention.

Looking at Table 2.2 horizontally, we observe that India, Australia, China, Japan, and South Korea are among the top ranked countries in the East Asia Summit region in terms of renewable energy investment policies, while Brunei Darussalam, Cambodia, Lao PDR, and Myanmar are far behind, with a score of only 1 or 2.Brunei Darussalam is rich in oil and natural gas reserves, and therefore renewable energy investment policies are not given enough importance and priority yet. The developing countries such as Cambodia, Lao PDR, and Myanmar, however, may face challenges in energy supply and need to boost their efforts to develop renewable energy in the future. Of course, this policy evaluation framework is better implemented within a more complete list of countries globally before we reach any concrete conclusions.

Table 2.2: Renewable Energy Policies in the East Asia Summit Countries

Country	Market			Profitability			Legislation uncertainty			Technology			Finance			Total
	RPS	REC	Net metering	FIT	PPA	Tax incentives	RET	Expiring policies	RE act	R&D grant	Smart grid	Data reliability	Subsidy	Public loan	VC	
Brunei Darussalam	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2
Cambodia	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2
Indonesia	1	0	0	1	1	1	1	1	0	0	0	0	1	1	0	8
Lao PDR	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2
Malaysia	1	0	0	1	0	1	1	0	1	0	0	0	0	1	1	7
Myanmar	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Philippines	1	0	1	1	1	1	1	0	1	0	0	0	1	1	0	9
Singapore	0	0	1	0	1	1	0	1	0	1	0	1	0	1	1	8
Thailand	0	0	1	1	0	1	1	0	0	1	1	1	1	1	0	9
Viet Nam	0	1	0	1	1	1	1	1	0	0	0	0	1	0	0	7
Australia	1	1	0	1	0	0	1	0	1	1	1	1	1	1	0	10
China	1	0	0	1	1	1	1	0	1	1	1	0	1	1	1	11
India	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	13
Japan	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1	12
South Korea	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	13
New Zealand	0	0	0	1	0	0	1	1	0	1	0	0	1	0	1	6
Subtotal	8	5	6	10	7	10	13	11	7	6	4	6	10	10	6	
Total		19			27			31			16			26		

FIT = feed-in tariff; PPA = power purchase agreement; R&D = research and development; RE = renewable energy; REC = renewable energy certificate; RET = renewable energy target; RPS = renewable portfolio standards; VC = venture capital.
Sources: Bloomberg New Energy Finance (2015); REN21 (2014; 2015); and various sources.

If we take 80% of policy prevalence as a threshold to think that the renewable energy policies are attractive to investors, none of the five dimensions are reaching the satisfactory level from the perspective of the whole EAS region (Table 2.3). However, legislation uncertainty and risk, with a policy prevalence of 64.6%, seems to be not a big issue to investors in the region. Renewable energy policies to ensure profitability and accessibility to finance resources are not adequate. However, the region needs to catch up and emphasise the dimensions on stimulating the development and adoption of new technologies and creating a market for renewable energy.

Table 2.3: Ranking Index Dimension

Ranking	Policies dimension	Prevalence
1	Legislation uncertainty	64.6%
2	Profitability	56.3%
3	Finance resources	54.2%
4	Market	39.6%
5	Technology	33.3%

Source: Prepared by the authors.

Ranking countries by the index of renewable energy policies, Table 2.4 shows that three of the EAS countries (India, South Korea, and Japan) are doing well with a score above 12 or prevalence above 80%. They are followed by China and Australia and two ASEAN countries (the Philippines and Thailand), which have average performance in terms of the presence of policies to promote renewable energy investment and development. Indonesia, Singapore, Malaysia, and Viet Nam, as well as New Zealand are lagging. But the countries that need most improvement in the renewable energy sector are the four ASEAN countries, Cambodia, Lao PDR, Brunei Darussalam, and Myanmar.

Table 2.4: Country Index Rankings

Ranking	Ranking definition	Countries
Good	Above 80%	India, South Korea, Japan
Average	Between 60% and 80%	China, Australia, the Philippines, Thailand,
Poor	Between 40% and 60%	Indonesia, Singapore, Malaysia, Viet Nam, New Zealand
Need much improvement	Below 40%	Cambodia, Brunei Darussalam, Lao PDR, Myanmar

Source: Prepared by the authors.

3.2. Renewable energy policy analysis by country

In this sub-section, we examine the renewable energy policies in the individual countries in detail.

Brunei Darussalam: Brunei Darussalam is rich in oil and natural gas reserves, and therefore it has had little interest in the development of renewable energy. However, due to worldwide focus on renewable energy and also to diversify its energy sources, Brunei Darussalam, in its 2011 Energy White Paper, set a goal of generating 10% of electricity from renewable energy by 2035 and in its 2014 Energy White Paper, another goal of reaching 124 GWh of renewable power generation by 2017 and 954 GWh by 2035. FITs are also being planning.

Cambodia: Cambodia has many renewable energy resources such as hydropower and biomass. It is estimated that renewable energy has the potential to generate 67,388 GWh per annum, which is about three times the total energy consumption in the country. However, the installed capacity is low at only 85 GWh in 2004 (Mallon, 2006). As shown in Table 2.2, the lack of policy support is one of the main problems. Although the government has targeted to have 15% of electricity generated with renewable energy by 2015 and enable 70% of rural people to have reliable electricity services by 2030 (Sarraf et al., 2013), the government has a long way to go to make its renewable energy sector attractive to investors. Various policy measures to expand and improve grid accessibility, develop capacity building, and provide financial incentives should be taken simultaneously.

Indonesia: Due to its volcanic geology, Indonesia has a huge geothermal potential, which is estimated to be 28,000 MW accounting for 40% of the world's potential geothermal resources (Hasan et al., 2012). In addition, as Indonesia lies on the equator and has large coastal areas, it also has potential in wind and solar energy. Furthermore, Indonesia is the largest palm oil producer in the world and as a result it can use biodiesel as an alternative fuel. While it has potential, renewable energy contributes to only 3% of power generation (Jotzo, 2011) because of the lack of fiscal and financial incentives and technological barriers. The government should put the promotion of renewable energy as its priority (Gunningham, 2013). Recently the government has taken steps such as developing energy policy and regulations, targeting 17% renewable energy in the energy mix in 2025 and expanding FIT support (REN21, 2014) but it will take time to see the effect.

Lao PDR: Lao PDR is a fiscally poor country with three quarters of land being mountains. As a result, there is little financial assistance to renewable energy investment. The country is in the stage of setting up strategies. Grid electrification is currently the most important energy strategy and using renewable energy technologies such as solar home systems is an option to consider. Another off-grid electrification technology – pico-hydropower, a technology that generates ≤ 1 kW at the individual household level– has been well established but neglected (Smits and Bush, 2010). In addition, central Lao PDR has good wind potential and the Lao PDR government targets to have 30% of renewable energy in the energy mix by 2025 (REN21, 2014).

Malaysia: Renewable energy was first targeted to be the major contributor to the electricity generation in 2001 when the five-fuel diversification policy was announced in the 8th Malaysia Plan (2001–2005). The aim to generate 500 MW of electricity to the grid and account for 5% of the energy mix was not reached and it ended up with only 12 MW at the end of the plan (Mekhilef et al., 2014). In the 10th Malaysia Plan (2011–2015) FITs were introduced and the Malaysian government targets to generate a total of 985 MW electricity from renewable energy during this period. To promote renewable energy investment and utilisation, there are many fiscal incentives implemented such as the 'Pioneer Status' where companies are exempted from income tax on 100% of statutory income for 10 years, sales tax exemption, import duty exemption, and investment tax allowance, among others (Malek, 2010). However, whether the target can be met is a concern, given the absence of renewable energy markets and constraints of technological and financial factors (Table 2.2).

Myanmar: In Myanmar, the electrification rate was 13% in 2009 (IEA, 2013) and 26% in 2010 (REN21, 2014). The renewable energy generation is virtually all from hydropower projects, while only 10% of hydropower resources have been tapped (EPI, 2013). Given its economic and political status, there are few renewable energy policies in place except a memorandum of agreement signed in 2014 between the Ministry of Electric Power and ACO Investment Group and a US-based energy company, Convalt Energy LLC, which aimed to build two 150 MW solar facilities in the Mandalay region.[4]

The Philippines: The Philippines is characterised with a tropical climate, high rainfall,

[4]Myanmar government website. 'Myanmar kick-starts its renewable energy development', http://www.myanmarpresidentoffice.info/en/?q=issues/asean/id-4084 (accessed 28 August 2015).

and volcanic geography. As a result, it has great potential in hydropower, wind, and geothermal energy development. In fact, the Philippines has managed geothermal energy well in the past (Bakhtyar et al., 2013). The Renewable Energy Act of 2008 is in existence to accelerate renewable energy development. The government began implementing E1-mandated (1% ethanol blended with gasoline) delayed since 2011 and brought into effect the net metering policy that was established in 2008. The Philippines FITs are typically for a 20-year period. Although it does not have degression rates, it is subject to review should any changes occur and therefore leads to uncertainty concerns for private investors. Policies to support development of renewable energy technologies and facility building are mostly missing in the country (Table 2.2).

Singapore: Singapore has limited renewable energy options and the most viable renewable energy option seems to be solar energy given its average solar irradiance of 1,150 kWh/m^2 per annum.[5] Singapore is investing heavily in renewable energy, amounting to $228 million during 2007–2015 with a focus on photovoltaic systems (Dulal et al., 2013). It raised the cap on total power provided by variable renewable energy to 600 MW during peak demand. The government also provided funding for research and development to aid the industry's capability development on promising renewable technologies. Innovative financing and offsite PPA are being explored to create business opportunities in the renewable energy sector.

Thailand: Thailand introduced a new FIT for distributed solar energy and revised others. Furthermore, it extended subsidies for solar water heaters to 2021 and established a $121 million fund to encourage deployment of photovoltaic systems on buildings. According to the long-term 10-year alternative energy development plan 2012–2021, the target is to increase renewable energy consumption in the energy mix to 25% by 2021, and ethanol consumption will be increased to 9 million litres/day and biodiesel increased to 5.97 million litres/day by 2021 (IEA, 2013). In 2030 20,546.3 MW of electricity will be generated from renewable energy, which will be 29% of total electricity generation (Chingulpitak and Wongwises, 2014). The FIT policies have been comprehensive and contributed to private investment in the renewable energy sector in Thailand (Tongsopit and Greacen, 2013). However, to further promote renewable energy technology and

[5]Singapore Energy Market Authority website. 'Overview', https://www.ema.gov.sg/Renewable_Energy_Overview.aspx (accessed 27 August 2015).

utilisation, the market for renewable energy investment is yet to be expanded and legislation is to be launched (Table 2.2).

Viet Nam: In 2008 the government approved the National Energy Development Strategy, which sets targets to achieve 3% renewable energy in the energy mix in 2010, 5% in 2020, 8% in 2025, and 11% in 2050. Biomass and hydropower are the leading renewable energy resources in Viet Nam (Toan et al., 2011). It is estimated that renewable energy such as hydropower, biomass, and geothermal would become less costly for 2010–2030 (Nguyen and Ha-Duong, 2009) while wind and solar are unlikely to be commercially exploited in Viet Nam in the near future (Do and Sharma, 2011). To encourage the development of renewable energy, some of the key difficulties the government need to overcome are lacking awareness and reliable data on renewable technologies and potentials as well as inadequate policy and regulatory framework (Table 2.2).

Australia: The share of renewable energy in total primary energy supply was 6% in 2013, in which hydropower contributes 20%, biofuels and renewable waste account for 63.7%, and the remaining is from geothermal, solar, wind, and tide (IEA, 2015). It has increased only slightly from 5.9% in 1990. According to Bloomberg New Energy Finance (2015), investment in wind, solar, and other clean energy sources in Australia fell by 35% in 2014, which is the lowest level since 2009. This is primarily due to the government's review of the renewable energy target and the policy uncertainty causing concerns among investors.

New Zealand: New Zealand was among the first to exploit renewable resources, but over the last 20 years development of renewable energy is slow. The inadequacy of renewable energy policies as shown in Table 2.2 is a case in point. In 2013, renewable energy mainly hydropower contributes to 75.1% of the electricity generation. The figure is targeted to increase to 90% by 2025. What's more, a fully renewable electricity generation is proposed (Mason et al., 2010). Economic studies suggest wind and geothermal sources are the most likely candidates to support the achievement of the target and policies to address the development barriers and coordinating competing resource demands are needed (Kelly, 2011).

China: China has abundant renewable energy resources. Since 2005 when the Renewable Energy Law was enacted, the government has launched a variety of policies to promote the development of renewable energy. Shen and Luo (2015) evaluate the effects of many renewable energy policies such as transfer payments, tax preferential policies, price control, and compulsory allocation. Due to the huge financial support from the government, China led the world in new renewable capacity installations in 2013 and 2014 (REN21, 2015). However, as shown in Table 2.2, the market appears to be incomplete and technologies such as a smart grid are still lagging (though it is said that the government will invest $240 billion to the smart grid project between 2016 and 2020).

India: India has been ranked the fifth most attractive market in the latest Renewable Energy Market Attractiveness Index. Schmid (2012) found that the Tariff Policy 2006, state-level policies, quantity-based instruments, and participation of the private sector contributed significantly to installed capacity from renewable energy power using a sample of nine Indian states from 2001–2009. The Electricity Act enacted in 2003 is a major boost for renewable energy promotion in India since it empowers the regulators to promote renewable energy and make specified policies (Huang, 2009). The 2006 National Tariff Policy sets a deadline for implementing renewable energy measures. In 2008, RPS (or the Renewable Purchase Obligation) was set to produce 15% of the electricity with renewable energy sources by 2020. Along with the RPS, RECs were launched in 2010. With all these renewable energy policies, electricity generated from renewable energy accounts for around 16% of the total production of electricity (IEA, 2014).

Japan: Japan is a country lacking domestic fossil energy sources; however, more than three quarters of primary energy supply in Japan is from fossil fuel (Chen et al., 2014). As a result, the country depends heavily on imported fuel, which has caused substantial concerns on energy security domestically. On the other hand, the Fukushima nuclear catastrophe in 2011 has drawn public attention to energy safety. Both forces have led to the growing renewable energy market. As shown in Table 2.2, Japan scores highly in the renewable energy policies. For example, RPS has been in practice since 2003, net metering for wind and solar energy was in place in 1992, and the solar FIT scheme began in 2009. In addition, the Energy Act has been updated over time, from the 1997 New Energy Act to the 2009 Non-Fossil Energy Act. One area the government may need to consider is policy support for more R&D activities and smart grid operation.

South Korea: South Korea has huge renewable energy potential of 2.3 million tonnes of oil equivalent (MTOE) theoretically (Chen et al., 2014). South Korea targeted to use 5% renewable energy sources in total primary energy supply by 2011 in the 2nd Basic

Plan for New and Renewable Energy Technology Development and Deployment and in the 3rd Basic Plan in 2008 raised the target to 11% by 2030.The government also supports R&D of green energy technologies aggressively (Ministry of Trade, Industry and Energy, 2011) and launched the Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy 2011 on top of the Energy Act 2006. However, due to the financial burden, the government discontinued FITs in 2011 and replaced it with an RPS programme.[6] Most of the renewable energy policies that encourage new investments are in place but how to make them sustainable and more attractive is the next challenge.

4. Conclusions and policy implications

This study attempts to build a framework to quantitatively assess renewable energy investment policies from the investors' point of view or that of financing of projects. Using five criteria – market, profitability, legislative uncertainty, technology, and finance resources, and three indicators under each criterion, this study compares the policies in the 16 East Asia Summit countries and derives implications for the region as a whole.

The market aspect examines whether policies helped to create and extend a market for renewable energy. The profitability aspect considers whether policies provided the environment in which potential profits from renewable energy investment can be improved. The uncertainty aspect examines whether there are laws that reduce risks relating to investment in renewable energy. The technology aspect shows whether and how policies helped to develop and adopt renewable energy technologies. The finance aspect presents policies that could improve the availability of funds by addressing issues on the supply side, including financial institutions, financial markets, financial tools, and business models.

The values of each indicator are collated and the cardinal values are converted into ordinal values for analysis. As the results for the 16 EAS countries show, India, Australia, China, Japan, and South Korea are among the top-ranked countries in the EAS region in terms of renewable energy investment policies, while Brunei Darussalam, Cambodia, Lao PDR, and Myanmar are far behind. By examining the whole EAS region, the renewable energy market exists, but could be developed further. Incentives such as feed-in tariffs or

[6] However, some local governments such as Seoul and Gyeonggi-do still have FITs in force for photovoltaic facilities less than 50 kW.

tax reductions are prevalent, while power purchase agreements are less common. As to legislation related to renewable energy, the establishment of renewable energy acts is one of many areas the EAS region could work on. Besides, policies that may advance technologies are scarcely seen. Financing resources (especially traditional vehicles), on the other hand, are already in place.

Through comprehensive quantification of the renewable energy investment policies in the EAS region, this study presents a systematic and quantitative measure to compare the effectiveness of policies in these countries and therefore policy implications could be easily drawn. For instance, the index can be used to help policymakers identify the weakness or gaps of their policy design and implementation, learn from the best practices of other countries, and also strengthen policy design and implementation. Furthermore, the index framework can be easily expanded.

Upon the construction of the index and analysis of the collated information, this study presents the following policy implications:

- In the EAS region, a weaker form of the renewable energy market exists. Policies such as REC and net metering should be implemented further to realise its potential.
- Renewable energy acts, which are commonly lacking in the region, could be the next step that individual countries and the whole region should work on to ensure the consistency and continuity of policies related to renewable energy investment.
- The development and advancement of renewable energy technologies have not been given enough emphasis, and policies targeted specifically at technology such as smart grids, as well as reliable, timely, and regularly updated data, and capacity building should be implemented.
- Policies related to the profitability and financial resources are prevalent in the region. Policy stability and predictability, especially in developing countries, becomes more important to ensure the investors' confidence to leverage the finance instruments such as preferential loans and grants available to carry out long-term renewable energy projects.
- ASEAN countries in the EAS region still lag in all the five aspects of renewable energy investment policies. ASEAN should focus on creating a market through legislation and introducing FIT or RPS so as to catch up with the international renewable energy markets.

The methodology and framework adopted in this study is scalable to capture more details and features of policy design and implementation in the region, provided that relevant data are available. The next steps in this stream of studies should be to build a policy database as detailed and as updated as possible and provide a more accurate assessment of how effective renewable energy policies are from the financing of projects point of view.

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Chapter 3

Assessment of Instruments in Facilitating Investment in Off-grid Renewable Energy Projects

Global Experience and Implications for ASEAN Countries

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Abstract

Renewable off-grid solutions play a critical role in giving people access to electricity. However, the challenges are enormous. Financing such off-grid renewable energy (OGRE) projects is one of the most significant challenges due to barriers such as limited financing access, low affordability for consumers, and high transactions costs. However, the benefits of electrification are beyond financial calculation, such as human development, improvement of life quality, generation of additional productive activities, access to information, and education. For these considerations, various instruments have been implemented to facilitate OGRE investment. However, which instruments shall be adopted is still a challenging question for policymakers. Answers to this question are practical and urgent for many Association of Southeast Asian Nations (ASEAN) countries that have the need to develop OGRE projects. This study assesses the effectiveness of those instruments from various perspectives and provides reference to further policymaking. Instruments that have been widely used are collected by this study through literature review and case study. The study proposes a framework consisting of three dimensions: feasibility, sustainability, and replicability for assessing the effectiveness of those instruments. The weights of each dimension were decided by surveying experts. Experts from various backgrounds, including policymakers, industrial players, and other relevant stakeholders evaluated each instrument from the three dimensions. Based on studying the literature and findings of the survey, policy implications for ASEAN policymakers were drawn.

Keywords: Off-grid renewable energy, rural electrification, investment facilitation

JEL code: Q28, Q47, I38

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1. Introduction

Energy lies at the heart of all countries' core interests, from education improvement to job creation, and from security concerns to full empowerment of women. Energy is also a necessary input for economic development that can be indicated by the whole supply chain, from growing crops, manufacturing, transport, and retailing, among others. Access to electricity is critical to human development as it is essential for certain basic needs, such as lighting and running household appliances. An individual's access to electricity is treated as the most important indication of a country's energy poverty status.

However, access to electricity, not only for meeting basic needs, but also for productive uses, is a significant challenge faced by policymakers and stakeholders in the developing world. A significant amount of the world's population has no access to electricity. According to the International Energy Agency (IEA), 18% of the world's population – 1.3 billion people – still don't have access to electricity, nearly 97% of them live in sub-Saharan Africa and developing Asia, and 80% of them live in rural areas (IEA, 2014).

Significant efforts are being made at various levels of governments and communities to increase a population's access to electricity. In September 2011, the United Nations (UN) Secretary-General, Ban Ki-moon, launched the Sustainable Energy for All initiative, which aims to make sustainable energy for all a reality by 2030. In order to achieve the goal of 'Energy for All', both mini-grid and off-grid electricity supply systems are suggested to be implemented together with on-grid solutions (IEA, 2013).

Off-grid solutions play a critical role in giving people access to electricity, especially in remote and rural areas, because it is more cost competitive compared to grid extension. In many remote non-electrified areas, grid extension is not sustainable not only due to the high capital cost of transmission infrastructure but also due to transmission losses and maintenance costs (Zhang and Kumar, 2011). The cost of grid extension in western or north-western China has been reported to range between $5,000 and $12,750 per kilometre (km) (Byrne et al., 2007), which makes grid extension uneconomic. Byrne et al. (2007) further reported that the estimated cost of electricity per kilowatt hour (kWh) from solar–wind hybrid systems in China ranged from $0.26 to $0.89, while the unsubsidised cost of electricity from the grid was roughly $3.32 per kWh. Furthermore, low per capita electricity consumption in remote areas will also make grid extension not financially sustainable. While in many cases, mini-grids could provide an ideal intermediary or even long-term solution when a central grid is absent, especially for small towns or large villages where enough electricity can be generated to power household use, as well as local businesses (Rolland, 2011). It is estimated that nearly 60% of additional generation capacity for universal electricity access by 2030 will come from off-grid installations, including both stand-alone and mini-grids (IRENA, 2012b).

Many cases show that it is feasible to electrify remote areas by renewable energy (RE) technologies. In off-grid electrification, solar, small hydro, and wind power are frequently employed. Renewable off-grid could be the least cost option compared with diesel generation. Off-grid renewable energy (OGRE)[6] generation technologies are reliable and cost-competitive compared with fossil fuel-based generation systems in rural areas. Meanwhile, RE stand-alone systems (for example, solar home systems [SHS] are more cost-effective than kerosene lighting on a life-cycle basis.

Going forward, kilowatt-scale mini-grids (MG) can provide reliable electricity for productive uses on top of the basic electricity that is provided by stand-alone systems and can be further developed into larger mini-grids that have several sources of generation to serve diverse loads (IRENA, 2012b). Rolland (2011) claimed that diesel-fuelled MG are likely to be more expensive than RE and diesel hybrid ones on a lifetime basis, and less autonomous as fuel availability cannot be assured, so that a well maintained and managed hybrid system can run for over 25 years and be more attractive than diesel MG. IRENA (2012b) observes that the falling costs and increasing technology maturity make RE the most appropriate option for mini-grids in most rural areas.

[6] In this chapter, off-grid systems include stand-alone and mini-grid systems.

A renewable energy based off-grid solution is also more likely to be implemented to provide electricity access, especially to rural and remote areas as it doesn't put extra pressure on the existing generation, transmission, and distribution capacities. It is more favoured due to the environment friendly technologies, because it can avoid the environmental issues related with grid extension by efficiently utilising local RE sources like solar, wind, biomass, and run-of-river hydropower (Deshmukh et al., 2013).

Policymakers face the challenges of choosing appropriate policy instruments to support off-grid RE projects. The answers, however, would likely differ among regions due to their differences in factors such as government structure, public financial capacity, local culture, and so on. However, the evaluation of the effectiveness of policies in the literature mainly focuses on developed countries, in particular, the European Union (EU). The EU's assessment of financial instruments (European Commission, 2014) is a salient example. However, these methods may not applicable to the energy sector or to developing countries due to date or capacity limitation or both. Other research focuses on qualitative analysis of the effectiveness of government policies (Agnolucci, 2007; Dijk et al., 2003) often rely on the judgment of the research team itself. Furthermore, the evaluation of renewable energy policies often overlooks time dimension and geographical dimension. IRENA has recently released major publications for evaluating RE policy (IRENA, 2012a, 2014). These studies investigate indicators used to evaluate renewable energy deployment policies. The analysis framework of the assessment focuses on effectiveness, efficiency, equity, and institutional feasibility. They are also conducted on a micro level, consisting of performance-based assessment without directly considering how individual RE projects are developed and financed. More assessment on RE policy instruments are qualitative and not comparable, such as (IRENA, 2012b), which reports on the assessment of some OGRE policies without quantification.

To the best of our knowledge, there is no quantitative assessment of OGRE project supporting instruments from a project's financial perspective. The difficulty of selecting policy instruments suggests the need to study what instruments can be used to develop OGRE projects in the Association of Southeast Asian Nations (ASEAN) region.

This chapter provides an assessment of prevailing supporting instruments used in facilitating the investment in OGRE projects. It aims to update governments on which instruments could be used to facilitate the development of OGRE projects, what are the advantages and disadvantages of each instrument, what are the pre-requirements to adapt these instruments, and how likely they can be replicated in projects located in different countries and/or regions. Ultimately, this study is expected to help governments formulate their policies for developing OGRE projects and thus improve energy access under different national, regional, and community contexts. In particular, the chapter aims to draw lessons from international experiences for supporting OGRE project development in developing ASEAN. Given the fact that more than one-fifth of the ASEAN population still has no access to electricity, and many countries have abundant RE, using RE for electrification would be a real policy issue. This study can provide value to energy policy decisions in many ASEAN countries.

The chapter (1) proposes a holistic assessment framework of policy instruments, not only considering feasibility, but also taking into account time dimension (sustainable) and geographical dimensions (replicable) at project level; (2) reveals weights that can be used to integrate index policies into one score that is easy to be understood; (3) focuses on the OGRE projects, which are prevailing in many less developed countries and thus providing a simple index for their reference; (4) surveys a diversified range of players with a wide geographical coverage from different perspectives, which makes the assessment comprehensive and representative; and (5) discusses the assessment results that are comparable among instruments due to the consistent framework and quantitative results. The perspective from projects, in particular, OGRE projects, is different from other studies in the literature.

The chapter proceeds as follows. In Section 2, motivations of the study are justified by reviewing the challenges of universal electricity assess and limitations of current studies. Section 3 explains the methodology, including the analytical framework and the data. Section 4 reviews and presents the major instruments that have been used in the literature. Results of the survey are explained in Section 5. Discussions and policy implications for ASEAN are further elaborated in Section 6. Section 7 concludes the chapter.

2. Supporting instruments in financing OGRE projects

2.1 Challenges

OGRE projects are necessary because they provide consumers who live in remote rural areas access to modern energy. Electricity access will not only provide modern energy per se, but also generate other benefits such as better education and health facilities, cleaner and more efficient appliances, and possibility for productive economic activities (that is, food processing) which have the characteristics of a ‘public good’.

However, OGRE projects often face challenges from high initial costs, limited local financial resources, low return rates, and low affordability (due to high costs of electricity and low income) for consumers. Although many studies have shown that OGRE products cost less than conventional energy sources, such as kerosene and candles, they usually require much higher initial investment. On the contrary, people who live in rural or remote areas often have low incomes and small electricity demand, thus a unit cost of electricity may be more expensive than providing a large-scale electricity service in rural areas. Besides the challenges analysed above, there is also a poverty–affordability deadlock which cannot be broken down without external interventions. Table 3.1 presents a non-exhaustive list of institutional and market failures that OGRE projects face.

Table 3.1: Institutional and Market Failures in OGRE Projects

Type	Examples
Government failure	· Shortage of public investment due to budgetary constraints · Lack of clear and transparent plan on future central grid extension, causing uncertainty to investors · Lack of effective institutional arrangements to ensure reliable and efficient operation and maintenance over time · Lack of standards and rules · Lack of quality control and assurance
Allocation efficiency	· Shortage of capital from the indigenous communities and thus existing equity gap for risk finance · Lack of financing at different stages of project development, especially at initial stage · Lack of affordable financing access for consumers · High investment risk due to low willingness to pay high technological risks, culture differences in local communities, limited catalytic investment to generate economic activities, among others
Externalities, Public goods	· Meeting basic energy needs is the goal of social development · Emission reduction being a public good · Future benefits such as nursing of productive usage cannot be foreseen and compensated · Lack of compensation for non-economic benefits (i.e., providing education, entertainment, and health care)
Transaction costs	· Difficult to collect information about communities in rural areas during the project preparation stage · Hard to gain local communities' trust to build the project · Difficult and expensive to collect tariffs from local communities and provide maintenance service · Financial administrative costs are not affordable for small-size projects · Long payback period and low return rate for investment
Imperfect information	· High costs of project development as OGRE projects are often on greenfields · Lack of community awareness about benefits of OGRE projects, such as underestimation of heath costs caused by indoor air pollution resulting from use of traditional forms of energy · Asymmetric information among local communities, project developers, and potential investors
Local technical expertise	· Lack of technical skills such as maintenance skills at the community level, leading to suboptimal performance or premature breakdown · Lack of technical skills in the market to support scale up of OGRE projects

OGRE = off-grid renewable energy.
Source: Authors' deliberation based on information from various sources (European Commission, 2014; IRENA, 2012b).

Several financial challenges exist in OGRE projects and rural electrification that cannot be solved by the current market mechanisms. One of the key issues associated with rural electrification is the ‘externality’ of public goods. Many of the benefits for communities induced by electrification cannot be reaped by investors. On the contrary, missing visions of the benefits of electricity access will reduce the willingness to pay and discourage OGRE projects. The consumers’ willingness and ability to pay signals the maximum price the operator can realistically charge (IRENA, 2012b) and thus play a determining role in financing OGRE projects. Local communities that have not had access to electricity, may not be able to assess the real benefits of electrification, and thus are reluctant to invest in OGRE.

Further, the unwillingness and/or the inability to pay can hinder OGRE development. Low-income residents may not be able to afford electricity fees. Specifically, if minimum monthly payments are required, consumers may find it hard to make payments due to their fluctuating income throughout the year (World Bank, 2008). In addition, consumers may fail to understand or respect the financing agreements and financing schemes that have been established and thus put OGRE projects at high risk (Gboney, 2009). Therefore, OGRE projects are generally not attractive to private investors, and the exiting lending terms set by lenders (or funders) are often unsuitable for OGRE projects.

Local communities are unlikely to address the above challenges by themselves. The communities may have limited financial strength to attract adequate investment to build an off-grid system. Policy intervention and government support is necessary for the development of an OGRE project, and in many cases, policy support from governments will need to be in place mid- and long-term until the project can be economically variable.

If scaled up, projects such as household solar panels, mini-hydro systems, local wind turbines, and biomass cooking could change the energy dynamics within ASEAN. Governments could design, finance, and operate policy facilities to provide enough financial viability to OGRE project developers. The financing issues concern not only sufficient funding for projects, but also the financial structure that can vary among projects and thus could make OGRE projects commercially viable (Jager and Rathmann, 2008). Only when either the costs are reduced or local communities have benefited from access to modern energy, can their willingness and ability to pay for electricity be improved, which will make OGRE projects economically and commercially viable.

2.2 Key support instruments to finance OGRE project financing

Policy instruments that have been adopted to support OGRE deployment include financial incentives (soft loans, grants, and publicly backed guarantees, among others), fiscal incentives (exemptions from import duty and value-added tax, among others), and elimination of market distortions (for example, fossil fuel subsidies) (IRENA, 2012a).

Government grants and support are necessary as the costs of RE technologies are still high and difficult to be financed by the rural population, which indicates that those rural electrification projects are not commercially viable yet. While donor funding can play an important role in supporting rural electrification programmes, especially in the early stages, experience shows that the role of donor funding can be reduced as the programme reaches a certain scale and the local off-grid market matures – as seen in the case of Bangladesh. The major financial components – grants and concessional finance – of the solar home system (SHS) programme, which was started by the Infrastructure Development Company Limited (IDCOL) are designed in such a way that dependence on external finance gradually recedes (IRENA, 2012b).

In addition, appropriate electricity tariff mechanisms and subsidies could be efficient to address the issue, that is, setting up a special fund to broaden the finance channels for off-grid projects, providing preferential interest rates for the loan, designing the tariff which can cover the initial, operation, and maintenance costs incurred during the project's lifetime, using capital subsidies or levying low import duties as a strong and direct financial support, among others.

Many instruments to strengthen the financial capability of an OGRE project have been widely adopted in many countries. Take the Philippines' case as an example. The Development Bank of the Philippines has provided low interest loans with the support from various overseas development assistance funds and the World Bank for renewable energy and rural power projects. Particularly, the Philippines offers special privilege tax rates to developers of hydropower, which is 2% of their gross receipts. Further, an income tax holiday for 7 years from the start of commercial operations is provided. The importation of machinery, equipment, and materials for mini-hydropower projects is exempted from payment of tariff duties and value-added tax (VAT) within 7 years from the date of awarding the contract. Tax credit is given to developers who buy machinery, equipment, materials, and parts from local manufacturers. VAT on gross receipts derived from the sale of mini hydropower (10%) is exempted. These fiscal incentives for mini-hydropower development were introduced in 1990s (Pacudan, 2005).

In the context of the OGRE project lifecycle, it may be useful to classify the financial challenges in phases as the investment in the different phases correlates with different risks and barriers (European Investment Bank, 2014). Below presents a brief discussion of various instruments.

2.2.1 Plan and development phase

In this study, we define the initial stage of an OGRE project as the stage that covers the site selection, feasibility study, material and equipment purchasing, and project build-up. During the project planning and/or pre-investment phase, grants or subsidies can be provided for feasibility studies, business plan development, technical planning, and capacity building and transaction costs (EUEI PDF, 2014). In developing countries, rural electrification investment cannot totally rely on revenues from clients in the short and medium term. It needs subsidies – yet subsidy schemes have to be well-designed to support rather than hinder mini-grid roll-outs (EUEI PDF, 2014). In Senegal, the initial investment cost subsidy is provided to private operators in the RE and rural electrification projects (Kfw, 2005).

Capital subsidy is one of the most widely adopted policy instruments to assist off-grid projects overcome the initial investment barrier (Kfw, 2005). According to Deshmukh et al. (2013), Brazil has successfully operated 15 small hydropower plants and one solar photovoltaic (PV) plant in remote Amazon regions through a special project manual issued by the Ministry of Mines and Energy. The manual provides 85% capital subsidy to the mini-grids, especially those based on renewable energy. The Indian Ministry of New and Renewable Energy also provided a large proportion for the capital subsidy as high as up to 90% (Palit and Sarangi, 2014). In the case of India and Sri Lanka, capital subsidy and soft loans succeeded to establish the market for solar home lighting installations, and a micro-credit system model succeeded in Bangladesh to develop the market in the rural sector (Mahajan and Garud, 2011).

Reiche et al. (2000) pointed out that reduced import duties on PV components can remove market distortions and make SHS more affordable for rural households. This method was used in the Comoros, a small island nation in the Indian Ocean. With the assistance of the UNDP/World Bank Energy Sector Management Assistance Program (ESMAP), the government granted the firm a 3-year grace period for taxes and duties, that is, it could import equipment without any tax burden. Other tax related incentives can help promote renewable energy development by reducing the costs of investment, such as accelerated depreciation (Deshmukh et al., 2013; Sawin, 2004). It allocates a large proportion of the system costs to earlier accounting periods and a smaller proportion to later periods (Zhou et al., 2001). Accelerated depreciation is widely-used to help OGRE investors cut the equipment cost and increase the profit (by reducing tax) (EUEI PDF, 2014).

(Solar) crowdfunding is a new financing mechanism in which investment funds in solar systems are raised from individual investors through the internet (Tongsopit et al., 2013). It has developed fast in recent years, and has been considered as revolutionary given its scale and applicability, especially compared to mechanisms subject to the excruciating dynamics of the United Nations Framework Convention on Climate Change (UNFCCC) like the Green Fund (Guay, 2012). The companies that run solar crowdfunding platforms pool small investments from many individual investors, and the individual investors receive interest and are paid back in full over a specified number of years.

Through crowdfunding, people are able to provide zero-interest loans to organisations and products they support (Quinn, 2012), or pure donations in many cases of OGRE projects. It substantially expands the finance channel for OGRE projects.

Meanwhile, it is also gives easy access for investors or donors to find and approach the projects and project developers. In remote rural areas, the most effective means of delivering energy is through small-scale systems, and with distributed clean energy. Since crowdfunding is a financing model that mirrors this scale and distribution (Guay, 2012), it could be an ideal financial and business model for OGRE projects. The Sun Funder platform finances small solar projects and businesses in off-grid areas in African countries (Tongsopit et al., 2013).

2.2.2 Operation and maintenance phase

'Designing a grant and subsidy regime is challenging but essential. Grants and subsidies should be affordable for the country to allow scaling up beyond a few pilot projects and upgrading of existing mini-grids. In most countries, this means that subsidies should be as low as possible, and as high as necessary'.(EUEI PDF, 2014). In the operation and maintenance phase, incentives based on energy generation (feed-in tariffs [FIT]) or a fixed subsidy per connection can help cover maintenance and operational expenses and eventually profit gaps (Deshmukh et al., 2013).

In addition to the capital subsidy, some forms of operation and maintenance (O&M) subsidies are essential to sustain project operations over a long period, particularly in the case of extremely remote areas with a poor ability to pay. For example, in India, around 10% of the project cost is supported by various programmes (for example, the Ministry of New and Renewable Energy's Remote Village Electrification Programmes and Decentralized Distributed Generation Programme) for 2 to 5 years (Palit and Sarangi, 2014). In Thailand, the government has introduced a pricing subsidy for the capacity generated by renewable energy from small power producers (ACE, 2013). In China, small hydropower producers benefit from both a lower value-added tax and income taxes that are either lowered or forfeited altogether (Zerriffi, 2011). Furthermore, subsidies can also be made available to the mini-grid operator upon reaching certain milestones (results-based subsidies) (EUEI PDF, 2014).

Training and capacity development should also be taken into account as human resources are a key issue to promote OGRE deployment. Well-designed policies and appropriate institutional arrangements along with effective financing mechanisms can address many of these challenges and enable the successful and sustainable deployment of OGRE projects (Deshmukh et al., 2013). Meanwhile, local involvement of operation and maintenance could save costs and create opportunities for income generation as well.

2.2.3 Energy use phase

The appropriate tariff scheme is complex and needs to consider the three following aspects: (1) to ensure energy affordability of low-income consumers, (2) to be cost-effective for private OGRE developers, and (3) to encourage consumers to manage their energy consumption more efficiently. From a private developer's perspective, tariffs must be cost-reflective. Otherwise, mini-grids cannot be run profitably, which prevents potential customers in rural areas from receiving high quality electricity at all (EUEI PDF, 2014). From a regulatory point of view, the critical issue of tariffs directly affects the business case for mini-grid deployment and the long-term sustainability of a project (IRENA, 2012b). Waddle (2012) also emphasised it is important to establish rational tariffs that allow full cost recovery of rural electrification programmes. There is no one-size-fits-all solution to tariff setting (IRENA, 2012b), thus, a balance needs to be achieved among these aspects.

In order to solve the challenges created by high initial costs of OGRE projects and low affordability of consumers together, governments and project developers try to convert the OGRE system from a system with high initial cost to one with long-term energy service. The World Bank Group has implemented the 'long-term consumer credit' to overcome the 'first-cost barrier' (the high initial system cost relative to conventional alternatives), and provided means that consumers can continue to pay what is roughly equivalent to their conventional energy purchases (Reiche et al., 2000). Recently, thanks to the fast technological improvement and the large-scale of RE applications worldwide, the costs of RE have been substantially reduced. Therefore, consumers are more likely to face smaller expenses under the consumer credit scheme.

Demand-side subsidies often incorporate the off-grid electricity tariff settings to support consumers of OGRE projects. For instance, consumption subsidies can operate through the tariff structure as a percentage discount applied to residential end-users' bills, and users with electricity consumption below a certain level could be considered as 'low-income' consumers and had the right to pay reduced tariffs in Brazil (Gómez and Silveira, 2012). The use of tiered electricity tariffs can be an effective method to address energy poverty, improve energy efficiency, and achieve financial viability, as the Tier 1 tariff could be set low so that low-income consumers can also have access to electricity (to meet their basic needs), while the tariff could increase at higher tiers to achieve higher efficiency. The tariff design also needs to consider the feasibility and costs of tariff collection.

A system of tariffs and subsidies is required to complement – but not replace – the limited contribution by low-income consumers and ensure the sustainability of the service (World Bank, 2012). While a large part of capital costs is usually subsidised through special-purpose funds, many low-income households cannot pay the full cost of operation. In addition, as Salih (2012) has also pointed out, in Sri Lanka the institution's financial viability and fragmented and complicated regulation and supervision are the major weaknesses in providing consumer credit.

Microfinance to rural households for SHS has been successfully implemented by Bangladesh's Infrastructure Development Company Limited (IDCOL) and Sarvodaya Economic Enterprise Development Services (IRENA, 2012b). In some cases in China, electricity was distributed free of charge at the beginning of the projects. However, the township government soon found that many village-level power stations went into bankruptcy and thus started to collect tariffs, but hospitals and schools were exempt (Cao, 2006). In Lao PDR (Lao People's Democratic Republic, interest free loans were provided to poor households to be paid back in a 3-year period (Bambawale et al., 2011).

In practice, consumer credit can be provided through: (1) local development finance institutions, (2) microfinance organisations, or (3) equipment dealers (IRENA, 2012b; Reiche et al., 2000). For instance, in Sri Lanka, a microfinance organisation provides consumer credit to reduce the amount of monthly credit repayments by a share of the per-system (Reiche et al., 2000). In Argentina, the energy-service concessions are given a variable grant amount (a one-time payment for each system installed), which declines for installations made in later years of the project and also depends upon system size (Reiche et al., 2000).

It is advised that results-based subsidies, which aim to subsidise connection fees for consumers are more efficient than operational subsidies or investment subsidies to investors. For instance, results-based connection subsidies of €380 for each new connection is offered in a private mini-grid in Tanzania (EUEI PDF, 2014). In addition, in diverse types of institutions such as banks and non-banks, the inclusion of an implementing organisation and direct access for loans for consumers are some of the strengths identified in the microcredit financial model (Salih, 2012).

2.2.4 Total lifecycle

In addition to appropriate instruments, various business models can also be adapted to support the establishment of OGRE projects and to improve their financial viability. Rolland (2011) summarised the business models in OGRE projects as four types: utility, community, private, and hybrid models. Utilities have more experience, financial resources, and technical capabilities to carry out rural electrification projects. The private model operates more efficiently, yet requires higher rates of return. Local communities have the best knowledge of the local conditions and could work more efficiently after appropriate training and capacity development. Further, cooperation with local governments can also be a more effective method compared with central governments. The hybrid model combines different players (or models) so that they can play different roles during the project's lifetime, that is, introducing the utility as the investor, combining the community as the operator and maintainer with the private organisation's technical (or financial) support.

Private operator models, where private investors build, operate, and maintain the off-grid system, have a high potential for scale up, for attracting private investments, and for mobilising the know-how of the private sector. However, it is rare to see those models based on pure private investment. Various forms of assistance should be offered to promote their development, that is. a publicly backed debt or credit enhancement facility may provide or facilitate long-tenor, low-interest loans that commercial lenders would not offer on their own. EUEI PDF (2014)EUEI PDF (2014). It is pointed out that loan guarantees provided by national banks or special facilities to commercial lenders may compensate the lender in the event of default, and such a loan guarantee may cover 50% of the loan on a shared-loss (rather than first-loss) basis (EUEI PDF, 2014).

Besides, public–private partnerships (PPPs) are also used to implement the de-politicisation of rural electrification, attract private investors, implement priority projects, and allocate capital subsidies through competition between public utilities and private investors (Salih, 2012). Palit and Sarangi (2014) studied a case in India where private companies such as Husk Power Systems has developed a franchisee-based business model for setting up mini-grids. Husk Power Systems follows the build, own, operate, and maintain; build, own, maintain; and build and maintain models for providing electricity services.

There are also instruments to address concerns about the consumer credit mechanism, specifically focusing on the credit risk issues. Financiers tend to be reluctant to extend credit to rural consumers with little credit history. In addition, credit administration and collection could also be costly. Three ways can be adopted to mitigate the risk, namely partial credit guarantee schemes, microfinance lending, and partnering promise via models (Reiche et al., 2000). Credit risk should be lowered from two perspectives, short term and long term. In the short term, governments or funding organisations can provide the credit guarantee for consumers. Guarantee schemes cannot only smooth the credit application from financiers or dealer, but also help prove consumers' affordability to the project developers or investors, so as to attract the investment.

In the long term, effective income creation of local communities is the key solution. By establishing local productive enterprises that can produce high-value added agricultural and rural industry products for export to national and international markets, local consumers' affordability can be strengthened, and the electricity demand may also increase so that unit cost of electricity could be reduced. In India, SELCO's experience of selling, servicing and financing over 135,000 SHS has shown that access to customised long-term affordable financing has made OGRE products available to rural households with limited income, mostly without grant support (IRENA, 2012b).[7] In addition to using supporting instruments, the sustainability of rural electrification projects could also be enhanced through joint development with other industrial activities (Cao, 2006) .

3. Methodology and data

3.1 Overview

This chapter uses both qualitative and quantitative methods to review the key supporting instruments that have been used globally to facilitate OGRE investment, assess their performance within a dedicated framework, and identify their applicability under various circumstances. Section 2 provided a critical review of policy instruments for facilitating OGRE project development through reviewing the literature. These instruments are then evaluated by a holistic assessment framework that integrates three dimensions. Each of these dimensions represents major challenges in OGRE project investment. The weights for each dimension and qualitative levels of effectiveness for each instrument are assigned by both experts and practitioners who work on OGRE projects across the world. The survey was conducted online and the respondents were invited individually. The level of effectiveness will then be further quantified and aggregated to generate a unified score for each instrument combining the different evaluation results at each dimension from the survey.

3.2 A holistic three-dimension assessment framework

This study assesses the prevailing instruments used to support OGRE projects from three dimensions: feasibility, sustainability, and replicability. According to the current European practice, in *ex ante* assessment of financial instruments (European Commission, 2014), major concerns for policy instruments will be their ability in addressing market failures, value added, and leverage of other public or private financial

[7] SELCO Solar Pvt. Ltd. is a for-profit social enterprise established in 1995. It provides sustainable energy solutions and services to under-served households and businesses in rural areas.

resources. These three perspectives are also embedded in the life cycle of OGRE policymaking: from building up a project to sustaining the operation and to replicating it in other circumstances to address the wide electrification challenges. Building up a project and achieving its long-term economic viability are two major challenges for any specific OGRE project, while replicating it would be a general challenge for policymakers who need to think beyond project level.

From a policymaker's perspective, while feasibility is a major concern, the long-term operation of a project should be a key of success. One of the key challenges for OGRE projects is to achieve the long-term sustainability, as many of the projects are set up by governments' or donors' support and face challenges of sustaining themselves. Many OGRE projects failed beyond the assisting stage due to financial difficulties, lack of technical resources, and limited capacity. A project cannot be considered successful or even completed if it fails beyond the assisting phase.

Furthermore, replicability should be taken into consideration as an assessment dimension. Even though OGRE projects often have unique features due to various local environments, resources, and communities, a supporting instrument or even a project which can be replicated in other projects or other regions would be more important and effective for policymakers compared to those that cannot be widely replicated.

The supporting instruments on OGRE projects should be assessed from the three dimensions with each instrument having different impacts on these dimensions. It has been found in the literature (IRENA, 2012b) that some supporting instruments, such as public and/or external support (for example, financial, and human, among others) make OGRE projects unsustainable and difficult to be scaled up. Therefore, each instrument will be scored by an integrated assessment framework, which covers various dimensions including feasibility, sustainability, and replicability. Considering the potential diversified views in policy assessment, we also keep a fourth dimension as optional for surveyed experts to decide. The assessment framework is presented in Table 3.2.

Table 3.2: Integrated Framework for Assessing Supporting Instruments

Dimension	Definition	Weight
Feasibility	Make the project possible to take off	(decided by survey)
Sustainability	Achieve long-term commercial viability (even beyond the assistant phase)	(decided by survey)
Replicability	Possible to be replicated elsewhere in other projects	(decided by survey)
Others	Other factors that are important to the assessment. Please specify	(decided by survey)

Source: Compiled by the authors.

For each policy instrument, surveyed responders are asked to assess the effectiveness on each of the three dimensions. The effectiveness is presented at five levels: very effective, effective, moderate, slightly effective, and not effective. The answer is then further translated to numerical results from 5 to 1, with very effective to be 5 while not effective to be 1. Table 3.3 presents the scaling.

Table 3.3: Quantifying the Effectiveness of Instruments

Performance	Very Effective	Effective	Moderate	Slightly Effective	Not Effective
Score	5	4	3	2	1

Source: Compiled by the authors.

A weighted average of each score across all three dimensions will produce an integrated score, or policy effectiveness index for an instrument. The method of measuring OGRE supporting instruments by means of different dimensions offers flexibility for policymakers to choose policies that suit different situations. This flexibility also implies that the index is adaptable to different institutional settings, which are often diversified in developing countries.

3.3 Data and information

Information is collected from reviews of existing literature, interviews and discussions with relevant stakeholders, a survey of experts and stakeholders, and case studies. The list of instruments is collected through a literature review. Those instruments that are frequently used in the literature are put into the list for assessment.

The assessment of the policy instruments is conducted through a survey, which draws on experts from academia, government agencies, the private sector, international institutions, nongovernment organisations (NGOs), and other OGRE project stakeholders. The experts are recruited from the energy policy, renewable energy, and off-grid energy systems fields at international conferences and workshops, as well as contact via email. The research team then internally reviewed the results of the assessment to ensure their consistency, and discussed them with experts in a workshop for refinement.

4. Empirical results and discussion

In total, this survey received 101 responses, with and 71 of them being complete. The following analysis is based on the complete responses only. Even though experts from academia and research institutions account for the largest share of participants (above 70%), the survey managed to investigate most of the perspectives of investment in the OGRE projects. A summary of survey results is presented in the Appendix.

4.1 Assessed weights of each dimension

As explained earlier, this study selects three dimensions: feasibility, sustainability, and replicability. Respondents are asked to give a score for each dimension based on their importance in the whole assessment framework, so that each instrument can have a weighted assessment score for its overall performance. There is also an option for adding ‘other dimension’ if experts believe that there should be other assessment dimension(s). The result of the weights of each dimension is shown in Table 3.4.

Table 3.4: Results of the Assessed Weights for Each Dimension

Assessment dimension	Response Average	Response Count
Feasibility	39.90%	71
Sustainability	35.96%	71
Replicability	24.14%	71
Total	100%	

Note: Other dimensions only account for 3.66%. They are timeliness, cost effectiveness, accessibility, safety and security, and implications on local communities (for example, social benefits, and job creation, among others), which actually cover the three dimensions above (cost effectiveness is related to all three dimensions). Therefore, the score of 'other dimension' is proportionally assigned to each of the three dimensions above.

Source: Compiled by the authors, data from the survey.

As shown in Table 3.4, 'feasibility' is considered the most critical assessment dimension, scoring 40%. In other words, the most important perspective in evaluating any instrument's performance in OGRE investment is that, it should be effective in establishing OGRE projects. Secondly, whether the instrument is effective in supporting the OGRE projects to achieve the long-term commercial viability (even beyond the assistant phase) – sustainability – is given a weighted score of 36%, showing that both feasibility and sustainability are key concerns of supporting investment on OGRE projects. Lastly, 'replicability' accounts for around 24%, which assesses whether the instrument can or has the potential to be replicated in other projects. The result is reasonable given the fact that OGRE projects are usually located in remote areas with varying features in resource endowment and local communities, among others, therefore, an instrument which is effective in one project may not necessarily work well in another. However, from the perspective of policymakers, instruments that can easily be replicated are not only favourable but also effective.

4.2 Scores of instrument assessment

4.2.1 Summary of the assessment

After building up the weighted assessment framework (Table 3.4), respondents were asked to evaluate instruments' performance from each dimension – feasibility, sustainability, and replicability (Table 3.5). Table 3.5 also shows the final weighted score of instruments based on the scores and the weights of each dimension.

According to the final weighted assessment score, the instruments with the five highest scores are PPP, loan guarantee, FIT and/or feed in premium (FIP), start-up grant, and power purchase agreements (PPA). PPP, FIT and/or FIP, and PPA are usually adapted in the mini-grid systems where generators sell all or part of electricity to the mini-grid. While for small-scale off-grid systems, such as those used for individual houses or small villages only, PPP, FIT and/or FIP, and PPA may not be applicable. In those cases, start-up grants and loan guarantees are more helpful because they can smooth the establishment process by reducing upfront costs and support sustainability by reducing operation costs.

Further, other instruments that also get high assessment scores on their overall performance include local engagement, tax concession and exemption, end-user subsidy, and end-user financing. For potential investors, especially those in the private sector, high risks of OGRE projects arise from various perspectives, including it is beyond their traditional investment sectors, and local communities have limited income sources and affordability of electricity consumption. Therefore, engaging local communities and strengthening their capacity through subsidies and end-user financing could be effective in attracting more investment and sustaining the projects over a longer time.

Table 3.5: Scores of Each Instrument

Instruments	Weighted Average Score	Assessed Score of Each Dimension		
		Feasibility	Sustainability	Replicability
Public–private partnerships	**4.16**	**4.20**	**4.20**	**4.06**
Local engagement in operation and maintenance	**4.10**	4.04	**4.15**	**4.11**
Feed-in tariffs/premiums	**4.06**	**4.14**	**4.08**	3.89
Start-up grants	**4.02**	**4.31**	3.82	3.86
Power purchase agreements	**4.02**	3.97	**4.11**	**3.96**
Loan guarantees	3.97	4.08	3.83	**4.00**
Tax concessions and exemptions	3.94	4.00	3.85	**4.00**
End-user subsidies	3.93	**4.23**	3.73	3.73
Grants/subsidies to cover operation and maintenance costs	3.90	**4.11**	3.69	3.85
End-user financing/microfinance/consumer credit	3.90	3.97	3.90	3.76
Concessional finance	3.86	3.89	3.85	3.85
Revolving funds	3.84	3.82	**3.92**	3.76
Tiered electricity tariffs	3.83	3.80	3.90	3.76
Capital subsidies	3.79	3.97	3.62	3.75
Leasing	3.75	3.70	3.89	3.63
Accelerated depreciation	3.70	3.73	3.65	3.70
Import duty exemptions for equipment	3.57	3.58	3.48	3.70
Crowdfunding	3.38	3.32	3.39	3.45

Source: Compiled by the authors, data from the survey.

From the perspective of feasibility, the five most effective instruments are start-up grants, end-user subsidies, PPPs, feed-in tariffs, and grants and/or subsidies to cover operation and maintenance costs. These selected instruments are helpful in reducing the financing costs or expanding the financing channels to overcome the barrier of high upfront costs. Start-up grants are a direct method to lower the initial cost of the project developer, feed-in tariffs and loan guarantees try to strengthen the financing capacity from the supply side, while end-user subsidies strengthen it at the demand-side which in turn will support project developers when they are seeking investment sources.

In terms of sustainability, PPPs, local engagement in operation and maintenance, PPAs, feed-in tariffs, and revolving funds score the highest values. Building up local capacity in techniques, skills, and financing is one of the key solutions to sustain the OGRE projects in the long term. As OGRE projects are often located in remote rural areas, it is critically important to seek local solutions to achieve sustainability of a project. Experience has shown that giving out equipment to local communities for free is usually the least efficient method, especially without proper training on how to use the equipment. Comparatively, helping them obtain the ownership of off-grid energy systems and letting them bear the responsibilities for operating and maintaining those systems have proven to be useful lessons learnt from the successful cases. Revolving funds have been used in several successful cases. It is a mechanism that saves part of the collected electricity tariff into a 'community owned fund', and uses this fund to maintain, operate, and even expand the off-grid energy system in the future. Therefore, local communities are able to strengthen their financial capacity over a longer time. Revolving funds work more efficiently when they can be combined with the productive activity as they generate more sources for the fund.

Finally, instruments that have the highest potential to be replicated in many projects are local engagement in operation and maintenance, PPPs, tax concessions and exemptions, loan guarantees, and PPAs. For policymakers and OGRE project developers, it could be an efficient message as they can try to adapt these instruments in many projects. However, each case may need special techniques and formats to seek local communities' trust to build up the project and keep it variable in the long term.

4.2.2 Comparisons of results from different groups of experts

This survey covered different groups of respondents, including academia and industry, and the results show different opinions. Academia, industry, and NGOs are three biggest groups of respondents. The results from these three groups are compared and listed in Tables 3.6 and 3.7.

Table 3.6: Comparison of Assessment Weight from Academia and Industry and Nongovernment Organisations

Academia (No = 54)		Industry and Nongovernment Organisations (No = 11)	
Assessment dimension	Assessment weight, %	Assessment dimension	Assessment weight, %
Feasibility	40.15	Feasibility	35.56
Sustainability	35.59	Sustainability	36.11
Replicability	24.26	Replicability	23.89
Total	100.00	Total	100.00

Source: Compiled by the authors, data from the survey.

Both feasibility and sustainability are considered as the most important dimensions when assessing the instruments' performance in facilitating OGRE investment. However, practitioners evaluate sustainability slightly higher than feasibility, while academia considers feasibility more important than sustainability. Both groups give the dimension of replicability the same score, around 24% in the total assessment system.

Table 3.6: Comparison of Assessed Scores from Academia and Industry and Nongovernment Organisations (top 10)

Academia (No = 54)		Industry and Nongovernment Organisations (No = 11)	
Instruments	**Final Weighted Assessment Score**	**Instruments**	**Final Weighted Assessment Score**
Public–private partnerships	4.12	Local engagement in operation and maintenance	4.47
Feed-in tariffs/premiums	4.03	Public–private partnerships	4.41
Power purchase agreements	3.99	Loan guarantees	4.24
Start-up grants	3.98	Start-up grants	4.20
End-user subsidies	3.96	Grants/subsidies to cover operation and maintenance costs	4.17
Local engagement in operation and maintenance	3.95	Concessional finance	4.11
Loan guarantees	3.91	Tax concessions and exemptions	4.10
Tax concessions and exemptions	3.90	Feed-in tariffs/premiums	4.06
End-user financing/microfinance/consumer credit	3.88	End-user subsidies	3.96
Grants/subsidies to cover operation and maintenance costs	3.86	Power purchase agreements	3.85

Source: Compiled by the authors, data from the survey.

Among the top 10 most effective instruments from two groups, seven of them are the same, however, they have different rankings. Experts from industry and NGOs value start-up grants, local engagement, tax concessions and exemptions, and loan guarantees more than academia. Given their field experience, it has proven the effectiveness of these instruments in practice.

In addition, detailed assessment results (top five) in different dimensions are shown in Table 3.7. An unexpected result is that several instruments, which are designed to be used in the operation stage of OGRE projects and support the sustainability in the mid and long term, are chosen to be the most effective tools to establish projects. Our explanation is that project developers and investors look beyond the establishment stage of a project while they are actually at this stage, therefore, instruments that facilitate future investment can effectively support OGRE projects to be built up.

In order to explain the results of the survey clearly, each instrument is analysed individually in the previous sections. However, it is important to point out that various instruments need to be combined and utilised together in complex systems like OGRE projects. Diverse stakeholders are involved in OGRE projects, therefore, it is critical to balance the costs and benefits among them, so that they are willing to cooperate and collaborate with each other efficiently. That is also the reason why this study provides a framework of supporting instruments together with a weighted assessment framework. It is helpful for both policymakers and other stakeholders to understand OGRE projects and the relevant investment process comprehensively.

Table 3.7: Top Five Scored Instruments, by Dimension

Feasibility		Sustainability		Replicability	
Academia	**Industry and NGO**	**Academia**	**Industry and NGO**	**Academia**	**Industry and NGO**
Start-up grants	PPP	PPP	Local engagement in operation and maintenance	PPP	PPP
End-user subsidies	Local engagement in operation and maintenance	Feed-in tariffs/premiums	Loan guarantee	Local engagement in operation and maintenance	Local engagement in operation and maintenance
PPP	Start-up grants	PPA	PPP	Tax concessions and exemptions	Loan guarantees
Feed-in tariffs/premiums	Grants/subsidies to cover operation & maintenance costs	Local engagement in operation and maintenance	Concessional finance	Loan guarantee	Concessional finance
Grants/subsidies to cover operation and maintenance costs	Tax concessions and exemptions	Tiered electricity tariffs	Start-up grants	PPA	Start-up grants

NGO = nongovernment organisation; PPA = power purchase agreement; PPP = public–private sector partnership.

Source: Compiled by the authors based on survey.

5. Policy implications for ASEAN

5.1 The need for off-grid renewable energy in ASEAN

These challenges are particularly significant to ASEAN countries. Several ASEAN member states still have low electrification rates. As of 2012, 23% of the region's total population – about 140 million people – had no access to electricity. Cambodia and Myanmar are the two countries that have the lowest rural electrification ratio. Indonesia has the highest number of people without access to electricity. In Indonesia alone, 103 million people still rely on traditional biomass for cooking, while it is close to 50 million in Myanmar, the Philippines, and Viet Nam (Table 3.8).

Table 3.8: Access to Modern Energy Services in ASEAN, 2012

Country	Population* (million)		Electrification Rate (%)			Population Relying on Traditional Use of Biomass for Cooking	
	Total	Without electricity	National	Urban	Rural	Total (million)	Percentage (%)
Brunei Darussalam	0.4	0	100	100	99	0	0
Cambodia	14.7	10	34	97	18	13	89
Indonesia	245.4	60	76	92	59	105	42
Lao PDR	6.5	1	78	93	70	4	65
Malaysia	29.5	0	100	100	99	0	0
Myanmar	61.0	36	32	60	18	49	93
Philippines	97.6	29	70	89	52	47	49
Singapore	5.3	0	100	100	100	0	0
Thailand	67.9	1	99	100	99	16	24
Viet Nam	88.8	4	96	100	94	45	51
ASEAN	617.2	140	77	92	64	280	46

ASEAN = Association of Southeast Asian Nations; Lao PDR = Lao People's Democratic Republic.
Note: * mid-year population data.
Sources: ASEAN Secretariat (2014); IEA (2014).

Since many local communities are located far away from central electricity grids, off-grid renewable energy can bring immediate and cost-effective (lifetime cost) solutions for rural electrification. Several ASEAN countries have counted on off-grid renewable energy, especially micro- hydro power projects, to substitute fossil fuel for power generation and to electrify the remote rural areas. In 2013, the ASEAN Centre for Energy (ACE) issued the 'ASEAN Guideline on Off-grid Rural Electrification Approaches', which gives concrete recommendations for the development and implementation of effective, efficient, and sustainable rural electrification approaches with renewable resources (ACE, 2013).

The ASEAN member states have used both fiscal and non-fiscal policy instruments to develop OGRE. Fiscal instruments include income tax holidays, equipment duty exemptions, and property tax exemptions, which have been adopted by the governments of Malaysia, the Philippines, Singapore, and Thailand. Non-fiscal instruments include easy repatriation of capital investments, remittance of earnings, subsidies to generators, and so on (ACE, 2013). Both direct and indirect subsidies are applied in ASEAN mini-grid electrification. Direct subsidies are in the form of capital subsidies targeting the initial investment; and non-fiscal instruments such as one-time subsidies granted according to the number of connections, topping-up kilowatt hour (kWh) premiums to the project investors, and subsidies supporting the operational costs of the power system. Indirect subsidies include technical assistance and some fiscal instruments such as VAT exemptions, import duty exemptions and income tax holidays, and so on (ACE, 2013).

Public-private partnerships were introduced to overcome capacity limit. In Lao PDR, since the government did not have the capacity to support the installation and implementation of off-grid electrification, the equipment was released to the households for a monthly fee (consumer loan) through provincial electrification service companies (PESCOs).[8] A village off-grid promotion scheme (VOPS) was established to manage the PESCOs, who worked with the village electricity managers (VEMs) to manage the off-grid systems. The monthly lease income was used to pay the PESCOs and the VEMs, among others. The remainder was put into a fund to further promote the development of off-grid systems. Finally, 80% of households had adopted the mini-grid systems in villages where it was available.

Engagement of the local community was institutionalised in Viet Nam. Viet Nam has developed a collaboration-based approach to electrify remote rural areas. The task of planning and promoting mini-grid rural electrification is assigned to local governments, which are requested to support the project developers to conduct site surveys and prepare proposals for target communities. Provincial governments are entitled to approve the proposals unless a grant and/or national budget support are needed, in which case the proposals will be passed to the central government for appraisal and approval (ACE, 2012).

In addition to those common challenges presented before, ASEAN countries still face many specific challenges. First, most ASEAN countries only have general policies and plans regarding off-grid electrification instead of specific policy frameworks (ACE, 2013). Second, existing technologies may also be insufficient to settle problems due to

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[8] PESCOs are local private companies and key implementers who are responsible for the off-grid systems.

ASEAN's geological and/or weather features. For instance, mountainous terrain can result in higher costs for infrastructure; and seasonal resource fluctuations – wind speed and river flows – may bring more technological challenges. Third, there is a lack of local expertise to guarantee long-term sustainability of these projects in remote rural areas in ASEAN countries. Fourth, several ASEAN countries are still economically less developed and have limited budgets.

However, the efforts of governments are not enough to electrify the rural areas. In the Philippines case, only modest investments were attracted from the private sector (Pacudan, 2005). Policies specifically designed for OGRE projects are needed. Even though OGRE projects could be more economically reasonable and attractive than centralised grid extension to remote areas, they usually have high upfront costs (compared with the limited financial resources in less developed countries, in particular their rural communities). Building sustainable financing mechanisms can be challenging. More effective and flexible financial tools need to be in place to address the challenges to build sustainable financing mechanisms.

5.2 Implications for ASEAN policies

ASEAN could use those top scoring instruments despite the limit of public finances in those countries that need electrification. PPP, if applied in the case of mini-grid projects, can offset the weakness of public finance while increasing efficiency. Although those ASEAN countries that need electrification often have weak fiscal capacity, the utilisation of tax concessions and exemptions will not comprise current tax revenues because without the projects, there would be no such revenue. Similarly, loan guarantees that are effective in promoting OGRE finance cost governments nothing.

In the process of PPP, clear prioritisation between social and commercial objectives of OGRE projects should be provided. While governments can fulfil social objectives of rural electrification through commercially viable entities aided by various support instruments, the conflict of interests within the entity could comprise the government's intention. However, as the case of Lao PDR, the entity could separate its social functions, or at least unbundle to various costs centres to minimise the conflicts (Bambawale et al., 2011).

Other effective policies, such as end-user subsidies, end-user financing and/or/ microfinance and/or/ consumer credits, grants, and subsidies, all need the use of public finance. Their application will depend on each country's specific conditions and may be limited due to limited public financial resources. However, the ASEAN countries could collaborate and cooperate with outside players, including international development financial agencies, donor agencies, NGOs, and technical experts, in order to expand access to finance and improve project management.

In addition to those supporting instruments, some other relative policies are also noteworthy. Governments should carefully protect the legal interests of the private sector that have contributed to the sustainable and replicable development of OGRE projects. For example, there needs to be an awareness of the shortcomings of the principle of affordable and accessible financing in OGRE project development. (Bambawale et al., 2011). In the case of off-grid electrification in Lao PDR undertaken in the form of solar home systems (SHS) (Rural Electrification Project Phase I), as the tariff was fixed and the PESCOs were not able to freely set the lease terms of SHS, their operation was limited. The percentage of the tariffs retained by some PESCOs was not enough to sustain their operations. While subsidies can facilitate electrification, the negative impact on the private sector that contributes to the electrification should be carefully managed. For example, Sunlabob, a private company that rents solar systems to rural households, was made uncompetitive by the Rural Electrification Project, which rents out systems at less than half of the Sunlabob's rentals. An unclear grid extension plan would add significant uncertainties and risks to OGRE projects and deter investment. The Mae Kum Pong 1 and 2 Projects in Chiangmai Province in largely used the free electricity from the state grid. Fortunately, there is no dispute from the private sector in this case, as the small hydro project is also owned by the state utility company. Grid extensions should be predictable, and if unexpected changes happen, the private investors should be properly compensated.

Information technology tools for remote fee collection and for metering, monitoring, and regulating consumption such as smart metres, prepaid systems, and mobile commerce, could be integrated into business models to address the high operational costs that are often incurred during metering and fee collection activities (IRENA, 2012b). In recent years, micro-grid developers in India are turning to advanced pre-paid metres to solve problems of customer over-use and poor tariff collection, this method can also improve the sustainability of the micro-grid system (Buevich et al., 2014). An acceptable and robust fee collecting system is crucial for the long-term sustainability of the projects.

Local community engagement in operation and maintenance is another support that ASEAN governments can introduce due to low, if not zero, cost characteristics. Local communities often make decisions by consensus within themselves, some of them may try to block development plans, because they cannot foresee the benefits of electricity access, as mentioned above. Even though they are supportive, they may not have the technical resources to sustain the projects, while it is cost prohibitive to outsource maintenance. Local communities could get involved not only in low-level functional roles, such as technical operating and monitoring activities, but also in the high-level decision-making processes before and during the operation of OGRE projects. It is critical that the local communities' actual and potential needs must be understood before a project starts, as they play a crucial role in supporting construction, operation, and maintenance of projects. For instance, Lao PDR has introduced community selection criteria to select suitable villages for mini-grid rural electrification. It is requested that at the initial stage, the project developer should visit the village and explain the technical features, the applications, and the payment schemes to the villagers before potential customers are listed. If the potential customers that are able to pay for the project are less than 50% of total households, then the village will be regarded as unsuitable for mini-grid electrification (REMP, 2010).

Capacity building, training, and setting-up of local service networks are fundamental conditions to guarantee long-term success and sustainable development of OGRE projects. Capacity building should be carried out to cover all the stakeholders:

public institutions, financing agencies, communities, and the private sector, among others (IRENA, 2012b). It should be kept in mind that as cultural and socioeconomic conditions vary among different local communities, it is important to ensure that any RE off-grid expansion does not destroy the cultural and socioeconomic circumstances.

6. Conclusion

OGRE projects play a critical role in giving people access to electricity. However, the challenges are enormous. Financing such OGRE projects is one of the most significant challenges due to barriers such as lack of access to finance, low affordability by consumers, and high transactions costs. However, the benefits of access to electricity are beyond financial calculation, including human development, improvement of life quality, generation of additional productive activities, access to information, and education.

Mindset has to be shifted away from grant-based approaches to more sustainable frameworks. For this purpose, various supporting instruments have been implemented to facilitating OGRE investment. Those supporting instruments, however, may have different impacts on the projects when assessed from different perspectives. For individual countries, which instruments should be adopted is still a challenging question for policymakers. Quantifying the effectiveness of those policy instruments could improve policy decisions in the future since policymakers will have information on each instrument and thus could select those that best meet their needs to make OGRE development successful.

This study assesses the effectiveness of those instruments from various perspectives and provides references for further policymaking. This chapter proposed a three dimensional framework to assess the effectiveness of supporting instruments. Those three dimensions are feasibility, sustainability, and replicability. Each of these three dimensions reflect some particular aspect of a project. The supporting instruments that have been recorded in the literature are tabulated for assessment.

The weights of each dimension and the scores for each instrument were quantified by experts. All the tabulated instruments are assessed to be at least modestly effective. The top seven scored instruments have little difference in their effective level. As expected, the rank of effectiveness among the overall weighted score and the dimensional scores are different, but the level of difference is not significant.

Although we have aggregated a single score from the three dimensional score, this, does not mean that the overall score is superior to the dimensional score. As policymakers often have different priorities, their preferences could be different and thus their choice of instruments would be decided case by case.

Based on a study of the literature and findings of the survey, policy implications for ASEAN policymakers were drawn. ASEAN should set priorities among various goals including social development and commercial development, balance affordable and accessible energy, engage local communities, and conduct capacity building during the process of OGRE development. It should also be kept in mind that OGRE development is often dealing with poor people from remote and rural areas. Therefore, it is critically important to identify efficient and effective support instruments. In this research, we find that the instruments with the five highest scores include PPPs, loan guarantees, FITs and/or FIPs, start-up grants, and PPAs. While for small-scale off-grid systems, such as those used for individual houses or small villages only, PPPs, FITs and/or FIPs, and PPAs may not be applicable. Start-up grants and loan guarantees are more helpful because they can smooth the establishment process by reducing upfront costs and support sustainability by reducing operational costs.

While the focus on the current study is on supporting instruments, it, however, does not undermine the role of other factors in promoting successful OGRE projects. Policy and regulatory barriers could hamper off-grid development. Corruption, political lobbying by more powerful energy companies, or even a lack of understanding on off-grid systems among policymakers could damage off-grid development. Low salaries will lead to high turnover of technical operators, and the quality of the operation will be reduced to a lower level that cannot meet the requirements of the operating needs. It is also very important that the process of OGRE development not be left to one or two parties alone, such as the government or energy companies. It should involve all the players, including governments, companies, public institutions, local communities, and NGOs. All the players shall cooperate to address barriers to OGRE project development. Only by this, can local economies be strengthened and communities be empowered along with OGRE project development.

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Appendix: Description summary of survey results

Table A1: Classification of Affiliations

Answer Options	Response (%)	Response (Count)
Private company (renewable energy related)	7.0	5
Government institution	4.2	3
International organisation (including Asian Development Bank)	2.8	2
Social enterprise	2.8	2
Nongovernment organisation	7.0	5
Academia/research institution	76.1	54
Answered question		71

Table A2: Basic Statistics of Scores of Instrument Assessment – Feasibility Dimension

Instruments	Minimum	Maximum	Median	Mean	Standard Deviation
Start-up grants	1	4	2	1.69	0.7
Capital subsidies	1	4	2	2.03	0.8
Import duty exemptions for equipment	1	4	2	2.42	0.85
Crowdfunding	1	5	3	2.68	0.95
Feed-in tariffs/premiums	1	5	2	1.86	0.79
Power purchase agreements	1	5	2	2.03	0.98
Grants/subsidies to cover operation and maintenance costs	1	5	2	1.89	0.94
Subsidies to cover operation and maintenance costs	2	3	2	2.2	0.4
Accelerated depreciation	1	4	2	2.27	0.73
Tax concessions and exemptions	1	4	2	2	0.8
Local engagement in operation and maintenance	1	4	2	1.96	0.74

Public–private partnerships	1	3	2	1.8	0.7
Loan guarantees	1	4	2	1.92	0.73
Concessional finance	1	4	2	2.11	0.8
End-user subsidies	1	4	2	1.77	0.79
End-user financing/microfinance/consumer credit	1	4	2	2.03	0.71
Leasing	1	4	2	2.3	0.7
Revolving funds	1	4	2	2.18	0.68
Tiered electricity tariffs	1	5	2	2.2	0.9

Note: The scores of ‘feasibility’ dimensions are taken as an example to show the variation of assessment, given the space constraints, other data could be provided upon request.
Source: Compiled by the authors based on survey.

Chapter 4

Business Models and Financing Options for a Rapid Scale-up of Rooftop Solar Power Systems in Thailand[9]

Sopitsuda Tongsopit[10], Sunee Moungchareon, Apinya Aksornkij, Tanai Potisat

Abstract

Business models and financing options play a large role in driving the expansion of rooftop solar markets. In Thailand, even though there is currently a pause in feed-in tariff support for rooftop solar systems, the market is moving forward with new business models and financing options for solar roofs. After reviewing United States-based business models and financing options, this study documents and analyses four emerging business models and one emerging financing option for customers to invest in rooftop solar systems in Thailand. The business models include roof rental, solar power purchase agreements (PPA), solar leasing, and community solar. The financing option includes two types of solar loans. We analyse the business models in terms of their components and structure, drivers for their emergence, and associated risks. In relation to the buying option, we further demonstrate the financial viability of two models – commercial solar PPA and residential solar leasing. When compared to the buying option, the commercial solar PPA model shows more attractive financial results based on the levelised cost of electricity (LCOE), net present value (NPV), internal rate of return (IRR), and payback period. By contrast, the residential solar leasing model is currently unattractive under the leasing conditions currently being discussed in the market. A number of policy recommendations are proposed in order to build an enabling environment for rooftop solar businesses to thrive. Among them include the implementation of net metering and support for residential-scale solar systems, such as in the form of tax incentives.

Keywords: Rooftop solar power, business model, financing, Thailand

[9] The authors would like to express our sincere gratitude to the key informants for our research, including business executives and government officials listed in Appendix A, for providing useful input and comments that helped with our analysis.

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1. Introduction

Thailand leads Southeast Asia in solar power development, not only in terms of capacity growth but also the availability of a capable workforce in the solar power sector. As of December 2014, grid-connected solar power capacity reached 1,354 megawatts (MW). Around 99% of this capacity comes from utility-scale installations whose sizes are greater than 1 MW.

For this reason, business models for solar power prior to 2014 were based on joint ventures for utility-scale solar power plants (solar farms) and the buying model for rooftop solar systems. Financial institutions previously offered no dedicated programmes for rooftop solar since their past experiences have been based mainly on project finance for solar farms. The lack of a stable policy and the relatively high cost of solar power further added to this lack of dynamism in the rooftop solar sector in the past.

Since 2013, however, a new feed-in tariff (FIT) framework along with low prices of solar systems and rising costs of grid electricity have made it possible for businesses to devise new, diverse models, including those that have succeeded in other countries' contexts. Our research is conducted at a time when a new ecosystem for the rooftop solar market is emerging in which existing businesses and new entrepreneurs are forming new partnerships and generating value creation. It is not yet clear which business models will succeed in expanding the rooftop solar market in Thailand, especially in light of current policy uncertainties. Therefore, this research helps build the academic foundation by identifying diverse and emerging business models in the Thai rooftop solar market between 2013 and 2015 and describing the conditions that enable their emergence. We review international rooftop solar business models and financial options that originated mainly from the United States and then surveyed emerging business models and financing options in Thailand. From the list of emerging business models, we then quantitatively analyse two selected models, which have the potential to rapidly scale-up the rooftop solar photovoltaic (PV) expansion. We conduct financial analysis of the two business models, solar leasing (solar leasing model) and solar power purchase agreement model (solar PPA model), and offer recommendations on policy and regulatory changes that will create a friendly environment for new business models to succeed.

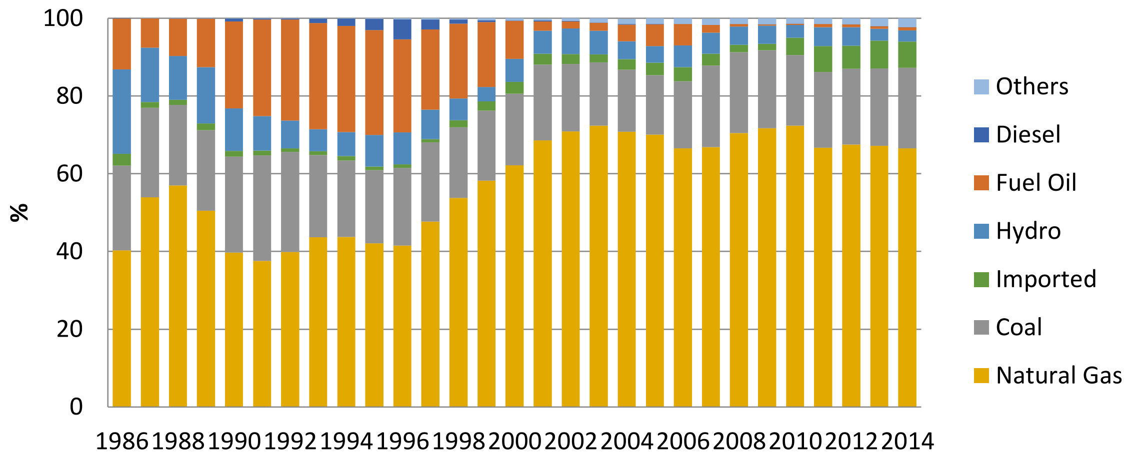
This report is structured as follows. After the introduction of Thailand's solar power policy and status described in Section 2, Section 3 discusses insights from a literature review on solar business models. Section 4 discusses the methodologies for our interviews and for financial modelling. Research results are discussed in Section 5, followed by policy recommendations in Section 6.

2. Thailand's solar power status and solar policy

2.1. The status of electric power in Thailand

Over the past 2 decades, Thailand has been increasingly dependent on natural gas for power generation. The Thai power sector currently uses natural gas for approximately 70% of its power generation (Figure 4.1).

Figure 4.1: Fuel Share in Thailand's Power Production, 2000–2014



Source: EPPO (2015).

Thailand has therefore set ambitious plans to develop its local renewable energy sources, as evidenced in the increasing targets for all types of renewable energy.

2.2. Policy and regulation to support solar power

2.1.1 Previous support scheme

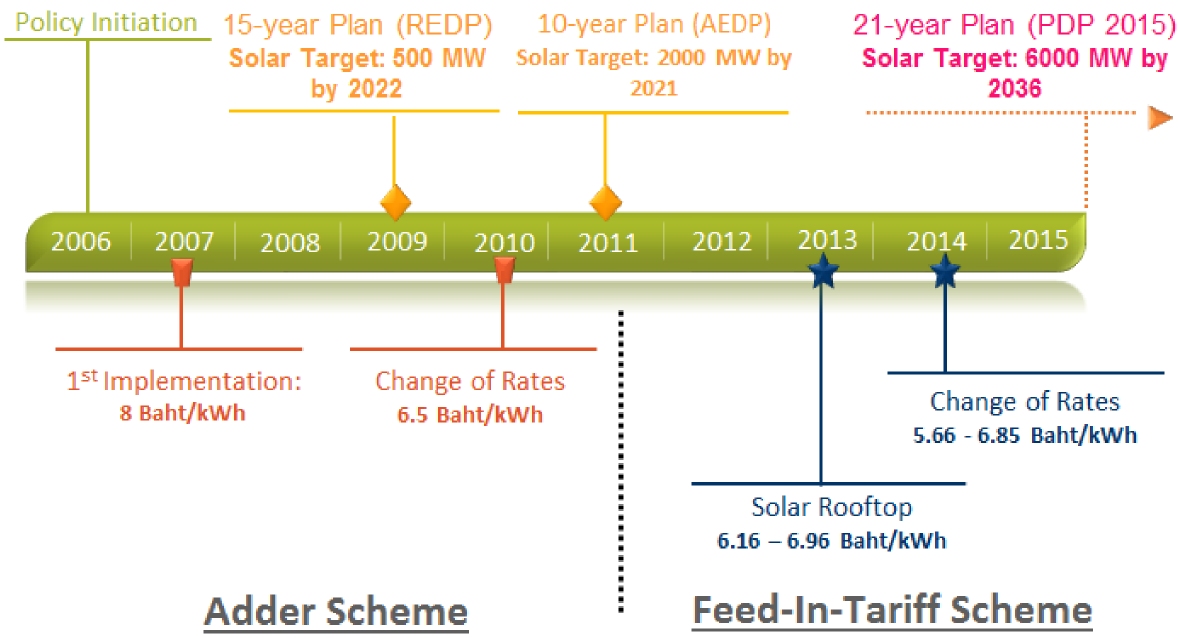
The first policy to support solar energy, along with other types of renewable energy (RE), in Thailand was initiated in 2006. Since then Thailand has combined a number of support measures, as shown in Figure 4.2, resulting in substantial growth in the installation of solar power systems.

The first scheme to support the growth of solar was called the 'adder scheme,' which was implemented in 2007. The adder scheme gives incentives to power producers selling electricity produced by RE at a certain tariff for a specified period of time (Tongsopit and Greacen, 2013). For every kilowatt hour (kWh) of electricity produced, the power producer will receive an adder rate on top of the utility electricity price; this is also termed as premium-price feed-in tariff (FIT) (Cory et al., 2009).

In 2007, power producers using solar energy received a power purchase agreement (PPA) from Thailand's electric utilities at an adder rate of B8 per kWh with a contract term of 10 years. Two years after the implementation, Thailand announced its first 15-Year Renewable Energy Development Plan (REDP 2008–2022). The target for solar energy was 500 MW of installed capacity to be achieved by 2022 (NEPC, 2009). Shortly after the announcement of the REDP, in 2009, there were a large number of requests from investors for PPAs in solar energy. In conjunction with falling market prices of solar PV systems, the situation led to a dramatic change of rates and regulations in 2010. The rates were reduced to B6.5 per kWh and strict regulations were implemented. By 2011, a large number of PPAs were given to investors leading to the capacity in the pipeline that far exceeded the 500 MW target in the REDP. Therefore, the REDP was replaced by the Alternative Energy Development Plan (AEDP 2012–2021) (NEPC, 2011). The AEDP aimed to increase the share of RE to 25% of the final consumption with a target of 2,000 MW for solar energy's installed capacity by 2021 (DEDE, 2012). This target was recently updated to 6,000 MW to be achieved by 2036.

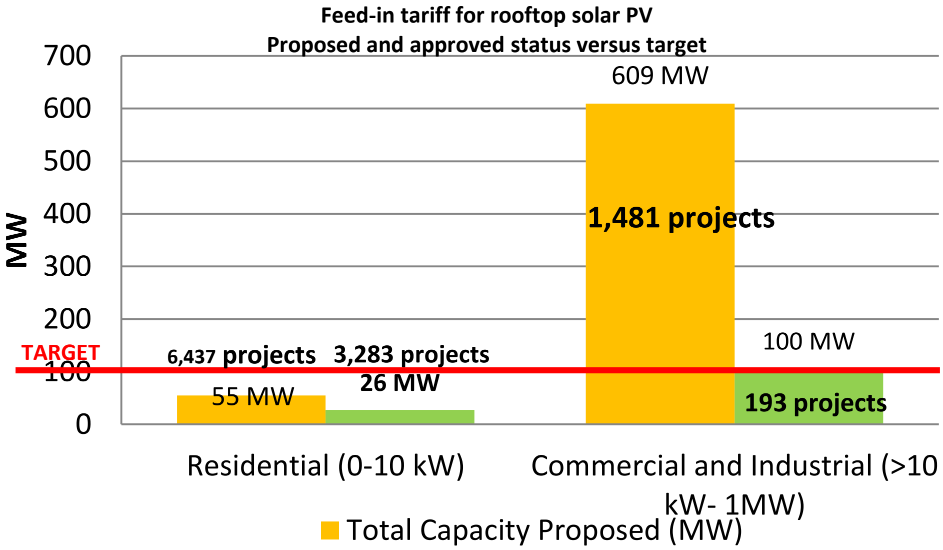
Due to concerns on the impacts to ratepayers, the adder scheme was discontinued in 2012 and replaced by the FIT scheme. The FIT scheme changed the structure of the incentives from a 'premium FIT' to a 'fixed-price FIT'. The FIT scheme was used to specifically support rooftop solar installations with a quota of 200 MW of PPA available. Within the 200 MW quota, 100 MW were allocated to residential roofs (≤10 (kilowatt peak [kWp]) and the remaining 100 MW were allocated for commercial roofs (10 kWp – 1 megawatt peak [MWp]).

Figure 4.2: Timeline of Thailand's Solar Power Policy



AEDP = Alternative Energy Development Plan; kWh = kilowatt hour; REDP = Renewable Energy Development Plan; PDP = Power Development Plan.
Source: Authors' analysis.

Figure 4.3: Number of Projects Applied for the Feed-in Tariff Scheme in 2013 (data as of May 2014)



kW = kilowatt; MW = megawatt, PV = photovoltaic.
Source: Analysed from MEA (2014) and PEA (2014).

Figure 4.3 shows the number of projects and its proposed installation capacity that applied for the FIT scheme in 2013. For commercial roofs there were 1,481 project proposals for a total of 609 MW, out of them only 100 MW of PPA were given to 193 projects. While residential rooftops received no more than 30 MW of PPA approval; this did not reach 50% of the intended 100 MW quota.

2.1.2 Future support scheme

After the military coup in May 2014, the policy and regulatory landscape for solar power in Thailand changed with the priorities set by political incumbents. In January 2015, the National Reform Council approved a quick win project entitled 'A Project to Support a Free Market for Solar Roof'. The main idea of the proposal was to eliminate quotas on solar rooftops and establish a new support scheme, net metering. With net metering, the electricity will have to first be self-consumed by the building, then excess electricity will be exported to the grid at a certain tariff or credited to the next bill. In addition to net metering, the proposal also includes other support measures such as import duty and income tax incentives. The approved proposal focuses only on rooftop solar for households (<10 kWp systems) and commercial buildings (<500 kWp systems). As an initial step, the Department of Alternative Energy Development and Efficiency, the distribution utilities, and the Energy Regulatory Commission (ERC) are charged by the Energy Policy Administration Committee to define a pilot area for first installations.

2.1.3 Other support incentives

Thailand's Board of Investment (BOI) also supports investment in the utilisation of solar energy. The BOI serves as the main government agency for encouraging investment in various sectors. In 2009, investment in the renewable energy sector was included for investment promotion. BOI investment promotion offers different types of tax incentives that will help promote activities in that sector. There are two investment promotion incentives that can be captured by using solar energy.

1) Production of electricity from solar energy

Activity 7.1.1.2: Production of electricity or electricity and steam from renewable energy, such as solar energy, wind energy, biomass or biogas, except from garbage or refuse derived fuel. Under the list of qualified businesses, 'Section 7: Service and Public Utilities' of the ‘Announcement of the Board of Investment No. 2 /2557 Policies and Criteria for Investment Promotion’:

The incentives include (BOI, 2014a):

- 8-year corporate income tax exemption, accounting for 100% of investment (excluding cost of land and working capital)
- Exemption of import duty on machinery
- Exemption of import duty on raw or essential materials used in manufacturing export products for 1 year, which can be extended as deemed it appropriate by the Board
- Other non-tax incentives

2) Utilisation of solar energy to improve production efficiency

Under the ‘Announcement of the Board of Investment No. 1/2557 Measure to Promote Improvement of Production Efficiency’, announced in September 2014. For existing projects that are eligible for investment promotion by the BOI, which utilise solar energy as an alternative to conventional sources, the incentives include (BOI, 2014b):

- Exemption of import duty for machinery regardless of zone
- Three-year corporate income tax exemption on the revenue of an existing project, accounting for 50% of the investment cost under this measure, excluding the cost of land and working capital.

The BOI incentive that grants 8-year corporate income tax exemption has produced a strong impact on solar farms since 2009. As of 31 December 2014, there are 364 projects with a total installed capacity of 1,383 MW approved by the BOI; 51 projects (121 MW) in this group are commercially operating. However, for solar rooftops this incentive is of smaller impact, as the BOI investment promotion can only be applied and granted to corporations. Rooftop solar projects can potentially benefit from the BOI’s September 2015 announcement, but the eligible parties have to be corporations with an investment cost in the rooftop solar system greater than B1 million ($28,571) or small and medium enterprises with an investment cost greater than B500,000 ($14,286).

3. Literature review

3.1 Definitions of business model

Since the mid-1990s, the concept of the business model has gained increasing interest among business practitioners and academics (Zott et al., 2010; Huijben and Verbong, 2013). Business models serve many functions, including bringing new technologies such as renewables to the market (Huijben and Verbong, 2013) and serving as management tools to design, implement, operate, change, and control their business (Johnson, 2010; Wirtz et al., 2010, cited in Richter, 2013). Innovative business models help spread solar technology swiftly by reducing or removing adoption barriers, for example, for new demographics to adopt PV (Drury et al., 2012).

There is no common definition of the 'business model' concept (Burkhart et al., 2011; Klang et al., 2010). However, numerous writings on solar business models are coalescing around the definition of business models by Osterwalder and Pigneur (2009) (for example, Richter, 2013; Huijben, 2013; IIED, 2013; GVEP International, 2013). The business model conceptualisation by Osterwalder and Pigneur (2009) is defined as follows:

- Value proposition: refers to the bundle of products and services that creates value for the customer and allows the company to earn revenue;
- Customer interface: comprises the overall interaction with the customer. It consists of customer relationship, customer segments, and distribution channels;
- Infrastructure: describes the architecture of the company's value creation process. It includes assets, know-how, and partnerships; and
- Revenue model: represents the relationship between costs to produce the value proposition and the revenues that are generated by offering the value proposition to customers.

3.2 Business model canvas

The business model canvas concept, developed by Osterwalder and Pigneur (2009), has been widely used by many authors in energy-related business model literature. The need for a canvas-like framework arose because it is 'simple, high level and easy to construct' for people with little prior business knowledge (Leschke, 2013). It has been successfully applied in many energy related fields such as renewable energy (Okkonen and

Suhonen, 2010) and energy efficiency (Paiho et al., 2015). The Business Model Canvas Framework defines a business model in terms of the nine 'building blocks' as listed in Table 4.1.

Table 4.1: The Nine Business Model Building Blocks

Business Model Canvas Building Blocks	Description
Value Propositions	the goods and services offered and their distinguishing advantage
Key Activities	the most important activities in executing the value proposition
Key Resources	the resources necessary to create value for the customer
Partner Network	relationships considered essential to accomplishing the value proposition
Customer Segments	the specific target market(s) intended to be served
Channels	the proposed channels of distribution
Customer Relationship	the type of relationship the firm wants with its customers
Cost Structure	characteristics of the cost and expense structure
Revenue Streams	the way the firm will make money, how it is paid, and pricing

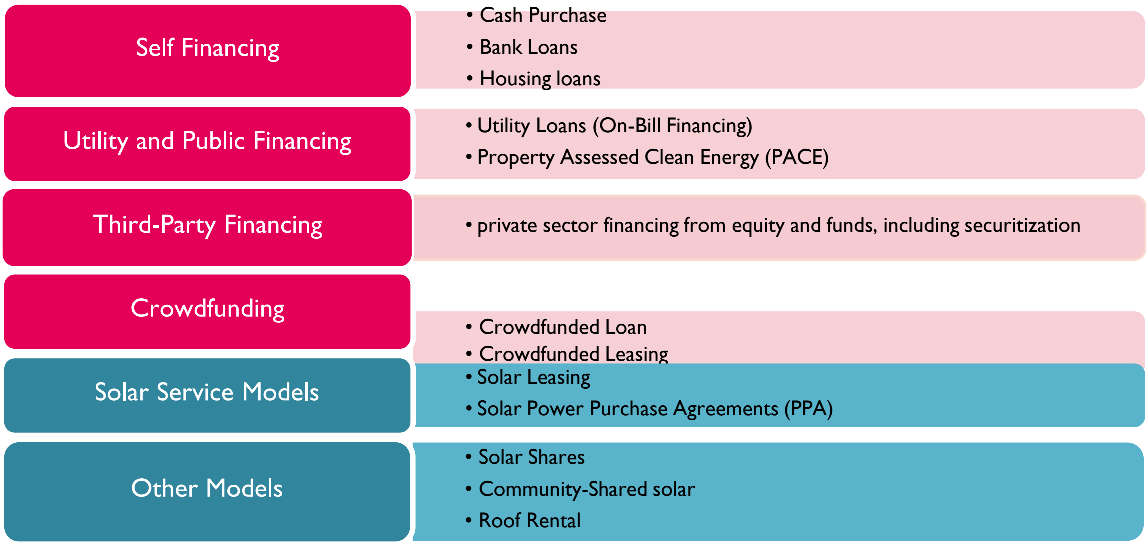
Source: Osterwalder (2010) cited in Leschke (2013).

This study uses the business model canvas to decompose the elements of the emerging rooftop solar PV business in Thailand and design the interview questions.

3.3 PV business models and financing options that exist internationally

A review of financing options for the solar rooftop market can be categorised into four types based on their sources of finance and two types based on the structuring of the business models (Figure 4.4). They include the conventional financing option of self-financing, localised municipal financing, utility financing, a more complex structure such as third-party financing, or a new and innovative financing mechanism called crowd-funding. The structure of business models includes solar service models and others. The section below summarises the concepts of these business models and financing options.

Figure 4.4: Categorisation of Financing Options and Business Models for Rooftop Solar Power Development



Note: Pink indicates the types of financing; blue indicates business models.

Source: Authors' analysis.

3.4 Financing options

Self financing

Self financing is used all over the world as the conventional way of financing, where the purchaser acquires an asset with their own money. Homeowners or building owners takes full liability of the cost in installing and maintaining the solar PV systems, resulting in high upfront costs that have prohibited widespread adoption of PV rooftop installations, especially in developing countries.

Utility and public financing

Local governments and municipalities have played a key role in accelerating the adoption of distributed solar power. Several municipalities have initiated programmes to increase the affordability of rooftop solar projects through the provision of financial incentives such as low-interest loans, rebates, and subsidies. In order to make such programmes possible, municipalities may need to initially raise capital through the issuing of bonds or find matching funds. The low-cost capital is then passed on either directly to the customer or to a developer to install systems on the customer's roofs. An example of a successful municipal financing is the Property-Assessed Clean Energy Program in the United States (US). However, these options are subject to the policies initiated by the local government. In addition to local governments, power utilities have begun to offer their customers the options of owning solar power systems. In this model, utilities would find a source of finance on behalf of its customers. The finance will be used either to install a large-scale solar farm in which customers can have a share or to lend directly to customers. This source of financing has several advantages including low-cost capital access by the utility, lower transaction costs of billing since the payments can be included in monthly customers' bills (on-bill financing), and guaranteed grid integration since utilities are able to assess good grid integration locations for solar. This financial scheme is offered in the US by Southern California Edison, San Diego Gas & Electric, SoCalGas, and Hawaiian Electric Co.

Third-party financing

The third-party financing or third-party ownership model has been responsible for the rapid scale-up of the residential solar market in the US since 2008. Third-party financing includes solar leasing and solar PPA (SEIA, 2015). According to Litvak (2014), third-party ownership represents 66% of the US residential solar market and a considerable portion of the commercial market (Litvak, 2014).

The solar leasing model in the US is financed by private or equity funds. Existing tax incentives in the US incentivised this type of financing by allowing the transfer of tax benefits from a portfolio of projects to the investors. Large players such as Google, CitiBank, and the Bank of America are financing rooftop solar through solar leasing and solar PPA companies.

While solar leasing may be considered a form of financing, it can also be considered a business model. In the US context, solar leasing offers financing for customers to own or have access to solar systems requiring monthly instalments and no upfront cost. However, it can be considered a business model at the same time since it is structured to provide value to customers through a combination of access to financing, operations and maintenance (O&M) service, and performance guarantee.

Solar crowdfunding

Solar crowdfunding is a new financing mechanism in which investment funds in solar systems are raised from individual investors through the internet. The companies that run solar crowdfunding platforms pool small investments from many individual investors, and the individual investors receive interests and are paid back in full over a specified number of years. The invested solar projects are commercial-scale rooftop systems on the properties of the customers, who pay for the electricity through solar PPAs or solar leases.

3.5 Business models

Solar service models

In solar service models, solar power is offered as a service, where the system is owned by a third party. Customers receive value from the service, in the form of cheaper electricity (compared to electricity purchased from power utilities), guaranteed performance, and O&M service. Solar service models have been a major driving force for rooftop solar market expansion in the US. In this model, a commercial company owns and operates PV systems on the customer's property. The electricity generated from the PV system is either used by the customer (solar leasing model) or sold to the customer (solar PPA model) (Bolinger, 2009). The structuring of the third-party financing model in the US also enables developers or investors to reap the benefits of tax incentives.

Other Models

There are various other business models offered by both the private and public enterprises. A programme offered by the Sacramento Municipal Utility District is called SolarShares, where customers can pay a monthly fixed fee to have shares in a local solar farm in exchange for a credit that can be used to offset their electrical bill (Coughlin and Cory, 2009). Private companies have also started offering similar business model, under the name community-shared solar. Roof rental is also a popular model in countries with FIT incentives. The developer company rents a roof to install and operate a solar system and sells the electricity for the FIT. The roof owner will receive benefits either through profit sharing or roof rental payments.

3.6 Solar business models in the literature

Much of the literature on solar business models in industrialised countries has drawn attention to the 'solar service' models. Overholm (2015) defines a solar service firm as 'a business model whereby firm builds, owns, and maintains solar panels on the premises of end-customers, only selling the electricity to the customer.' Solar service firms are believed to have originated in the US around 2005 (Drury et al., 2012) and has since grown to serve new geographical locations across the U.S. (Cather, 2010). Another term used to represent the solar service model is 'third-party financing' (NREL 2010). Two examples of the solar service models include solar leasing and solar PPAs.

Solar service models or third-party financing account for over 70% of all residential installations, in three major US solar markets: California, Arizona, and Colorado (GTM Research, 2014). Due to the fact that net electricity prices supplied from cash purchase system are considerably higher at $0.37/kWh when compared to $0.23/kWh supplied by the leasing option, the option to buy will only be more competitive to leasing when the homeowner can access tax breaks from depreciating capital equipment (Liu et al., 2014). Studies show that in California third-party ownership is more highly correlated to the lower-income household, and customer owned PV systems are positively correlated to the higher household income segment (Drury et al., 2012). In contrary, another study conducted in Texas found that buyers and lessees of PV systems do not differ significantly along socio-demographic variables (Rai and Sigrin, 2013). Within the same socio-demographic groups, those with tighter cash flow situations opt for leasing if the option is available. Therefore, Rai and Sigrin findings suggest that solar leasing helps accelerate solar PV adoption by opening up the cash-strapped but information-aware segment of the population.

Solar leases offered in the US typically require zero-down payment, have a long lease term (typically 20 years), and provide the option to buy at the end of the contract[11] (Coughlin and Cory, 2009). Overholm (2015) described how solar service ventures created value for their customer in several ways: removing customers' upfront cost, selecting, installing, and securing permits for the technology, and taking full responsibility for the long-term operation and maintenance of the solar system.

In addition to solar leasing and solar PPAs, other models are emerging in the US, including community solar. A community-owned solar system is defined by Asmus (2008)

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[11] Examples of solar leasing terms can be found from the leasing packages offered by US based SolarCity, SunRun, Sungevity, SunPower, and Real Goods Solar.

as a business model with ‘the ability of multiple users – often lacking the proper on-site solar resources or fiscal capacity or building ownership rights – to purchase a portion of their electricity from a solar facility located off-site’ (Asmus, 2008; p.63). It leverages the volume purchasing by collective participation of locals and internalises the market segments, like tenants or vacant community space, which used to be excluded from the commercialised activities (Huijben and Verbong, 2013).

In developing countries’ context, the majority of research on solar business models and financing options has been focused on off-grid applications for the low-income market. Literature focuses on the design elements of off-grid models, such as the requirement of down payment and after-sales service. Friebe et al., (2013), conducted quantitative research of solar home system (SHS) markets in Africa and Asia and found that entrepreneurs prefer 30% down payment instead of no down payment at all for credit sales and service models (leasing and fee-for-service). A 30% down payment or 100% cash payments are evaluated to be equally reasonable for businesses. Business owners highlighted that down payments are necessary to show the end user’s commitment to the solar systems. Results also reveal that businesses prefer to provide only 1 year of maintenance service (Friebe et al., 2013) contrary to longer offers in the US of 20 years. However, for the rural population in developing countries, Pode (2013) concluded that fee-for-service models are popular in sub-Saharan Africa due to unaffordable finance and the requirements for collateral. The study further suggested that rural customers are different to urban customers, those businesses with strong after sales service would be more successful than the sale and forget method (Pode, 2013).

All of the reviewed business models above remain relatively new in developing countries’ urban context, and hence we found no published papers on this topic. Our research finds that different models of solar services are being studied and experimented upon in Thailand. While some models help address many barriers that exist in the market, other models’ widespread adoption depends on setting clear regulations and getting clarification on its legality.

4. Methodology

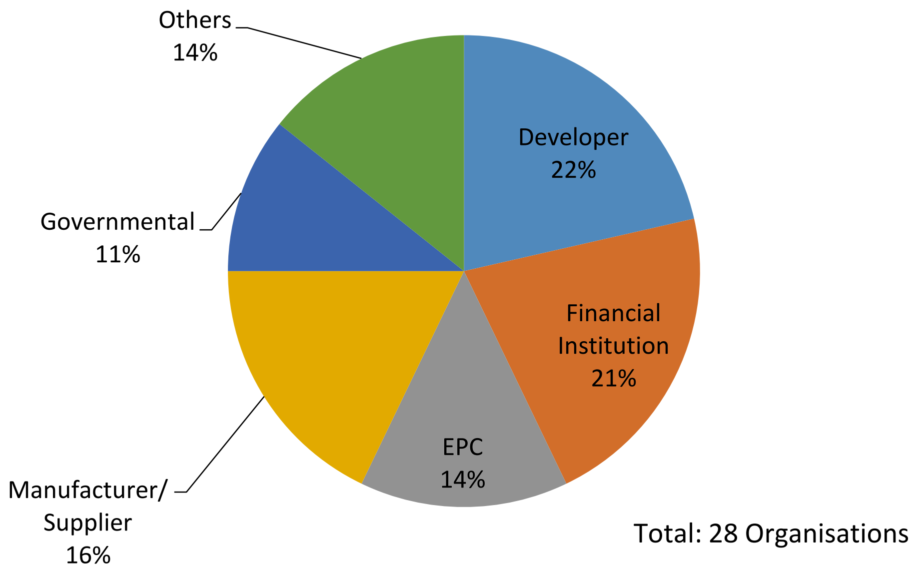
4.1 Interviews

After an extensive literature review of academic and non-academic sources, we compiled a list of solar business models that exist in Thailand for rooftop solar PV systems and the active players in the Thai market associated with the identified models. We then used Osterwalder (2009)'s 'blocks' in the business model canvas to decompose the business models into major elements, from which we used as a basis to develop interview questions. We then conducted semi-structured interviews with the business model pioneers to verify the elements of the business models that are emerging in Thailand. The respondents included chief executive officers and management-level staff from banks, solar manufacturers, solar power developers, leasing companies, and government agencies (listed in Appendix A).

The interviews comprised five parts. First, we asked the respondents to describe their company's role in the solar value chain – whether they were a manufacturer, developer, equipment supplier, engineering, procurement, and construction (EPC) contactor, or a combination of these roles and how different roles complement each other in their businesses. Then, we referred to the changing policy context for rooftop solar power development in Thailand and asked them to describe their current rooftop solar business activities and plans. During this process, we also sought understanding of the elements of the models as categorised by Osterwalder and Pignuer (2009). After the interview, respondents described current and planned business models, and identified the drivers, barriers, opportunities, and risks of their emerging or planned business models. We also asked them to provide key financial parameters essential for the companies' business plans, including expected IRRs and payback period. Other financial parameters that are not completely under their control were verified with them, such as system costs and O&M costs. And lastly, we asked the interviewees to identify policy and regulatory issues that are supporting or constraining their business model expansion.

We conducted a total of 30 interviews with 28 organisations. The informants included five manufacturers, six developers, four EPC contractors, four banks, two leasing companies, two government officials, one industry group representative, one representative from the Energy Regulatory Commission, and three other types of informants. The informants were manager-level or in higher positions. Figure 4.5 show the composition of the informants and Appendix A lists the names and companies of the informants.

Figure 4.5: Share of Interviewees by Type of Organisation



EPC = engineering, procurement, and construction.

Source: Authors' analysis.

We then described the results of the business models that have been identified in Section 5.1. Two business models are selected and chosen for the development of financial models, whose results we describe in Section 5.2. Criteria for defining business models for rooftop solar scale-up are as follows:

- Potential to rapidly scale up market
- Broad-based reach: the business models can be used for residential, commercial, and industrial scale and the typically unreached sector of the population, that is, low-income
- Potential to continue without the presence of FIT

4.2 Financial model methodology

We investigated the viability of two business models from the customer's perspective – the solar leasing model and the solar PPA model. The analysis was conducted in comparison to the results from the buying model. Hence, we had to develop three cash flow models (leasing, PPA, and buying) to examine detailed costs and benefits through the projects' lifecycle. The assumptions used to run the models were drawn from our market studies and interviews. We present the results in terms of levelised cost of electricity (LCOE), net present value (NPV), internal rate of return (IRR), payback period, and net cash flow. The detailed methodology for the solar PPA model and solar leasing models are described in following sections.

4.2.1 System cost and benefit structure

1) System cost structure

The cost structure for the roof owner varies according to the business models. The owner incurs the upfront cost in the buying model and no upfront cost in the solar PPA and leasing model.

In the buying model, the structure includes the system installation cost (also referred to as capital expenditure or CAPEX), the annual operation and maintenance costs (also referred to as O&M, operating expenses or OPEX) that includes the cost of system maintenance such as cleaning and electrical checks, inverter replacement cost, and insurance cost, as shown in Equation (1).

$$Annual\ O\&M\ Cost_{Buying,n} = System\ Maintenance_n + Inverter\ Replacement\ Cost_n + Insurance\ Cost_n \qquad (1)$$

As for the solar PPA model, there is no initial cost to the customer as the developer takes up the investment. The cost for the customer is the agreed price per kWh produced from the PV system according to the PPA contract. The price per kWh is offered at a discount from the retail electricity rate, hereafter referred to as the PPA deduction rate.[12]

$$Annual\ Cost_{\ PPA,n} = E_n \times T_n \times (1 - PPA\ deduction\ rate) \qquad (2)$$

For the solar leasing model, the down payment is considered as the initial cost or CAPEX, while the remaining system cost is included in the lease payment. Consequently, the annual costs, or OPEX, are the combinations of lease payment cost, O&M cost, inverter

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[12] The PPA deduction rate in this paper is referred to as the 'pre-tax discount rate for a PPA' by Feldman and Margolis (2014). The cost per kWh paid by the roof owner is the PPA price.

replacement cost as Equation 3. The insurance cost is not taken into consideration in our study.

$$Annual\ Cost_{\ Lease,n} = Lease\ payment_n + O\&M\ Cost_n + Inverter\ Replacement\ Cost_n \qquad (3)$$

2) System benefit

In our study, the benefit of a rooftop solar system is considered as the electrical cost saving based on PV generation in all cases. The saving is derived from the avoided cost of paying electrical tariffs to the utility and hence the benefit can be expressed as shown in equation 4.

$$Total\ Benefit = \sum_{n=0}^{N}(E \times T)_n \qquad (4)$$

Where:
T_n is the electrical tariff by the utility at year n (THB/kWh)

4.2.2 Economic indicators: NPV, IRR, LCOE, and payback period

After accounting for the savings and expenses incurred annually by the rooftop owner, we can then find the net benefit derived from the solar system each year, as shown in Equation (5):

$$Net\ Benefit_n = Total\ Benefit_n - Total\ Cost_n \qquad (5)$$

1) Net present value (NPV)

To account for the time value of money, yearly net benefit was discounted and then summed, to see how present value of benefit compares to the other.

$$NPV = \sum_{n=0}^{N}\frac{B_n - C_n}{(1+r)^n} \qquad (6)$$

Where:

N is lifetime of solar PV system (25 years)

n is point in time (n=0 means present)

B is benefits gained by rooftop solar system owner

C is cost incurred by the rooftop solar system owner

r is discounted rate

2) Levelised cost of electricity (LCOE)

As described in Hernández-Moro and Martínez-Duart (2013), the LCOE of the system is calculated from the sum of the initial cost and discounted annual cost divided by the sum of the discounted energy over the economic lifetime of the rooftop solar system. A constant annual value for the LCOE is shown in Equation (7).

$$LCOE = \frac{(Initial\ Costs + \sum_{n=1}^{N} \frac{Annual\ Costs_n}{(1+r)^n})}{\sum_{n=1}^{N} \frac{E_n}{(1+r)^n}} \tag{7}$$

Where:

E_n is produced energy of solar PV system at year n (kWh)

3) Internal rate of return (IRR)

The IRR is the discount rate that ‘forces NPV to equal zero’ (Brigham and Ehrhardt, 2010) as expressed in Equation (8).

$$NPV = \sum_{n=0}^{N} \frac{CF}{(1+IRR)^n} \tag{8}$$

Where:

CF = Cash flow

IRR = Internal Rate of Return

4) Payback Period

Payback period is an indicator that measures when the investment will pay off for itself, as shown in Equation (9) (Brigham and Ehrhardt, 2010):

$$Payback = Number\ of\ years\ prior\ to\ full\ recovery + \frac{Unrecovered\ cost\ at\ start\ of\ year}{Cash\ flow\ during\ full\ recovery\ year} \quad (9)$$

Lastly, sensitivity analyses were conducted to observe the effect of five parameters on the LCOE and the NPV, as will be discussed in more details in the next section.

4.3 Assumptions

To reflect the actual economic environment in Thailand, we conducted a system price survey for residential-scale systems in June 2015 and obtained other assumptions related to the CAPEX and OPEX of the systems from direct interviews with solar developers and EPC contractors. The list of adopted assumptions and their sources are shown in Table 4.2.

Table 4.2: Assumptions of Financial Models

Parameters	Values		Units
	Commercial Scale (120kWp)	Residential Scale (5kWp)	
Technical Assumptions			
System Assumptions			
System Size	120	5	kWp
System Life	25	25	year
Performance Ratio	79.6	77.8	%
Capacity Factor	17.06	16.71	%
Module Degradation Rate	0.5	0.5	%/year
Site Assumptions			
Irradiation Values	1,805	1,805	kWh/m²/year
Load Consumption	1,642,684	10,288	kWh/year
Consumption Growth	0.73	0.73	%/year
Financial Assumptions			
Costs Assumptions			
System Installation Cost*	60	83	B/Wp
Inverter Cost	5	6	B/Wp
O&M Cost	0.5	0.5	B/Wp/year
Insurance Cost	0.14	0.14	% of EPC cost
Benefits Assumptions			
Tariff rate			B/kWh
On Peak	4.27	4	B/kWh
Off Peak	2.77	4	
Tariff Escalation	3.5	3.5	%/year

Discount Rate	10	10	%
Specific Assumptions Related to Each Business Model			
Solar PPA Assumptions			
PPA Deduction rate	10	-	% per kWh
Contract Term	25	-	year
Solar Leasing Assumptions			
Down Payment	-	30	% of EPC cost
Contract Term	-	8	year
Interest Rate (Effective Rate)	-	8.88	%/year

B= baht; EPC = engineering, procurement, and construction; kWp =kilowatt peak; O&M = operations and maintenance; PPA = power purchase agreement; Wp = watt peak.
Source: Compiled by the authors.

To account for variations in real-market conditions, the chapter also selects and analyses the sensitivity of our indicators (LCOE, NPV) to certain variables. The variables selected are ones that have high uncertainty or volatility that may have an effect on the LCOE. These parameters are summarised in Table 4.3 and discussed below:

- **PPA deduction rate:** This is the agreed rate of deduction from the utility prices between the developer and customer – the higher the PPA deduction rate the more savings the customer can obtain. As developers in the market offer different deduction rates, ranging from 5% to 15%, the chapter explores the impact of these variations on the LCOE and NPV.
- **Down payment:** it is an initial upfront portion of the total amount due in the leasing scheme. A down payment reduces financial institute's risk and demonstrates that the borrower's finance is sound enough to service the debt. The size of down payment determines by how financial institution or lender is protected from various risks. This chapter explores the impact of varying levels of down payment (0%, 30%, and 50%) on the LCOE and NPV.
- **Retail electrical tariff:** Tariff's from the utility could be volatile over the next 25 years, and the historical trend has shown that it is on the rise. Therefore, this chapter explores a varying escalation rate between 0% and 5%, with 3.5% being the base case.
- **Energy yield:** The annual energy output from the system was assumed as a base case referring to the PV Syst Photovoltaic Software output that yields a system performance ratio of 79.60%, equivalent to a capacity factor of 17.06%. The positive case is +5% and the negative case is +–5%.
- **Discount rate:** The discount rate is used to predict the present value; discount rates can vary depending on the customer's circumstances. Other literature has reported to use a discount rate between 3.5% and 15% (Rai and Sigrin, 2013; Branker et al., 2011).

Table 4.3: Sensitivity Assumptions

Parameters	Best Case, %	Base Case, %	Worst Case, %
Discount Rate	5	10	15
Retail Tariff	5	3.50	0
Yield	5	0	–5
PPA Deduction Rate	15	10	5
Down payment	0	30	50

PPA = power purchase agreement.
Source: Authors' analysis.

5 Results

Our interviews revealed four types of emerging rooftop solar business models and one type of financing option – solar loans – in Thailand.

Business Models:

- Roof rental
- Solar PPA (or solar shared saving)
- Solar leasing
- Community solar

It should be noted that solar leasing can be considered a business model and financing option. It is a business model in the sense that it is structured to enable value creation for the business owner and the customer. It is also a financing option because it provides the capital needed for the customers to own a solar system.

5.1 Description of the business models and financing option

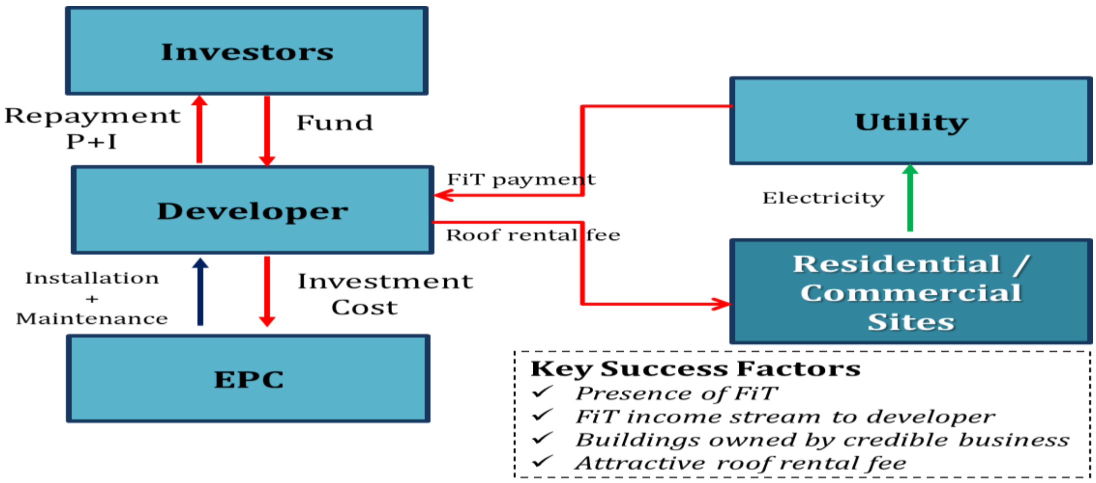
5.1.1 Roof rental business model

1) Components and structure

In 2013 when the government announced a 200 MW feed-in tariff (FIT) quota exclusively for rooftop solar systems, a new business model emerged – the roof rental model. Developer companies saw an opportunity to rent existing roofs, install and own the solar system, and sell electricity to the grid to receive a constant FIT income stream. The model consists of three key players 1) the roof owner, 2) the developer company, and 3) the utility. As shown in Figure 4.6 and described below:

1. The roof owner agrees on a 25-year roof rental contract with the developer company.
2. The developer company acquires a 25-year power purchase agreement (PPA) from the utility.
3. The developer then installs and operates the solar system on the rented roof.
4. Every kWh produce by the system will be exported to the grid.
5. Revenue from the sales of electricity will go to the developer.
6. The roof owner will receive a rental fee as agreed in the contract.

Figure 4.6: Structure of Roof Rental Business Model



EPC = engineering, procurement, and construction; FIT = feed-in tariff.
Source: Authors' analysis.

In this model, the roof owner does not have a liability in the rooftop solar system; therefore all the cost, including the investment cost, insurance cost, and O&M cost are born by the developer. It is beneficial to roof owners who want solar on their roof but do not want to take liability in the system. Another benefit of this model is that the roof owner does not consider solar PV part of their core business and therefore would not like to invest in it. The developer company looks for the following criteria:

1. A credible roof owner that will be able rent out the roof for 25 years.
2. Large roof area: an installation capacity of 1MW requires approximately 8,000 square metres.
3. Strong roof structure, which can withstand the additional load from the solar panels.

2) Drivers

In Thailand, those rooftops that fall into the criteria are mostly commercial rooftops including warehouse roofs, industrial and/or factory roofs, and shopping mall roofs. The roof owners benefit from the rental fee and the reduction of heat absorption to the roof, thereby reducing power consumption. There are concerns by roof owners about the risk of roof damage that may affect the assets under the roofs, for example leaking of the roof, building structural damage, or roof collapse. These risks are covered by the developer company through an all-risk insurance, which insures against all damages from installing the solar system.

3) Barriers

The main barrier that is limiting the widespread use of this model is the quota of PPA given. Developer companies have suggested that even with a reduction of FIT rates from B6.16/kWh to B6.01/kWh, the roof rental will still be attractive. Currently, the roof rental model is only successful for commercial roofs even though there have been attempts to apply this model to residential rooftops in certain parts of Thailand.

4) Risks

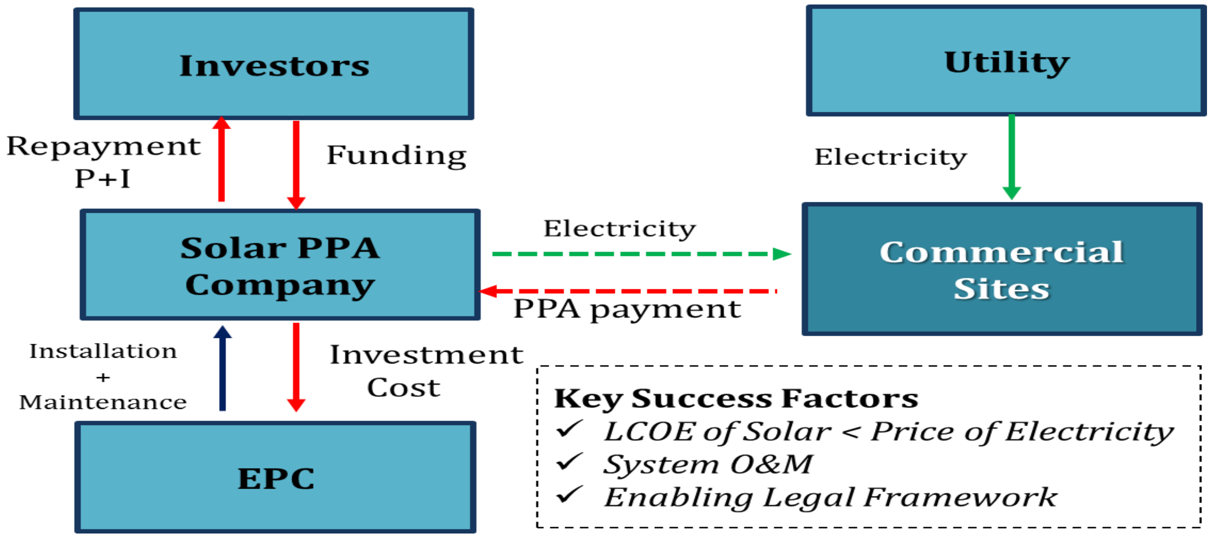
From the developer's perspectives, risks are associated with the use of the building, including cases in which the buildings are taken over, retrofitted for other purposes, or demolished. These anticipated risks are covered in the contract between the developer and the customer. From the customer's perspectives, the risk of roof damage or collapse is already mitigated by an insurance (all-risk insurance) paid for by the developer.

5.1.2 Solar shared saving or solar PPA business model

1) Components and structure

Because of policy uncertainties on the continuation of the feed-in tariff and a lack of clear regulation on selling electricity to the end-user by the third party, some Thai developers devised an innovative business model that fits the current investment climate. The solar shared-saving model is proposed for energy-intensive buildings and factories in order to reduce electricity cost. Based on time-of-use electricity rate, theses consumers have to pay for peak and/or off peak electricity rates and demand charges every month, which constitute a substantial share of their yearly expenses. As a result, the solar shared-saving business model is expected to provide a win-win solution for developers and energy intensive consumers. The structure of this model is shown in Figure 4.7.

Figure 4.7: Structure of Solar PPA Model



EPC = engineering, procurement, and construction; LCOE = levelised cost of electricity; O&M = operations and maintenance; PPA = power purchase agreement.
Source: Authors' analysis.

The main players in this model consist of the customer (roof owner), the developer, and the utility. The roof owner, who wants to reduce electricity costs, agrees on a shared-saving contract with the developer company. The contract typically lasts 20 to 25 years. The developer installs, owns, and operates the commercial-scale solar PV system on the site. Then, PV electricity units are sold at a discount, typically 5–10% lower than the grid electricity tariff. In this sense, it appeared as if the roof owner could lower his consumption by 5% to 10%, which is the reason for the term 'shared saving.'

The solar shared-saving model can be interpreted as a variation of the solar PPA model, which is now common in the US. Under the solar PPA model, the developer also installs, owns, and operates the solar system on the customer's site. The difference lies in the contract. Under the solar PPA model, the customer agrees to purchase electricity from the developer at a certain tariff (B/kWh) for a specified number of years. The tariff is offered as a discount of 5%–10% in comparison to the retail tariff rate. This is different from the PPA model in the US in which the PPA tariff is set by the developer with a built-in escalation rate. For example, in the case of SolarCity's residential solar PPA contract (as of

June 2015), the price per kWh increases by 2.9% per year after the first year's rate of $0.15 per kWh (SolarCity, 2015).

Another difference lies in the legal precedent of the solar PPA model. Since the developer owns the solar system and sells power to the customers, it essentially acts as a retail utility. Because Thailand's electric power industry structure remains partially deregulated, the retail utilities (the Provincial Electricity Authority and the Metropolitan Electricity Authority) have traditionally been the only parties that sell power in their service territories. Though not stated in the law that no party other than the utilities can sell power to customers, the legality of the model in which a third party provides power to customers in competition with the utilities remains unclear to many developers. This lack of clarity was confirmed by our conversation with two developers who are pursuing a solar PPA model. One developer then sought a formal letter from the regulator to confirm that the model is legal. However, an ERC senior staff member stated in the interview with us that the model could be pursued legally. The solar PPA model developers are regulated by the ERC and would only be required to get permits that are associated with the sizing of the solar system.

For both the solar shared-saving model and solar PPA model, proper system sizing is important to ensure that all of the PV electricity is consumed and not fed to the grid. The excessive amount of power that is not used and fed to the grid is not compensated for under the current regulation.

2) Drivers

There are two major drivers for the solar shared-saving model and solar PPA model: policy uncertainties and economics. Uncertain prospects of continuous FIT for commercial-scale installations urge businesses to adopt a model that is shielded from government policies. Solar PPA is a model that has succeeded in the US and Australia, and hence the subsequent knowledge transfer through multinational corporations. Furthermore, solar economics in Thailand is beginning to become feasible for large electricity users with high energy consumption and daytime peak. The solar shared-saving model and solar PPA companies hence can market their plans based upon expectation of rising electricity costs. Another driver is common of solar service models – the fact that the O&M burden is borne by the service provider, who owns the PV system and has more proficiency at managing the risks associated with ownership.

The concept of the solar shared-saving model is very similar to the energy service companies (ESCO) concept, in which the ESCO's share the income stream that comes from energy savings with the client. By extending this logic, it seems reasonable that ESCOs that typically share the income stream from energy savings with building owners may be in the position to add rooftop solar to their energy efficiency (EE) retrofit. Indeed, we found an EE project that included rooftop solar as a component of the project. The project combines energy efficiency upgrade to a commercial building and a rooftop solar installation. Because the payback period of an EE project of this size is typically 3–4 years, when combined with the payback period of a solar project of around 10 years, it is expected that a payback period of 7 years can be achieved. The financing that is currently being structured will likely come from 100% loan or 100% equity. The combination of EE and solar offers new business opportunities for solar developers as well as ESCOs. However, both types of players have so far been focused in their fields and such combination of EE and solar offered in one package to commercial buildings is still rare.

3) Barriers

The only barrier identified by the interviewees includes the uncertainty surrounding the legality of this model as discussed earlier. Furthermore, in our research study period, we have not yet identified a solar shared-saving model/solar PPA model for the residential sector. The high investment cost and high transaction cost may be the main barriers preventing developers' interest in the residential scale.

4) Risks

The risks from the solar PPA model developer's standpoint are few since most of them, if materialised, can be remedied in the contract between the developer and the roof owner. However, a risk that remains inherent in the solar PPA model is the rate of electricity price rise. If the price of grid electricity does not rise as fast as was predicted in the assumption, the lower income stream will affect profitability.

From the roof owner's standpoint, there are a few risks to consider. For example, the load pattern may change due to the change in activities of the buildings or factory. The change in load pattern along with a lack of a net metering regulation can result in PV electricity that exceeds consumption and flows back to the grid without being credited for. The roof area may be required in the future for other purposes – this is especially true for flat roofs on university campuses.

5.1.3 Solar leasing

1) Components and structure

Solar leasing is a structure that allows the consumers to pay for the solar system over time and avoid the high upfront cost. The structure of solar leasing is shown in Figure 4.8. The leasing company (or solar lessor) enters into a leasing contract with the customer (solar lessee), allowing the lessor to own, install, and operate a rooftop solar system on the customer's roof. The solar lessee pays for the solar system through a combination of down payment and monthly instalments and uses the solar electricity or sell it to receive feed-in tariff. Therefore, the customer receives benefits from the solar PV system in the form of energy saving or feed-in tariff income. The leasing model that thrives in the US and pioneered by SolarCity has a leasing term of 15–20 years and is driven by the presence of federal investment tax credit. However, the leasing model in Thailand is emerging in the context of transitioning away from feed-in tariffs. The leasing terms being offered or planned by the interviewed stakeholders range from 6–8% with a leasing term not exceeding 7 years. Some potential leasing companies are of the view that the leasing term cannot exceed 5 years in Thailand. These stated leasing terms affect the economics and are discussed further in Section 5.2.

2) Drivers

In Thailand, there are interests in the leasing model from both the supply and demand side. From the supply side, the major driver for the solar leasing model is the interest from financial institutions and existing leasing companies that have already offered leasing services for other kinds of products, such as cars, factory machinery, and office equipment. They already have the business infrastructure to offer leasing services, including customer acquisition, marketing, logistics, and payment collection. Solar leasing presents market expansion opportunities as well as allowing the companies to provide green investment options to their customers. When the first solar leasing product was marketed to commercial-scale customers in 2014, there was still an availability of feed-in tariffs for rooftop solar PV investment. Therefore, the company's solar leasing package could be designed to receive feed-in tariff income or for self-consumption.

Another driver for this model from the demand side is that there is a huge, untapped group of potential customers that typically would not be able to afford solar PV upfront. According to the Chairman of Thailand's Solar PV Industries Association, '99% of the households that joined the feed-in tariff programme are from the high-income segment' (Sano and Tongsopit, 2014). Our interviews also revealed that the rural farming population has a strong interest in leasing solar technologies. If the solar leasing model becomes available, it can potentially make solar power more widespread among building owners and households.

3) Barriers

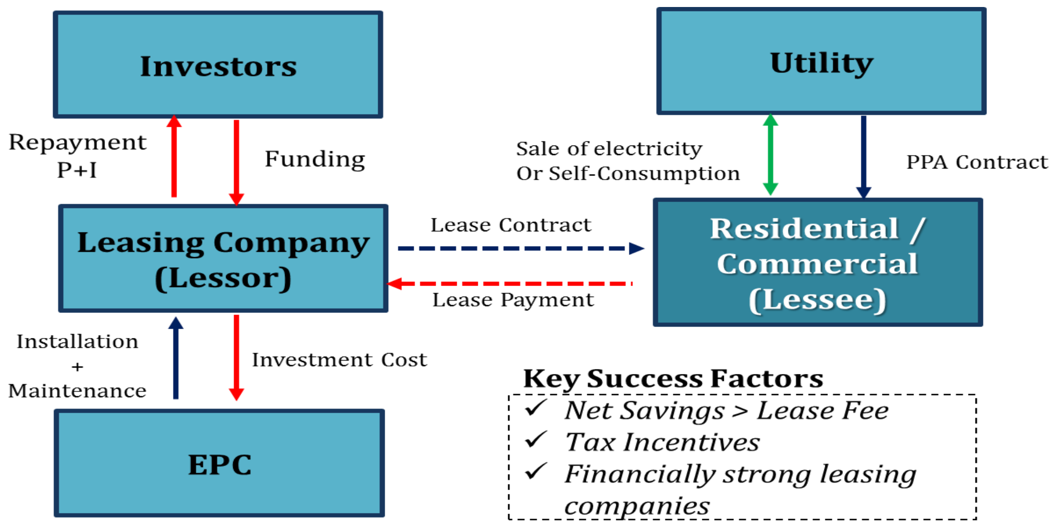
– Lack of feasibility at small scale

Given the fact that the solar leasing model is currently emerging in a non-subsidised (no FIT) environment, a major barrier is the economics of the leasing scheme, especially for smaller-scale systems. As we will see in the financial analysis in Section 5.2, the saving from leasing a residential system is not enough to pay the monthly leasing fee. In addition, the net present value is negative in the base case and in most sensitivity cases. For residential-scale leasing, especially, the terms currently discussed by potential leasing companies will not be attractive to customers unless additional incentive is given, such as in the form of tax incentives or subsidised interest rates.

– Lack of an equipment registration system and a secondary market

Another major concern that some potential leasing companies and financial institutions raised is the lack of a third-party registration system for solar system components. A third-party registration system would give each set of equipment (modules and inverters) serial numbers that would allow the lenders and/or lessors to track its history and evaluate resell values. In the case of default, such a system can help the companies take over the system and resell them in a secondary market just like cars. Despite this concern by the potential leasing company, however, we note that the current legal framework and associated regulation in Thailand allows for such registration.

Figure 4.8: Structure of Solar Leasing Business Model



EPC = engineering, procurement, and construction; PPA =power purchase agreement.
Source: Authors' analysis.

4) Risks

The risk to the solar lessor is mainly the risk of default or non-payment, which is then associated with the lack of a third-party equipment registration system that some of the potential lessors are concerned about. Non-payment results in the repossession of the solar system, for which a secondary market is still not extensive. One interviewed leasing company said that they would prevent the risk of default by choosing only credible commercial-scale customers. On the other hand, another respondent whose company aims to focus on individual customers would prefer to see a third-party registration system and an active secondary market before the company can launch a leasing product. These limitations result in the potential lessors' predetermination on leasing terms that are unattractive from the customers' perspectives, as a way to mitigate the lessor's risks.

From the lessee's perspective, if the leased system does not perform well, then the lessee will suffer from low saving or low feed-in tariff income. While the released commercial leasing product offers a form of performance guarantee that can help mitigate this risk for the customer, it remains to be seen what type of performance guarantee the Thai residential leasing schemes will offer.

5.1.4 Community solar

1) Components and structure

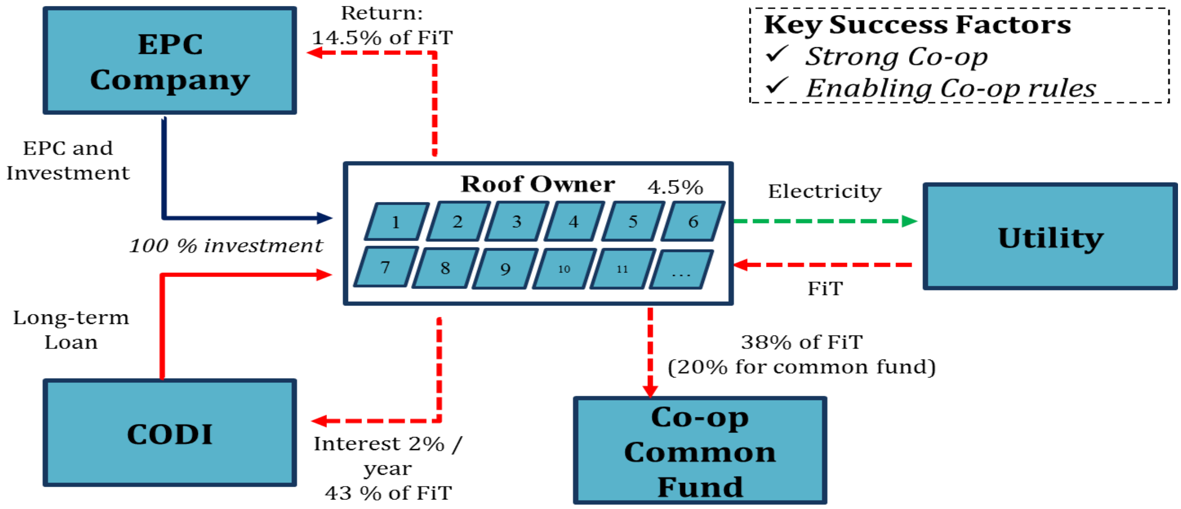
Since the launch of rooftop FIT in 2013, there has been a group of savings cooperatives that were interested in producing solar electricity and selling it to the grid. The group comprises approximately 40 households with a total installed capacity of 120 kilowatts (3 kW per household). However, delays caused by the interpretation of cooperative objectives resulted in the failure to pursue the business model that they previously planned on a large scale. Nevertheless, this model is worth reviewing because it represents the first attempt at designing a community solar scheme to benefit from feed-in tariffs. It can potentially be adapted for future self-consumption schemes.

The proposed business model resembles project financing. The project represents a community that receives financing from the Community Organizations Development Institute (CODI) (loan) and the EPC contractor (equity). The loan offers a low interest (2%) and a long-term loan of 15 years. The equity investor provides 14.5% of the total investment cost, and the other 85.5% is lent by CODI. The FIT income is therefore used to pay back to the investor, the lender, and kept in the community for O&M cost and profit. The monthly FIT income is split as follow (Figure 4.9):

- 43% to CODI, as a loan payment
- 38% to the co-op common fund
- 14.5% to investor/EPC as a return of investment
- 4.5% is kept by the roof owner

This structure enables the community to acquire and manage the residential rooftop system as a combined portfolio, sharing the capital cost and O&M cost. The participation of the EPC company as an investor ensures that systems of high quality are chosen and installed at the highest standard. At the same time, combining many households together into one community allows economies of scale that can help bring down the cost for PV system. In addition, the agreement also included training community members to install solar systems.

Figure 4.9: Proposed Solar Cooperative Business Model



CODI = Community Organizations Development Institute; EPC = engineering, procurement, and construction; FIT = feed-in tariff.

Source: Authors' analysis.

2) Drivers

Urban and rural residents that have a strong local network of neighbours can adopt this model. And it is possible that one successful community model could inspire other communities to adopt the model, as demonstrated in the 'peer effect' of solar power adoption (Bollinger and Gillingham, 2012). This particular model was developed together by five communities of housing cooperatives and many more communities expressed interest in the investment in solar power. The current government also has proposed a policy framework that in principle favours the development of community solar cooperatives since a main driving force for the policy design is to distribute solar access and income to a wider group of population.

3) Barriers

The structuring of business models for a group of households faces the challenge of financing. What would be the potential source of low-cost capital, considering that the returns also have to be shared with many households? In this unique case, we find that membership to CODI enables access to very low-cost capital, which is not available elsewhere. Therefore, scalability of this model is only applicable to CODI communities. Elsewhere we have also found efforts to structure community business models for large-scale solar farms in Thailand, but up until 2014 the projects failed to secure financing even with the presence of FIT (Thansetakit, 2014).

4) Risks

From the investor's perspective, there is a risk of non-sharing of income since the FIT income flows directly into the account of individual rooftop owners who are contractual partners with the utility. This risk is mitigated by adding a three-way contract between the roof owners, the community (which is a housing co-op in this case), and the investor. From the community members' perspective, poor products can lower their incomes, which would then have to be shared to the community and the investor. These risks may not make the scheme attractive since the transaction costs of banding together and jointly managing the system are already high.

5.1.5 Solar loans

Up to the date of this writing, two solar loans are available in Thailand as shown in Table 4.4.

Table 4.4: Existing Solar Loans in Thailand (as of 30 June 2015)

	K-Energy Saving Guarantee Program	Krung Thai Bank
Launch date	December 2014	April 2015
Customer segments	Commercial buildings, factories	Households (with minimum income of B50,000)
Financial programmes	Loan	Personal loan
Range of interest rate	MLR (6.63%)	8–9%
Maximum credit line	100% of investment cost	70–80%
Down payment to contractor	N/A	20–30%
Maximum term	12 years (maximum)	8 years
Partners	Solventia +Yingli+Huawei	SPCG+HomePro
Role of partners	Solventia = EPC and performance guarantee Yingli, Huawei = suppliers	SPCG = EPC
Collateral	Yes (may be less than conventional loan	No collateral but must meet

	K-Energy Saving Guarantee Program	Krung Thai Bank
	due to deduction from energy saving benefit and performance guarantee by the EPC contractor)	the following criteria: • Income>B50,000 • Good credit history • Must have PPA

B= baht; EPC = engineering, procurement, and construction; MLR = minimum loan rate; N/A = not applicable; PPA = power purchase agreement; SPCG = Sun Power Company Limited.
Sources: SPR (2015); K-Bank (2014).

The K-Energy Saving Guarantee Program is designed for commercial-scale solar installations. The uniqueness of this loan is that it can offer up to 100% financing at a term that can be extended up to 12 years. The reason why the bank is able to offer these attractive terms is because the EPC contractor is able to guarantee performance of the system through the loan term, thereby reducing the risk to the lender.

For the residential sector, the only available loan is through Krung Thai Bank. The loan is offered at an effective interest rate of 8–9% for up to 8 years. There is a specific target group of the clients, including those with incomes above B50,000 per month and never have had bad credit history. The Thai Military Bank recently signed an agreement with Solartron to provide loans for solar rooftops. But the details are yet to be released at the date of this writing.

5.2 Financial model results and discussions

5.2.1 Solar PPA model versus buying model results

1) Base case results

The base case results for our 120 kWp commercial-scale case show that the solar PPA model is more feasible in terms of NPV and LCOE values. The IRR and payback period cannot be calculated for the solar PPA model because there is no initial investment and therefore no negative NPV (Table 4.5).

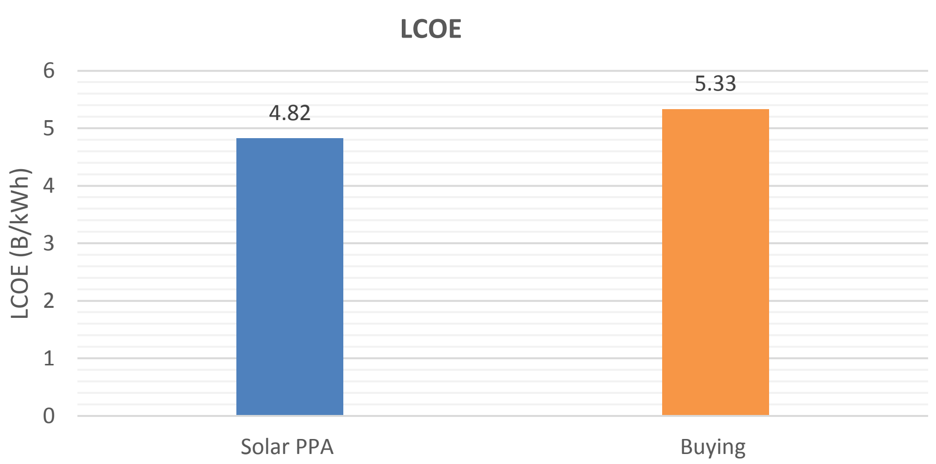
Table 4.5: Solar PPA Model Compared to Buying Model (base case results)

Base Case – Commercial Scale (120 kWp)		
Financial Indicators	Solar PPA model	Buying model
NPV (baht)	839,903	41,335
IRR (percent)	-	10.06%
Payback period (years)	-	9.73
LCOE (B/kWh)	4.82	5.33

kWp = kilowatt peak; IRR = internal rate of return; LCOE = levelised cost of electricity; NPV = net present value; PPA = power purchase agreement.
Source: Authors' analysis.

The LCOE for the solar PPA model is B4.82/kWh ($0.14/kWh) or 9.56% less than buying the system at B5.33/kWh ($0.16/kWh) (Figure 4.10). The difference is the cost structure for each model. The buying model has a significantly high upfront cost with relatively low annual cost. Upfront cost, or hereby denoted as 'initial costs', is of present value and is not discounted. On the other hand, the solar PPA model has a zero upfront cost but the customer pays for the electricity produced by the system, reflected as 'annual cost', to be discounted over 25 years.

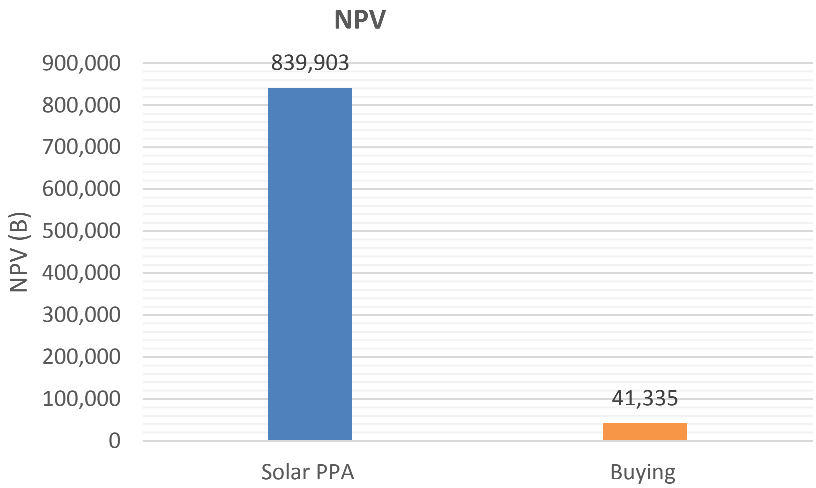
Figure 4.10: Base Case – LCOE of Solar PPA Model versus Buying Model



B =baht; kWh = kilowatt hour; LCOE = levelised cost of electricity; PPA = power purchase agreement.
Source: Authors' analysis.

For the NPV, both models show a positive NPV at B839,903 ($24,796) and B41,335 ($1,220) for the solar PPA model and buying model respectively (Figure 4.11). The higher NPV in the solar PPA case results from the customer never having an annual net negative cash flow. The high upfront cost in buying the system results in a negative net cumulative cash flow with a payback period of 9.73 years.

Figure 4.11: Base Case – NPV of Solar PPA Model versus Buying Model

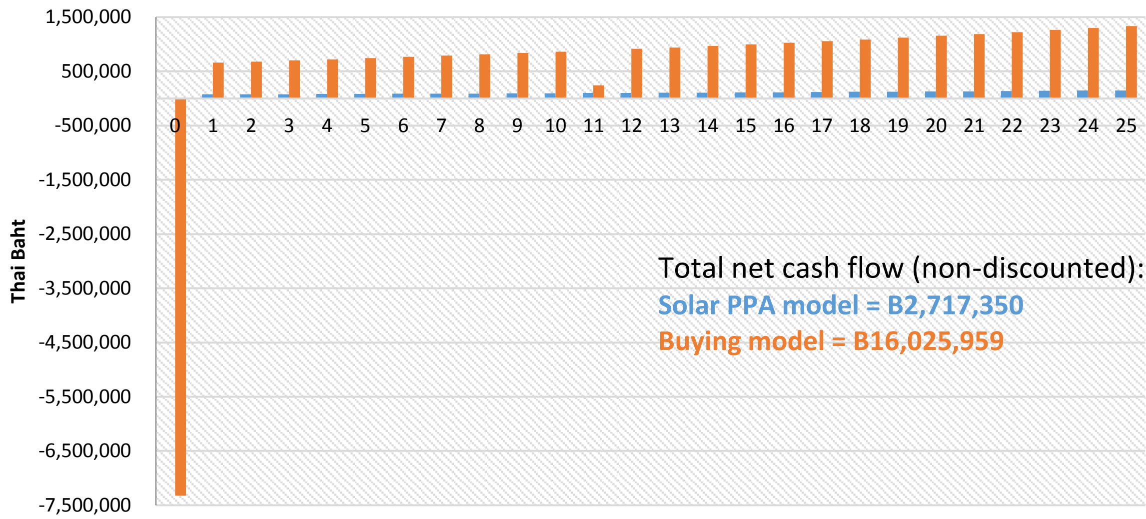


B = baht; NPV = net present value; PPA = power purchase agreement.
Source: Authors' analysis.

Figure 4.12 illustrates the difference in annual net cash flow (non-discounted) for the customer. The buying model (orange) has an initial investment cost of B7,325,000 ($216,921) (for a 120kW system). After the installation, the customer benefits through cost-savings and, once deducted by some O&M cost, will leave the customer with a positive annual net cash flow throughout the project life cycle. In the 11th year, as mentioned in our assumptions, we included the cost for inverter change of B642,000 ($19,012). Even though it is a significant cost, the saving outweighs the cost and yields a positive net cash flow within a year. In total, the cumulative net cash flow of the buying model is B16,025,959 or $474,590 (including deduction of investment cost).

For the solar PPA case, as the customer always buys electricity at a lower price than the grid prices they will never have a negative cash flow. The PPA deduction rate agreed with the developer therefore determines how much savings the customer will receive over the years. For the base case, we assumed that developers will give a 10% deduction from the utility prices. The results are that over 25 years, the customer will have saved B2,717,350 ($80,471). When compared to the buying model, this value may appear small, but considering that the customers have little to no liability, from not having to invest, operate, and maintain the system, it may be a better option for some customers.

Figure 4.12: Annual Net Cash Flow Solar PPA Model versus Buying Model (non-discounted)



B = baht; PPA = power purchase agreement.
Source: Authors' analysis.

2) Sensitivity analysis results

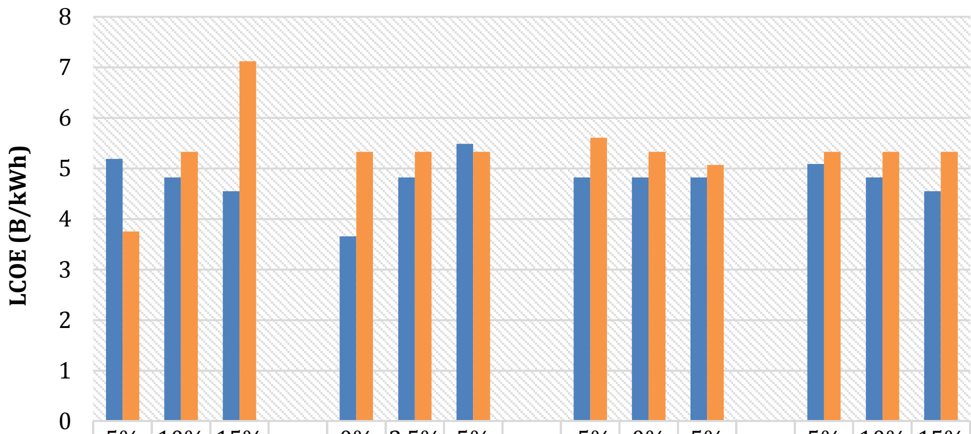
The sensitivity analysis reveals the impacts to the expected values of LCOE and NPV in the base case when certain parameters change. As shown in Table 4.3, the parameters tested were: discount rate, retail tariff escalation, energy yield, and PPA deduction rate.

LCOE and NPV sensitivity analysis results are summarised in Figure 4.13 and Figure 4.14. The following points were found:

- The solar PPA model offers a lower LCOE in all cases except two, that is, in the case of a 5% discount rate and a 5% retail tariff escalation. In these two cases, the buying model provides a lower LCOE.
- Both the NPV and LCOE for the buying model are highly sensitive to the varying discount rate. The lower the discount rate the more attractive is the investment for buying the system. It is clear for the NPV, a 5% discount rate yields a high NPV whereas a 15% discount rate shows a negative NPV.
- Retail tariff escalation has a positive correlation with the solar PPA's LCOE, the higher the escalation, the higher the LCOE. This is because the agreed PPA price is linked with the retail tariff rates – as the tariff increases the amount paid to the developer increases as well. This is not the case with the buying model, in which the cost structure is not influenced by tariff escalation.

- In contrast, the NPV of the buying model is very sensitive to the retail tariff escalation due to the fact that retail tariff escalation directly effects the amount of cost saving benefit for the consumer.
- The results show that energy yield had no influence on the LCOE for the solar PPA model, but is negatively correlated with the LCOE in the buying model.
- As expected, higher PPA reduction rate is more beneficial and attractive to the customer, yielding a higher NPV and a lower LCOE.

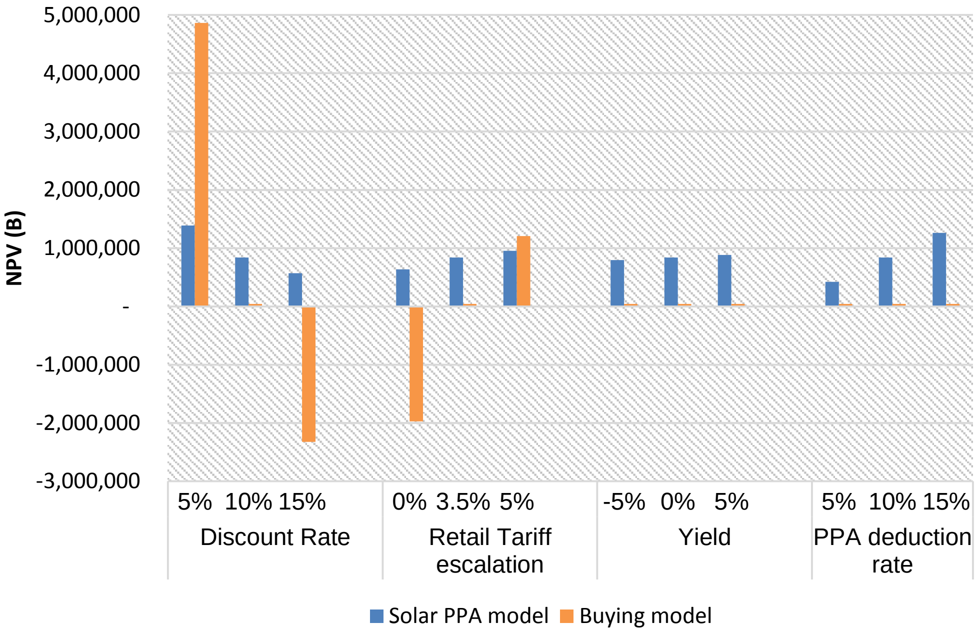
Figure 4.13: Sensitivity Analysis – LCOE Solar PPA Model versus Buying Model



	Discount Rate			Tariff Escalation			Energy Yield			PPA deduction rate		
	5%	10%	15%	0%	3.5%	5%	-5%	0%	5%	5%	10%	15%
Solar PPA Model	5.19	4.82	4.55	3.66	4.82	5.49	4.82	4.82	4.82	5.09	4.82	4.55
Buying Model	3.75	5.33	7.12	5.33	5.33	5.33	5.61	5.33	5.07	5.33	5.33	5.33

B = baht; kWh = kilowatt hour; LCOE = levelised cost of electricity; PPA = power purchase agreement.
Source: Authors' analysis.

Figure 4.14: Sensitivity Analysis – NPV Solar PPA Model versus Buying Model



B= baht; PPA = NPV = net present value; power purchase agreement.
Source: Authors' analysis.

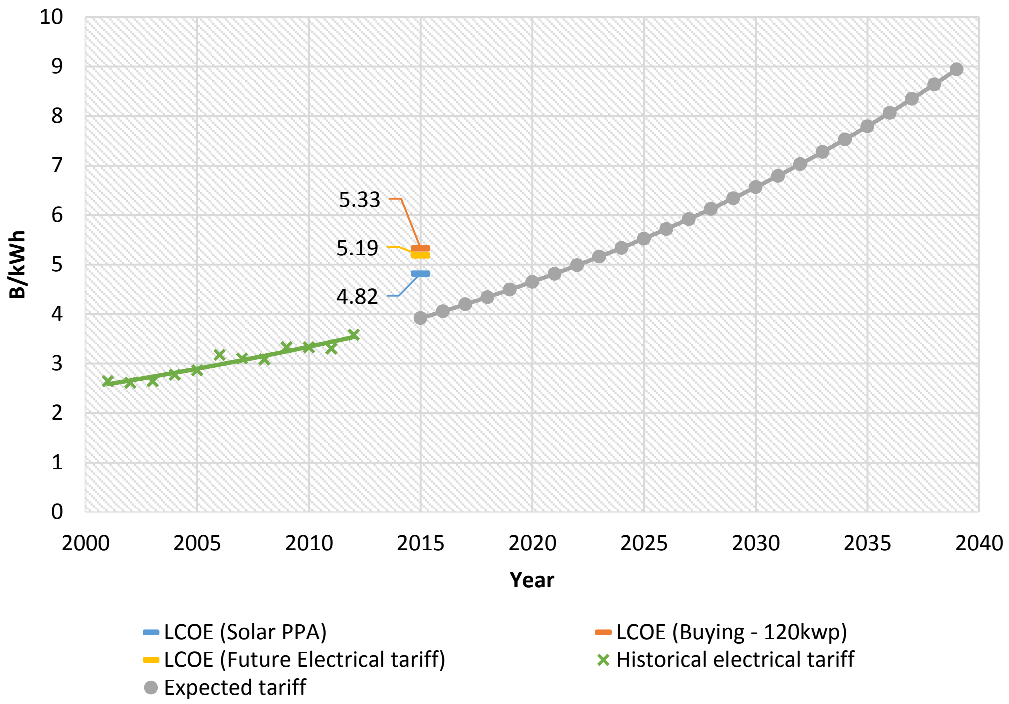
5.2.2 Solar PPA model versus buying model discussions

1) LCOE versus retail tariff

The results have shown that the solar PPA model has a lower LCOE than the Buying model in the base case and most sensitivity cases. So from a cost perspective, the solar PPA model proves to be a more attractive option since the cost of solar electricity over its lifetime is lower in the PPA case than the buying case. Figure 4.15 compares the LCOE of both options to historical and projected retail tariff, with the current average prices (2015), at just under B4.00/kWh ($0.12/kWh), both models have a higher levelised cost per kWh than the retail tariff. Future retail tariff rates here are shown according to our assumptions at a projected escalation rate of 3.5% year on year.

However, for a fair comparison, the future retail tariff should be levelised to present value as well. Therefore, the LCOE for buying electricity from the grid over the next 25 years is equal to B5.19/kWh ($0.15/kWh) (Figure 4.15). This means that the LCOE for the solar PPA model, B4.82/kWh ($0.14/kWh), is lower than buying from the grid over 25 years. This result further confirms the attractiveness of the PPA option over the buying option. Following the current assumptions, the buying model will reach grid parity by 2024. To reach grid parity means that the LCOE from solar energy is less than or equal to the prices purchased from the grid. Upon reaching grid parity, solar power will not only be cheaper than grid tariffs, but will act as a tool to hedge against escalating retail tariff in the future.

Figure 4.15: LCOE versus Retail Tariff Rates for a 120 kWp

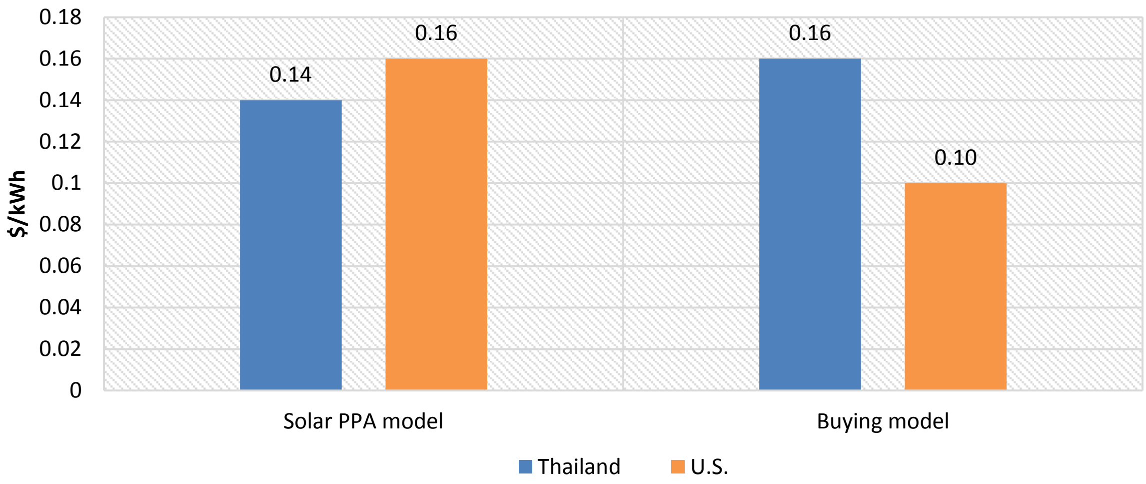


B = baht; kWh = kilowatt hour; kWp = kilowatt peak; LCOE = levelised cost of electricity; NPA = net present value; PPA = power purchase agreement.
Source: Authors' analysis.

2) Comparison to the United States

To see how the LCOE for the solar PPA model in Thailand compares to the US, an impressive market for solar PPA, we compare our results to that of Feldman and Margolis (2014), which reported an LCOE of \$0.16/kWh for the solar PPA model and \$0.10/kWh and for the buying model (Figure 4.16). Based on these numbers, Thailand's solar PPA LCOE is 12.5% lower than LCOE for the US solar PPA model. In the buying model, the Thai LCOE is 60% higher than the US case. This is due to the difference in terms policy support, the investment tax credit has been taken into account, which is up to 30% of the investment cost (Feldman and Margolis, 2014). The LCOE in this chapter does not include any kind of additional incentives, mainly because policies are not stable. Shifting and unstable policy was one of the reasons for the emergence of solar service models in Thailand.

Figure 4.16: LCOE of Solar PPA Model versus Buying Model in Thailand and the United States



kWh = kilowatt hour; LCOE = ; PPA = power purchase agreement.
Source: Authors' analysis.

3) Influential factors in decision-making

Even though the results suggest that between the solar PPA model and the buying model, solar PPA has a lower LCOE, there are two cases in the sensitivity analysis that lowered the LCOE of the buying model below the solar PPA model. The two cases highlight the major factors that influence the decision in buying the system or buying the service – the discount rate and retail tariff escalation rate.

The first case happens when using a 5% discount rate. For customers with low discount rates, or low opportunity cost for other alternative investment, buying the system is more feasible than the solar PPA. For higher discount rates, the solar PPA model is more attractive because the costs are spread out into the future, leaving available cash for higher-return investments at the present time.

The second case in which the buying model appears more attractive is when there is a 5% retail tariff escalation. This is because the cost structure for the solar PPA model is linked with retail tariffs. The higher the tariff, the higher the cost per kWh of electricity. This is not the case with the buying model, as the initial cost is fixed and annual costs are mainly O&M costs. So from the cost perspective only, the buying model is indifferent to the escalation of tariff prices.

4) Other economic factors

Overall, the solar PPA model financial indicators look to be more attractive to customers. But as our assumptions for the buying model are based on 100% equity financing from the customer, which may not be true in real investment situations, we may not have captured a comprehensive view of the buying model. Though not yet widespread, forms of financial product specifically designed for rooftop solar investment are beginning to emerge for the commercial scale, they are offered in terms of long-term loans with high debt-ratio (up to 100% debt). These types of financing can significantly help in reducing the weighted average cost of capital through increasing the debt to equity ratio. By lowering the cost of financing it will reduce the LCOE of the buying model. In that case, commercial-scale grid parity of the buying model may be even closer than our prediction at 2024.

5.2.3 Solar leasing model versus buying model results

1) Base case results

Similar to the commercial-scale (120 kWp) analysis, we show a comparison between buying the system (buying model) and leasing the system (solar leasing model) for residential scale (5 kWp). The results are shown in Table 4.6. Using NPV as an indicator, both models yield unattractive results. However, the IRR and the payback period show favourable results for the customers buying the system instead of leasing.

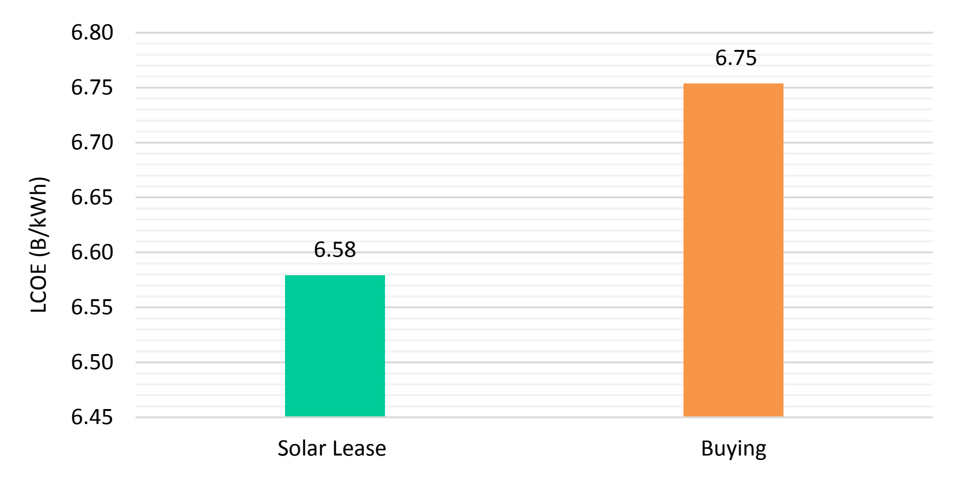
Table 4.6: Solar Leasing Model Compared to Buying Model (base case results)

Base Case – Residential Scale (5 kWp)		
Financial indicators	Buying model	Solar leasing model
NPV (baht)	−71,910	−60,123
IRR	7.96%	5.99%
Pay back period (years)	12.23	16.04
LCOE	6.75	6.58

IRR = internal rate of return; kWp = kilowatt peak; LCOE = levelised cost of electricity; NPV = net present value.
Source: Authors’ analysis.

Interestingly, the solar leasing model has a slightly lower LCOE at B6.58/kWh ($0.19/kWh) or 2.5% less than the buying model at B6.75/kWh ($0.20/kWh), as shown in Figure 4.17. This is because, when discounting all values to the present, the relatively high initial cost of buying the system far outweighs the combination of the down payment and lease payments in the leasing option. As a result, the LCOE of the buying model is higher than solar leasing model.

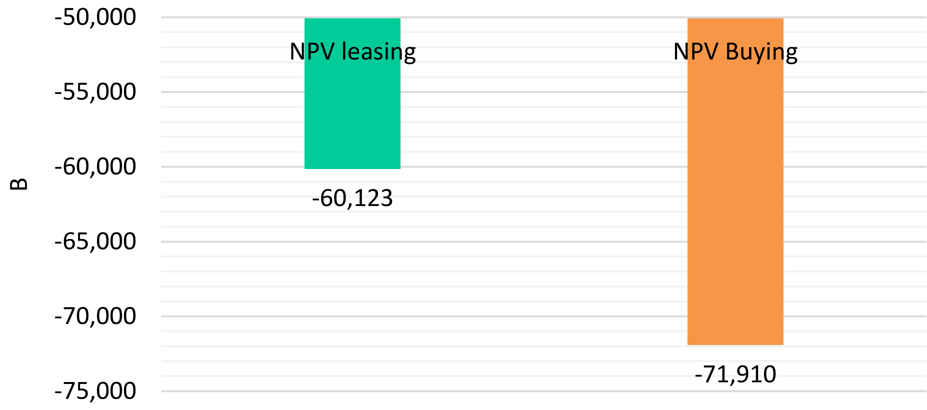
Figure 4.17: Base Case – LCOE of Solar Leasing Model versus Buying Model



B = baht; LCOE = levelised cost of electricity.
Source: Authors' analysis.

In this study, the NPV takes into account annual operating costs and electricity saving from a 5kWp system production that occur in different time periods. When given a discount rate of 10%, the NPV (Figure 4.18) are negative in both the buying and leasing cases. Yet, the NPV of the solar leasing model is slightly greater than that of the buying model at –B60,123 and –B71,910, respectively, due to smaller non-discounted initial cost.

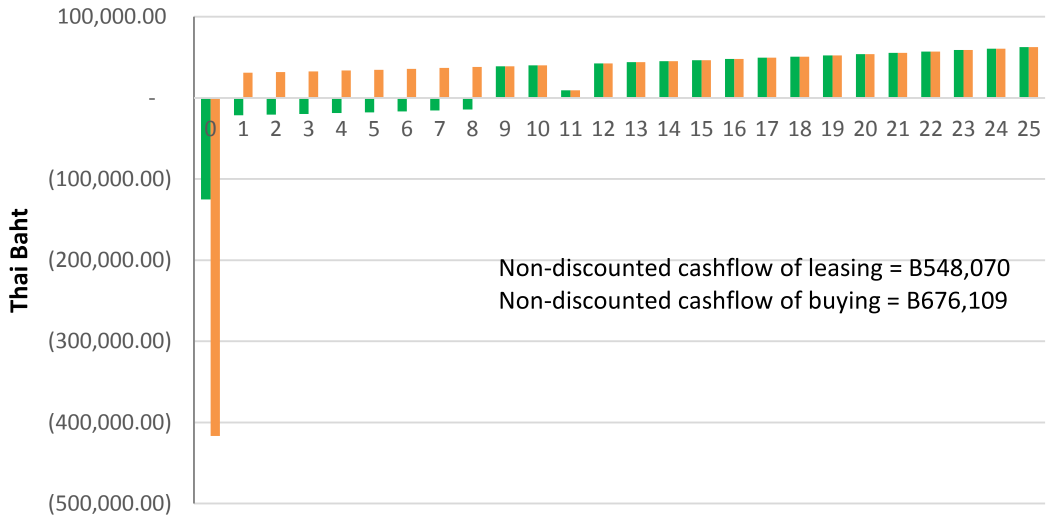
Figure 4.18: Base Case – NPV of Solar Leasing Model versus Buying Model



B =baht; NPV = net present value.
Source: Authors' analysis.

Even though cost structures of both business models are similar, the differences are in the size of initial cost and annual cost structure. For the solar leasing model, down payment is considered as an initial cost, which is 30% of total solar PV system cost. By having an 8.88% effective interest rate, the average annual lease payment is B52,466 ($1,640), which is then combined with an annual O&M cost of around B3,000 ($88). At the same time, average electricity saving amounts to B37,163 annually ($1,161). This annual saving is insufficient to pay the annual cost. Hence, the net cash flow from years 1–8 is negative, as shown in Figure 4.19. This may not attractive to the customers and may require additional incentives. Nevertheless, the sum of non-discounted cash flow of the solar leasing model is B548,070 which is slightly less than buying at B676,109 (Figure 4.19).

Figure 4.19: Annual Net Cash Flow of Solar Leasing Model versus Buying Model (non-discounted)



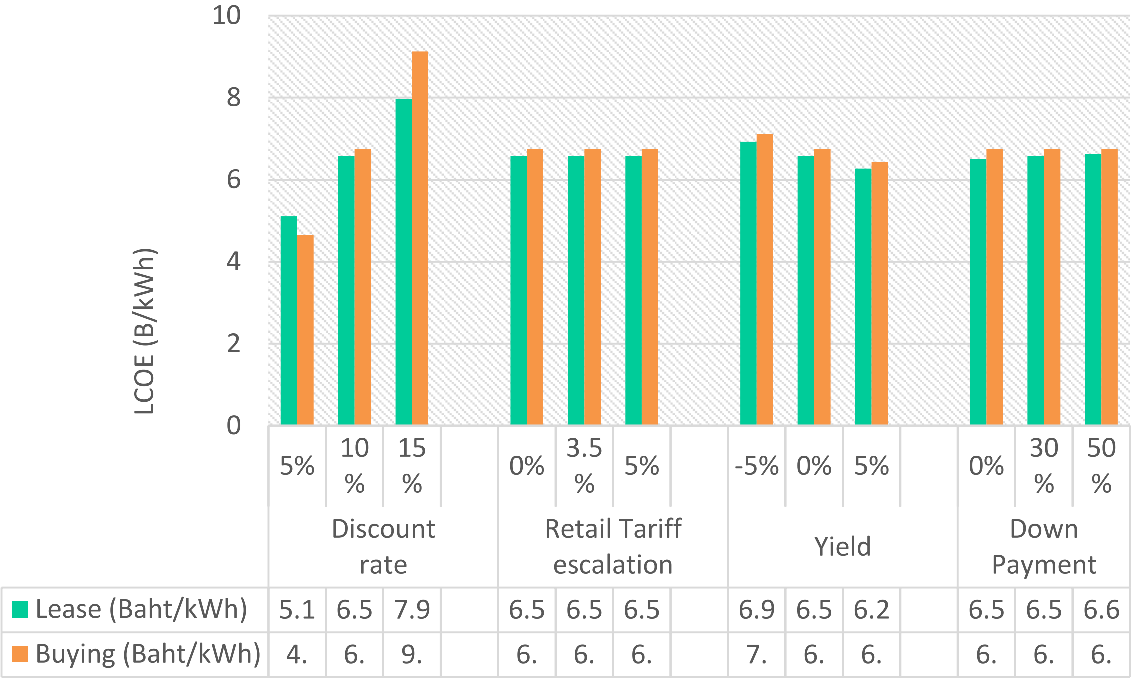
B = baht.
Source: Authors' analysis.

2) Sensitivity analysis results

The results of sensitivity analyses for the comparison of the buying model versus the leasing model are displayed in Figures 4.20 and 4.21. The following points are found:

- Solar leasing model provides lower LCOEs than buying in most of the cases. An exception is the case of a 5% discount rate, in which the LCOE of the solar leasing model is slightly higher than the buying model.
- Both leasing and buying models are most sensitive to the discount rate, as can be seen in LCOE and NPV. Between these two models, the buying model is more responsive to the changes of this parameter. As expected, the best case for leasing appears when discount rate is at 5%, which results in a minimum LCOE and a maximum NPV.
- Electric tariff escalation has no effect on the LCOE of all cases. In contrast, it has a positive correlation with the NPV, the higher the retail tariff escalation, the greater NPV. The reason is because the value of electric saving is considered as the income stream that offsets the costs. Thus, a higher electricity price means more money to be saved from PV production.
- The system yield has inverse relationships to the LCOE for both the solar leasing model and the buying model. However, it has no impact on the NPV.
- Changes of down payment cause small changes to the solar leasing model LCOE. The greater the down payment, the higher the LCOE.

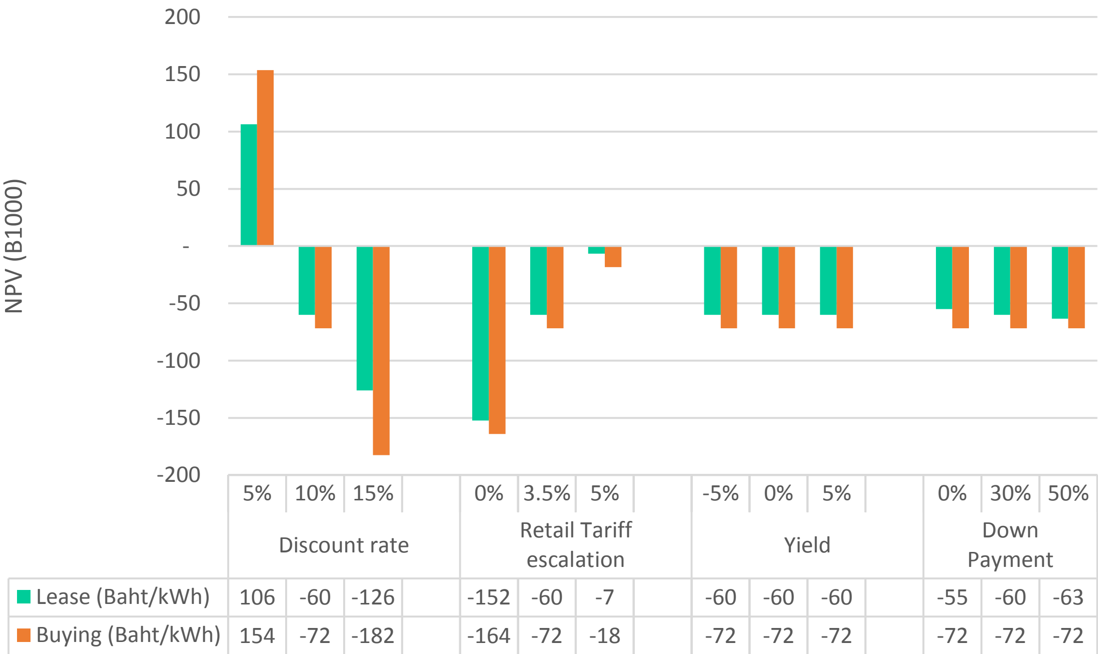
Figure 4.20: Sensitivity Analysis – LCOE Solar Leasing Model versus Buying Model



	Discount rate 5%	Discount rate 10%	Discount rate 15%	Retail Tariff escalation 0%	Retail Tariff escalation 3.5%	Retail Tariff escalation 5%	Yield -5%	Yield 0%	Yield 5%	Down Payment 0%	Down Payment 30%	Down Payment 50%
Lease (Baht/kWh)	5.1	6.5	7.9	6.5	6.5	6.5	6.9	6.5	6.2	6.5	6.5	6.6
Buying (Baht/kWh)	4.	6.	9.	6.	6.	6.	7.	6.	6.	6.	6.	6.

B = baht; kWh = kilowatt hour; LCOE = levelised cost of electricity
Source: Authors' analysis.

Figure 4.21: Sensitivity Analysis – NPV Solar Leasing Model versus Buying Model



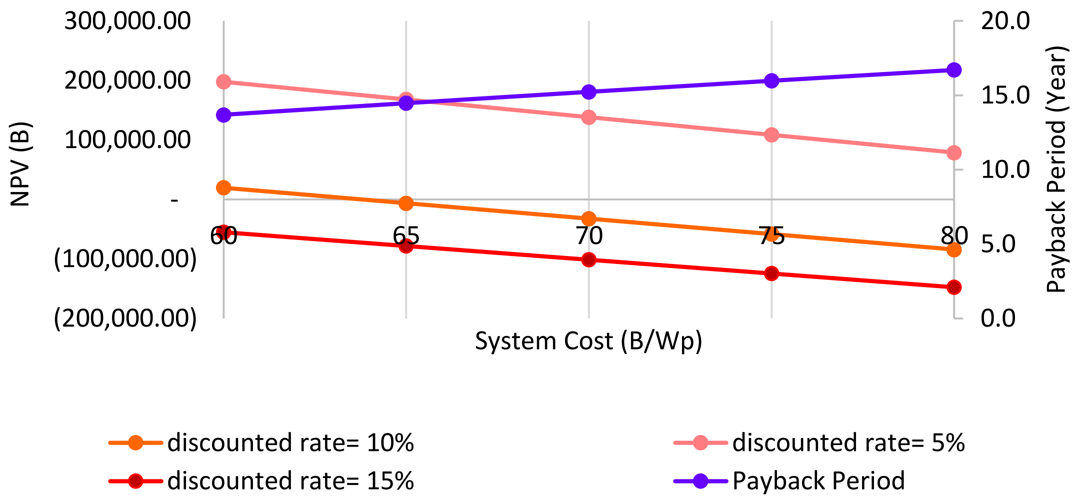
	Discount rate 5%	Discount rate 10%	Discount rate 15%	Retail Tariff escalation 0%	Retail Tariff escalation 3.5%	Retail Tariff escalation 5%	Yield -5%	Yield 0%	Yield 5%	Down Payment 0%	Down Payment 30%	Down Payment 50%
Lease (Baht/kWh)	106	-60	-126	-152	-60	-7	-60	-60	-60	-55	-60	-63
Buying (Baht/kWh)	154	-72	-182	-164	-72	-18	-72	-72	-72	-72	-72	-72

B = baht; kWh= kilowatt hour; NPV = net present value.
Source: Authors' analysis.

3) Sensitivity analysis on system costs

Since the high upfront cost is the main barrier of PV rooftop adoption, system cost is a major factor that needs to be taken into consideration. According to our market price survey (Appendix B), the current installation cost of a residential-scale (5 kWp) PV system ranges from as low as B44/watt to a B104/watt high). The interviews with EPCs and developers revealed that the investment cost may potentially reduce to B60/Wp in future. Taking into consideration the continued decline in PV module costs and businesses' diverse ability to reduce their PV module purchase price, it would be worthwhile to analyse the results' sensitivity to system costs. To see the impact of the system installation cost on leasing, our study varied system cost from B60 to B80/Wp as shows in Figure 4.22. With a 10% discount rate, the system cost below B64/Wp results in a zero NPV which mean this leasing scheme will yield exactly 10%. As expected, the investment becomes less valuable when the discount rate moves higher to 15% and becomes more valuable with a lower discount rate of 5%. Besides, the system cost is positively correlated to the payback period. For instance, the payback period is 13.7 years at B60/W, 15.2 years at B70/W and 16.7 years at B 80/W of system cost.

Figure 4.22: System Cost Variation – NPV Solar Leasing Model and its Payback Period under different discount rates



B/Wp = baht/watt peak; NPV = net present value.
Source: Authors' analysis.

5.2.4 Solar leasing model versus buying model discussions

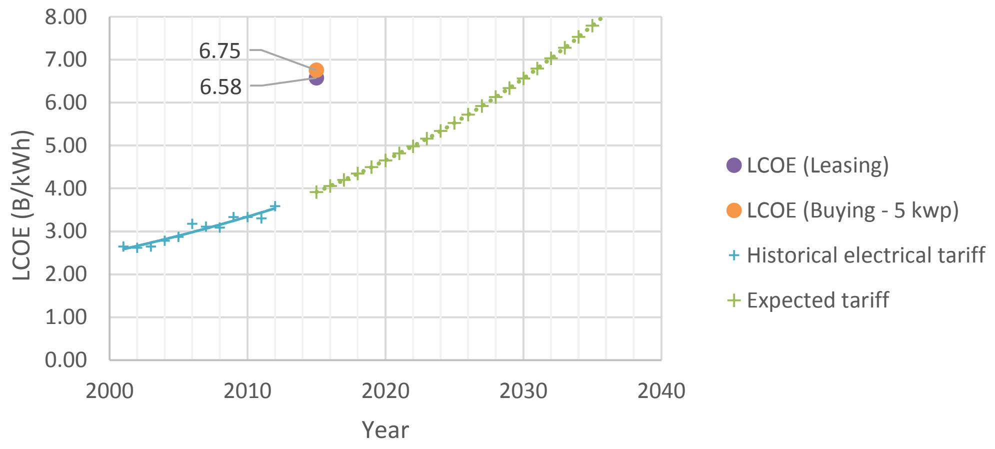
Key stakeholders with the potential to offer solar leasing model products, including financial institutions and leasing companies, have expressed interest in the solar leasing model due to its potential to capture a wide base of customers. However, as of the date of this writing, the banks and leasing companies cannot yet design a leasing programme for residential PV rooftop systems because of the lack of feasibility and their concerns of the risks. Risk factors for the lessors include the lack of a second hand market, potential rapid changes in PV technology, and the ease of PV system dismantlement. The presence of these risks results in higher interest rates and short lease terms. Based on these leasing terms, our financial analysis shows that that this investment is not attractive from the residential customer's viewpoint.

1) LCOE versus retail tariff

The results show that the LCOE of leasing is slightly lower than buying over its lifetime. From the cost perspective, the leasing LCOE proves to be slightly better option than buying as shown in Figure 4.23. With the current average electricity price at just below B4/kWh [$0.12/kWh], there is a big gap between the current electric tariff and the levelised cost per kWh of both the leasing and buying model. The LCOEs of both models remain far from grid parity, which is expected to happen as far as 2030.

There are two main factors that can accelerate the approach to grid parity, the first condition is if the future electrical tariff rises more than our assumptions at 3.5% year on year. The other case is when the cost assumptions can be significantly decreased, mainly for the investment cost which is assumed at B80/kWp for a 5 kWp system. The decrease in investment cost can come from continuous decline in PV module prices, the increase in economies of scale, or the reduction of soft cost.

Figure 4.23: Comparison between Electric Tariff and LCOE of Solar Leasing Model and Buying Model



B = baht; LCOE = levelised cost of electricity.
Source: Authors' analysis.

2) Results of support policies on solar lease

To solve the inflexible leasing conditions, governmental policies may help by offering support schemes to address the main barriers such as investment cost and short lease term. We therefore took into consideration whether having an investment tax credit and extending the lease term will help financially.

The results (Table 4.7) show that a tax return of 25% of total investment cost enables a positive NPV with a value of B41,105 ($1,213). In addition, this scheme results in a decline of LCOE to B5.08/kWh ($0.15/kWh), which is 23% less than the base case. Though the LCOE of the case that incorporates the tax credit is still not competitive when compared to the current electrical tariff, B4/kWh ($0.12/kWh), it can shorten the gap of the anticipated grid parity from the year 2030 to the year 2022. On the other hand, if the 20-year lease time is adopted, the lease investment is viable with an NPV of B25,114 ($741), LCOE of B5.32/kWh ($0.16/kWh) and is expected to reach grid parity by 2025. Regarding payback periods, the support policies can shorten it to approximately 13 years.

Table 4.7: Results of Sample Support Scheme on Solar Leasing Model

Solar Leasing Model Support Schemes			
Financial Indicators	Base case – leasing	Tax Credit – 25% of total investment	20-year lease term
LCOE (B/kWh)	6.58	5.08	5.32
NPV (B)	–60,123.06	41,105	25,114
Payback period (years)	16.04	13.04	13.80
IRR (%)	6.0	10.5	9.7

B= baht; IRR = internal rate of return; LCOE = levelised cost of electricity; NPV =net present value.
Source: Authors' analysis.

In summary, the investment on residential-scale solar leasing is currently unattractive in the customer's perspective, given the current lease terms being discussed in the market. Because of inflexible lease conditions, the model results in insufficient annual saving to repay lease payment and O&M cost. Furthermore, the LCOE of solar lease may not competitive with retail electricity tariff. However, additional incentives in the form of tax credits or long-lease terms can solve these issues. Thus, governmental support is a key to drive residential PV rooftop adoption from current emerging stage to rapid growth stage.

6Policy recommendations

Based on the results from the interviews and financial analysis, we conclude our study with two important messages about the Thai rooftop solar market:

1) The Thai rooftop solar market is still in a formation stage. With the current policy and regulatory conditions, we predict that the market could not take off and expand rapidly on its own.
2) Further support is needed, but the support should be different for different scales of installations.

The government and regulatory agencies play a large role in helping to build conditions that will help new business models to emerge and expand the market. Broadly speaking, these conditions include driving down the costs and reducing risks for the private sector. The results of our study indicate that the different scales of PV rooftop system require different support measures. Due to the lower investment cost and the projection of rising electricity price, commercial-scale solar PPA can exist without any form of government subsidy. On the other hand, residential-scale solar leasing can be more attractive with government support in the form of tax credits, which are expected to ease the leasing terms for customers. We hereby provide recommendations for the rapid scale-up of the rooftop PV market, with views of grid parity in the horizon.

Recommendation 1: Implement net metering regulations

Even without any form of subsidy, our study demonstrates that commercial-scale solar PPA is now emerging and expected to reach grid parity in the near term (within 5 years). In addition, residential solar leasing for self-consumption can potentially emerge with additional incentives. Therefore, the government should be ready to support the expansion of rooftop solar especially in the post-grid parity era by introducing net metering. As the LCOEs of rooftop solar systems in Thailand are approaching grid parity, the government should consider removing existing subsidies that may distort the market for rooftop solar PV. Aside from the FIT, developers or installers of commercial-scale rooftop solar can qualify for tax incentives from the Board of Investment.

Net metering is a practice by which owners of PV units may offset electricity consumed against their production during a certain period of time (Eid et al, 2014). Unlike the FIT, net metering is a milder incentive that gradually changes power consumers' behaviour to use less energy and enjoy the benefit of PV production more. But the details of net metering can affect project economics as well as the sustained regulatory support for solar PV in the long run. Detailed regulations on rates, rolling credit timeframe, and cap of capacity need to be designed carefully to ensure fairness between net metered and non-net metered customer. As already happening in several states in the US, there is a debate on how much to pay and to charge the net-metered customers. Some studies (for example, Borlick and Wood, 2014, pp.7–8), suggest that utilities increase the charges to the distributed generation owners or reduce the payment to the distributed generation owner to the level equal to utility's avoided costs, that is, the cost that the utility otherwise had to incur through generation or purchase to supply the distributed generator if there was no generation by distributed generator. While Thailand is in the initial stage of its net metering study, we recommend that the net metering scheme is designed with the balancing goals of speeding market expansion for rooftop solar while preventing sudden impact on the utilities' ability to recover their investment cost.

Recommendation 2: Provide more support for residential rooftop PV

For the residential-scale, there is no existing incentive apart from the FIT that elicited weak responses from consumers during its two rounds of application periods. The lack of economies of scale coupled with the lack of strong competition in the market result in a relatively high upfront cost for residential-scale rooftop solar – that is, at the cost between B43.55–104/w ($1.29–3.08/w) as of June 2015. Aside from global market forces that continue to drive down PV module costs, the Thai government should aim to drive down the cost of PV systems through a combination of measures, including lowering information cost for consumers and simplifying the permit process. Information about costs, installers, and processes that is made widely available to the public can help build an enabling business environment of rooftop solar at any scale.

In addition, the tax incentive for solar customers that was proposed by the National Reform Committee in January 2015 should be further pursued to make it a reality. This will help the residential leasing model to be more financially feasible as discussed in our financial analysis section.

Recommendation 3: Simplifying permit processes

The permit process for solar PV has continuously been improved since 2013 but it can be improved further for future net metering regulation. Rooftop PV systems so far have experienced a permit process designed under the FIT context. For rooftop solar, the process of getting FIT starts with the application to the utility to get FIT approval, to sign a contract with the utility, to acquire building and zoning permits, and an ERC licence exemption. All of these steps can take over a year, which increases the cost for the installers and consumers. In moving toward the net metering regulation, Thailand should redesign the permit process because the focus is no longer on ensuring that there is a PPA between the utility and the customer to guarantee payment. Following international best practices, the permit process for net metering should provide:

- ✓ A one-stop online platform to apply for all permits
- ✓ A clear flowchart of the process, a clear response time, and allow the tracking of the process within the online platform
- ✓ The minimisation of inspection trips to one to two trips
- ✓ The minimisation of total time it takes from applying to synchronising with the utility's grid

Recommendation 4 :Build a qualified installation workforce

A good programme for solar installation certification not only helps increase the number of qualified installation workforce but also increase consumers' confidence, making it easier for consumers to decide whether they would like to invest in a solar system. To date, the certification system of solar installers in Thailand has not been designed to meet these goals. Poor quality can occur both during the design and installation stages, resulting in lower consumers' confidence. Poor designs mean that consumers will not receive as many benefits as expected from the solar system. Inadequate workmanship that results in damage to properties or lives can severely impact the adoption rate of rooftop solar. A better certification programme would include training for the design and installation to the highest standard before accreditation.[13] We therefore recommend that the government should aim at building a qualified installation workforce, which is an important factor that will help expand the rooftop solar market.

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[13] See, for example, the North American Board of Certified Energy Practitioners' Certification Handbook for the Process of Certification. Available at: http://www.nabcep.org/wp-content/uploads/2008/11/NABCEP_Certification_Handbook_V7.2_06.09.14.pdf

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Appendix A: List of Interviewed Experts

	Date of Visit	Title	Company
1	12 Jan 2015	Chairman	Thai Photovoltaic Industries Association
2	14 Jan 2015	CEO and COO	Solartron Plc
3	14 Jan 2015	Executive VP Sales and Marketing	GoldenSun Solar
4	15 Jan 2015	Acting Managing Director	PEA Encom
5	15 Jan 2015	Purchasing and Procurement Manager	Thai Solar Energy (TSE)
6	20 Jan 2015	CEO	Solar D
7	22 Jan 2015	Managing Director	SE Sun
8	22 Jan 2015	Business Development Manager	SCB
9	27 Jan 2015	Vice Managing Director/Business Development Manager	G Capital
10	2 Feb 2015	Chairman and Chief Executive Officer	SPCG Public Company Limited
11	3 Feb 2015	CEO Business Development Associate	Symbior
12	3 Feb 2015	Chief Wholesale Banking Officer	TMB Bank Public Company Limited
13	5 Feb 2015	Director and Executive VP	Thai ORIX Leasing Co., Ltd.
14	5 Feb 2015	Business Development Manager	Gunkul Engineering
15	17 Feb 2015	Deputy Secretary	Federation of Thai Industries
16	19 Feb 2015	Vice President, Corporate Credit Product Management Department Corporate and SME Products Division	Kasikornbank
17	20 Feb 2015	Business Development Manager – ASEAN	Solventia Solar Co., Ltd.

	Date of Visit	Title	Company
18	23 Feb 2015	Managing Director	Ekarat Engineering Public Co.
19	25 Feb 2015	Director of Environmental Engineering Group, Vice President Business Development & Strategy (Weng Group)	Eco-Kinetics Company Limited
20	11 Mar 2015	Investment Promotion Office, Professional Level	Thailand Board of Investment (BOI)
21	13 Mar 2015	Thailand Sales Manager	Jinko Solar Co., Ltd.
22	24 Mar 2015	COO	Solartron Plc.
23	3 April 2015	Community Leader	Bang-Bua Chersapanmai 1 Community
24	26 May 2015		Green Power Industries, Co. Ltd
25	10 June 2015	Business Development Manager, Senior Sales Executive Sales and Marketing	TUV Rheinland
26	16 June 2015	Director Bureau of Solar Energy Development	Department of Alternative Energy Development and Efficiency
27	19 June 2015	Deputy Secretary General	Office of Energy Regulatory Commission
28	24 June 2015	Country Manager – Thailand USAID Contractor	Private Financing Advisory Network for Asia Program (PFAN-Asia)
28	26 June 2015	CEO	Climate Change Solutions Co., Ltd
29	26 June 2015	Director Bureau of Solar Energy Development	Department of Alternative Energy Development and Efficiency

Appendix B: Solar System Installation Cost Survey

Residential Scale (5 KWP)

Company	Investment Cost (B/Wp)
1	43.55
2	72.20
3	62.00
4	75.97
5	55.00
6	83.10
7	100.00
8	70.00
9	76.00
10	84.44
11	104.00
12	64.20
13	87.50
14	65.00
15	46.00
16	88.59
17	65.00
18	66.00
19	80.25
AVERAGE	**73.09**

Source: Project's prices survey as of June 2015.

COMMERCIAL SCALE (>100 KWP)

COMPANY	Investment Cost (B/Wp)
1	70
2	50
3	50
4	55
5	60
6	65
7	50
8	60
9	52
10	70
11	52
12	62
13	60
14	58
AVERAGE	**58.14**

Source: Authors' compilation.

Chapter 5

Analysis of Distributed Solar Photovoltaic (DSPV) Power Policy in China[14]

Sufang Zhang[15]

Abstract

Distributed solar photovoltaic (DSPV) power, either located on rooftops or ground-mounted, is one of the most important and fastest growing renewable energy technologies. Since the second half of 2012, China has shifted from large-scale solar PV (LSPV) to DSPV and a series of policies to promote DSPV power deployment has been put in place. Unfortunately these policies were not well performed due to myriad constraints on DSPV power deployment across the country. Building mainly on non-academic sources including government documents and presentations, industry reports and presentations, media reports, and interviews, this chapter firstly provides a comprehensive review of China's policies on DSPV passed between the second half of 2012 and the first half of 2014, then barriers associated with DSPV deployment are identified. This is followed by an account and discussions of recent policy changes since September 2014, and major local incentives. In addition, policy performance is briefly reviewed. Conclusions and policy implications are provided at the end of the chapter. This chapter provides an understanding of the recent DSPV policy progress in China and insights for policymakers in other economies that are experimenting with DSPV power policies.

Keywords: Distributed solar photovoltaics, PV, renewable energy policy, China

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1. Introduction

Solar photovoltaic (PV) power is currently, after hydro and wind power, the third most important renewable energy source in terms of globally installed capacity. More than 100 countries use solar PV power. The major installations of solar PV power are ground-mounted (utility scale or large-scale) PV (LSPV) power, and distributed solar photovoltaic DSPV power. DSPV power projects have different definitions. For instance, according to the National Development and Reform Commission of China (NDRC, 2013) and the State Grid of China (SGCC, 2013), DSPV power projects are defined as projects with generation on or close to the user site, instantaneously consumed by end users themselves, that is, self-consumed, and for which excess power can be grid-connected and the system can be balanced in the grid (NDRC, 2013), with project sizes smaller than 6 megawatts (MW) (State Grid, 2012). Whatever the definition is, DSPV power is solar energy–essentially rooftop and small, local, plants, that is either not sent to a grid, or, may be supplied to a local distribution network rather than to a high-voltage grid.

DSPV power projects have several advantages over remote LSPV power projects: (1) by being situated close to demand centres, the total energy and economic efficiency of the energy system is enhanced as line losses and investment costs in the transmission infrastructure could be reduced or eliminated; and (2) typically installed on rooftops, they require little land, which is at a premium in China.

DSPV power has become a noticeable source of electricity generation in Germany, the United States (US), and Japan. In China, although DSPV power generation dated back to 1996 when the Brightness Programme was initiated, which was followed by the Township Electrification Programme in late 2002, the domestic solar PV power market – both LSPV power and DSPV power – didn't see much growth due to lack of support from the government until 2009 when two national subsidy programmes for DSPV power projects, namely the Rooftop Subsidy Program and the Golden Sun Demonstration Program, were implemented, in the hope of incentivising domestic demand to rescue the domestic ailing solar PV manufacturing industry suffering from the 2008 global financial crisis.[16]

[16] During 2004–2008, driven jointly by the explosive growth of global demand for solar PV starting in 2004 as well as by a number of domestic factors, China' solar PV policy was export-oriented and over 95% of its solar PV products were exported.

Thanks to these two national subsidy programmes, the DSPV market has expanded. By the end of 2012, the cumulative capacity of DSPV across China reached 2.5 gigawatts (GW), accounting for 36.4% of the solar PV market (Zhang et al., 2013; Zhang et al., 2014).

Though these two projects did stimulate the domestic market, to some extent they have also contributed to the overcapacity in China’s PV manufacturing industry. Overcapacity coupled with trade tensions with the US and Europe over China’s solar PV products since the end of 2012, prompted the government to increasingly attach importance to its booming domestic solar market (Zhang et al., 2013). Given that the retail and/or commercial electricity tariffs are high in the eastern provinces, and the lack of grid transmission and land availability will constrain utility scale projects in the country, the government decided to attach more emphasis on distributed installations.

As a consequence, since the second half of 2012, China's DSPV market development strategy has witnessed a series of policy changes aimed at making DSPV power development an equal priority with LSPV power development. However, the DSPV power market has not developed as expected. The share of DSPV power in the total cumulative capacity of solar PV in the country was only 16.65% in 2014, and the new installation of DSPV in the year was only 2.05 GW, lagging the target of 8 GW set by the government in the beginning of 2014 (NEA, 2015).

Our literature review shows that along with the solar PV industry development over the past decade and the emergence of China’s domestic solar PV appliance market, studies have provided accounts of the Chinese solar PV policy and development (Zhao et al., 2013; Zhang et al., 2013; Sun et al., 2014; Zhang et al., 2014; Zhi et al., 2014; among others). Yet, to the best of our knowledge, there is little literature specifically focused on DSPV power deployment in the country. A few exceptions are Yuan et al. (2014) and Zhang et al. (2015). While Yuan et al. (2014) employed an analytical framework of levelised cost of electricity (LCOE) to estimate the generation cost of DSPV in China, Zhang, et al. (2015) reviewed China’s DSPV market development and policy changes since 2013, presented cost and time requirements for installing DSPV in China, which provide some insights for this study.

Nevertheless comprehensive studies on China’s DSPV power policy progress from the end of 2012 to early 2015 seem unavailable. The purpose of this study is to fill this gap. To this end, the chapter is organised as follows. Section 2 presents the DSPV power policies implemented from the second half of 2012 to the first half of 2014 and Section 3 analyses the major constraint on DSPV power deployment in the country, which provides the reasons for new policies. This is followed by Section 4, which makes a comprehensive analysis on the policy changes since September 2014. In response to the call from the central government, many local governments have also promulgated a number of policy incentives. Section 5 gives a brief account of these incentives of the selected provinces and municipalities. DSPV policy performance is analysed in Section 6. Section 7 provides conclusions and policy implications.

This study is built on data sources and interviews. The data sources are mainly from non-academic sources like industry reports and presentations, websites, media reports, government documents, and presentations. The interviews were conducted during September 2014 and May 2015 at several national solar PV power conferences or through Skype and WeChat. Our interviewees include eight DSPV project developers, two government officials, three renewable energy policy researchers, three managers from grid utilities, and six bankers. Interviews elicited information on the main constraints in the process of completing projects. Most managers interviewed had been engaged in PV deployment and/or research and development for at least 3 years.

The eight DSPV project developers are selected from China's eastern cities in Jiangsu and Zhejiang province and Shanghai municipality, which are the main locations of DSPV projects in China. The three government officials are from the Department of New Energy and Renewable Energy under the National Energy Administration (NEA). The three renewable energy researchers are from the Energy Study Institute affiliated with the National Development and Reform Commission (NDRC). The three managers from grid utilities are involved in implementing the policies. Among the six bankers, three of them are from China's policy banks, two are from the National Development Bank of China, one is from the Export and Import Bank of China, and the other three are from China's national commercial banks.

2. DSPV policy between the second half of 2012 and the first half of 2014

In this section, we provide accounts for China's DSPV power policy regime during the second half of 2012 and the first half of 2014. The key government document that represents the milestone of DSPV development at this stage is the Opinions on Promoting the Healthy Development of Solar PV Industry issued by the State Council on 15 July 2013 (State Council, 2013). Subsequent to the promulgation of this document, more than 30 national documents with regard to specific aspects of DSPV power development have been put in place (Table 5.1). I group the policies provided in these documents into four categories: (1) scale control and registration management; (2) on-grid tariff, subsidy, financing, and fiscal incentives; (3) market promotion – the establishment of demonstration areas of DSPV power generation; and (4) power grid-connection, measurement, and settlement policy.

2.1. Scale control and registration management

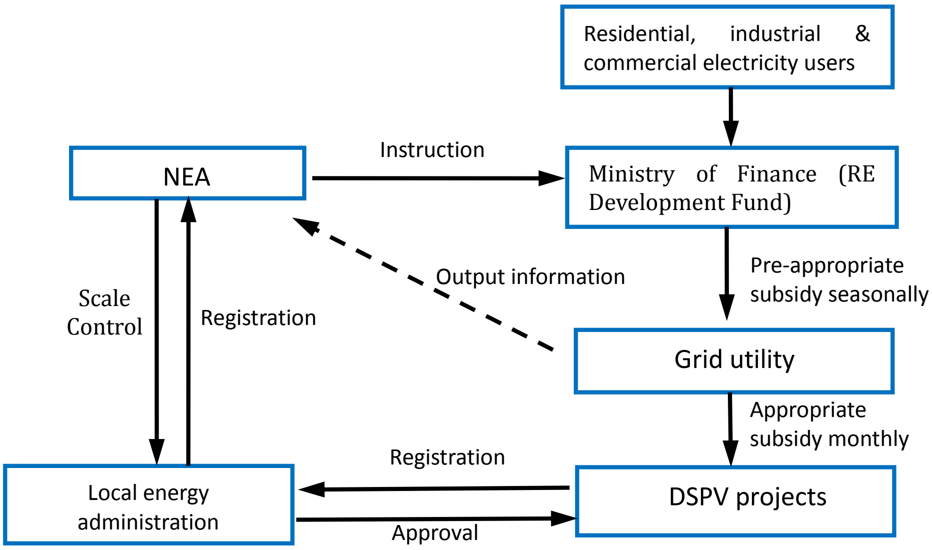
(1) Scale control

As in other countries, due to its high upfront cost, DSPV power in China requires government financial support. If we suppose 6 GW DSPV power is installed each year and a minimum of 7 billion kilowatt hour (kWh) power is generated, then the total subsidy required from the government would amount to CNY2.94 billion based on the government subsidy policy of CNY0.42 per kWh (for subsidy policy, see Section 2.2). As such, it is necessary to control the scale of DSPV power projects that require government subsidy. The scale control policy provides that the provincial energy authority shall propose the application for the national subsidy according to the local development of the DSPV power projects. The NEA will issue the scale for the next year after coordination of the scale application of the DSPV power generation across the country, and any unused quota will automatically lose effect in the subsequent year. It has to be noted that the quota is limited to the project enjoying the national subsidy (State Council, 2013; NEA, 2013a,b).

(2) Registration management

Except for DSPV demonstration areas where applications and approvals are made uniformly, other DSPV projects enjoying the national subsidy are applied with the registration management. DSPV projects are required to register with local energy administration. The provincial-level government confirms the detailed registration process. The permit process for DSPV is streamlined. Requirements are waived for generation business licences, planning and site selection, land pre-approval, water conservation, environmental impact evaluation, energy conservation evaluation, and social risks evaluation. Apparently, this could significantly cut the time and paperwork for DSPV projects (NDRC, 2013) (Figure 5.1).

Figure 5.1: Scale and Registration Management



DSPV = Distributed solar photovoltaic; NEA = National Energy Administration; RE = renewable energy.
Source: Author's compilation based on the documents issued by the National Energy Administration and the State Grid Corporation of China.

2.2. On-grid tariff, subsidy, financial, and fiscal incentives

The NDRC issued the Notice to Play the Role of the Leverage of Electricity Tariff to Promote the Healthy Development of Solar PV Industry on 30 August 2013, which provides that the central government will grant a subsidy of CNY0.42/kWh ($0.07) of output from DPSV projects. The subsidy runs for 20 years, to be provided by the China Renewable Energy Development Fund (NDRC, 2013). The grid company must pay for any surplus power PV systems exported to the grid at the local benchmark price of desulfurised coal-fired power units, which ranges from CNY0.25/kWh to CNY0.52/kWh (Ma, 2011), depending on the location of the project. Hence, by generating and consuming his or her own electricity, the host customer not only avoids a power bill, but also receives CNY0.42/kWh from the government for the power generated. The subsidy is pre-appropriated to local grid companies by the state revenue seasonally, and the grid company repays the subsidy on a monthly basis, making sure that the subsidy is in place in time and at the full amount (NEA, 2013a).

Meanwhile, in order to provide more financing support, the NEA and China Development Bank (CDB), one of China’s policy banks, jointly promulgated the Opinions on Financial Services to Support Distributed Solar PV in August 2013. According to this document, CDB would provide a credit line to financing platforms (that is, lump sum borrower) established by local governments, while providing loans directly to various eligible DSPV project investors (NEA and CDB, 2013).

In terms of fiscal incentives, DSPV projects are exempted from four government funds collected on the basis of generation power, including the renewable energy surcharge, the state's major water conservancy construction fund, the large and medium-sized reservoir resettlement support fund, and the fund for repayment of rural grid construction loan (MOF, 2013). A refund of 50% of value-added tax (VAT) upon collection is granted to DSPV projects. In addition, VAT is exempted for those DSPV projects if the monthly income of power sales is less than CNY30,000 (MOF and SAT, 2013).

2.3. Market promotion

In order to promote the deployment of DSPV projects, in September 2012 the NEA released the Notice on Applying for Demonstration Areas for Scaling up DSPV Power Generation. The notice invited each province to apply for no more than three DSPV demonstration areas with a maximum installed capacity of 500 MW and stated that priority would be given to the eastern and central regions in the country where local electricity demand is high (NEA, 2012).

In July 2013, the State Council issued the Opinions to Facilitate the Healthy Development of Solar PV Industry, which announced that the country would build 100 DSPV demonstration areas and 1,000 DSPV demonstration towns and villages (State Council, 2013). In August 2013, the first batch of DSPV demonstration areas was released by the NEA, which involves 18 demonstration areas in seven provinces and five cities, totalling 1.823GW (NEA, 2013b). In November 2014, the NEA announced 12 more DSPV demonstration areas in five provinces and the installed capacity completed in 2015 is expected to reach 3.35 GW (NEA, 2014a).

2.4. Power grid-connection, measurement, and settlement policy

1) Free grid-connection services

The two major state-owned grid companies, the State Grid Corporation of China (SGCC) and China Southern Grid (CSG) provide free connection services for DSPV electricity producers located close to customers, which cover technological assistance such as equipment testing and integration plan development, among others (SGCC, 2013; Zhang and He, 2013). (CSG operates in five southern provinces, Guangdong, Guangxi, Yunnan, Guizhou and Hainan, while SGCC operates in the rest of China). This not only guarantees that DSPV systems can connect to the grid, but also significantly reduces the cost of DSPV projects for installers by waiving both service fees and engineering fees.

2) Streamline grid-connection permit process

Upon receipt of the application for power grid connection, the grid utility will issue opinions on the grid connection within 20 working days, or 30 working days in the case of a multi-point connection. Transformation of the public power grid will be assumed by the power grid, while transformation of the user-side power grid will be assumed by the construction company. The grid utility bears the cost of integration charges for DSPV projects into the public grid and the incurred reinforcement charges. Distributed projects have been exempted from the need to hold a power generation licence since April 2014 (SGCC, 2013).

3) Power measurement and settlement

The grid utility offers free electric metre and backup capacity of the system and shall not charge any service expense in any part. The grid-connected tariff and subsidy shall be settled on a monthly basis and the surplus power may be sold to other power-consuming enterprises (SGCC, 2013).

Table 5.1: DSPV Policies Passed between the Second Half of 2012 and the First Half of 2014

Category	Time	Agency	Document
Scale and registration management	2013-08-12	NEA	Provisional management measures of distributed power projects
	2013-08-29	NEA	Provisional management measures of distributed solar PV power generation projects*
	2014-02-12	NEA	Notice to allocate new construction scale of solar PV projects in 2014
	2013-11-26	NEA	Provisional regulatory measures on the operation of solar PV stations
Tariff, financing, and fiscal incentives	2013-08-26	NDRC	Notice to play the role of electricity tariff leverage to promote the healthy development of solar PV industry
	2013-09-10	NDRC	Notice to adjust renewable energy surcharges
	2013-07-24	NDRC	Notice of the generation-based subsidy policy of distributed solar PV and other relevant policies
	2013-09-27	MOF	Notice on the value added tax policy of solar PV power
	2013-11-19	MOF	Notice of issues about the exemption of government fund for self-generation and self-consumption distributed solar PV
	2013-08-22	NEA CDB	Opinions on financial services to support distributed solar PV
Market promotion	2013-08-09	NEA	Notice to carry out the construction of demonstration areas of distributed solar PV application
Grid-connection, measurement, and settlement	2012-10-26	SGCC	Opinions on providing good services for the grid – integration of distributed solar PV (provisional)
	2012-10-26	SGCC	Opinions on promoting the grid-integration management of distributed solar PV power (provisional)
	2013-02-27	SGCC	Opinions on providing good services for the grid-integration of distributed solar PV (revised)
	2013-02-27	SGCC	Opinions on promoting the grid-integration management of distributed solar PV power (revised)

CDB = China Development Bank; DSPV = distributed solar photovoltaic; MOF = Ministry of Finance; NDRC = National Development and Reform Commission of China; NEA = National Energy Administration; PV = photovoltaic; SGCC = State Grid Corporation of China.
Source: Compiled by the author.

3. Major constraints on DSPV power deployment in China

Through a literature review and interviews with stakeholders, the major constraints on the implementation of DSPV policy and the diffusion of DSPV technology in China are identified as follows.

3.1. Rooftop resources problem

1) Insecurity of rooftop ownership

There are two problems associated with the insecurity of rooftop ownership. Firstly, in China the ownership of land and the ownership of the building on it are separated. In other words, an owner of a building is not an owner of the land on which the building is built. While the ownership of commercial buildings lasts for 50 years, the ownership of residential buildings lasts for 70 years. This implies that there are legal risks for investment in long-term and large-scale DSPV systems.

Another problem associated with the insecurity of rooftop resources is how to protect the project developers' right when their customers move out and the new property owners refuse to continue purchasing rooftop solar energy. Moreover, China is now in the process of urbanisation and forced house demolitions can take place.

2) Collective property ownership

In China, most urban citizens live in apartment buildings, the roof space of which is collectively owned by all households living in the building. This means any household who wants to construct a roof PV system needs the approval of all other households in the building. This could be time-consuming and difficult. For a PV developer who wants to rent an apartment roof to build a DSPV system or station, the negotiation process will not be easy. In China, there are cases where the property is collectively owned.

3.2. Unattractiveness of on-grid tariff and low proportion of self-consumption

As noted in Section 2, 'self generation, self consumption model with excess sold to the grid' has been a previous requirement for the DSPV development model (NDRC, 2013). Under this model, the proportion of self-generation and self-consumption has a great impact on the internal rate of return (IRR) of a DSPV project. Whilst the host owner of a DSPV project could benefit from avoided electricity bills, that is, the retail electricity tariff is within the range of CNY0.30-1.40/kWh and at the same time receive a subsidy of CNY0.42/kWh from the government for self-generation and self-consumption of DSPV power, the benefit for surplus DSPV power exported to the grid is the local benchmark on-grid tariff for desulphurised coal-fired power units, which is between CNY0.25-0.52/kWh (Ma, 2011), plus the government subsidy of CNY0.42/kWh.

Evidently, this policy disincentivises power export to the grid. And the greater the proportion of self-consumption is, the more revenue there is for the DSPV project. Indeed, the idea behind this feed-in tariff (FIT) scheme is to incentivise self-generation and self-consumption so as to reduce the influence of the DSPV power on the grid security as much as possible.

A policymaker interviewed told the author that this tariff scheme was based on the assumption that 80% is self-consumption and 20% will be exported to the grid. But the reality is that, due to various factors, self-consumption proportion was largely below 80% thus causing a negative impact on the IRR of the DSPV projects, which tempered the interest of investors in the projects.

3.3. Barriers to grid connection

Although government documents have called for the grid utility to provide timely grid connection again and again, and in response, the two major state-owned grid companies have committed to provide free connection services for DSPV projects and detailed streamline grid-connection permit process are provided, as of today the grid connection procedure is still cumbersome. For instance, a local grid company may require the installation of unnecessary facilities supplied from manufacturers nominated by the local grid company, and the prices of which are much higher than the market price. For instance, a DSPV project developer in Jiangsu province told a correspondent of the newspaper *China Energy* that when his customer, an owner of a small household DSPV system valued at CNY20,000, applied for grid connection, his customer was told that for grid security reasons, a current doubly-fed electronic monitoring equipment must be installed in the system. Further, the brand, the model, and the manufacturer of equipment were designated by the grid company. Since this equipment costs several thousand yuan, his customer had to give up the application for grid connection (Zhong, 2013).

A survey shows that in the leading DSPV provinces of Guangdong, Zhejiang, Jiangsu, and Shandong, it is not uncommon that residents, when going through grid-connection procedures for their rooftop PV systems, couldn’t find the staff in the local company responsible for carrying out the procedures of grid connection or the relevant staff are unaware of the grid-connection process and relevant policies.

There are probably two major reasons for this. Firstly, the grid connection policy is implemented through the grid companies’ management networks, namely their local branches or subsidiaries at provincial, city, or county levels. Policy implementation from the central level to the provincial and local grid companies takes time. Secondly, local grid companies are often more resistant to DSPV development, because DSPV generation reduces their electricity revenue and increases administrative costs.

3.4. Difficulty in obtaining financing

Undoubtedly, the above uncertainties have led to difficulty in obtaining financing from financing agencies. It has been difficult to obtain bank financing – banks are simply not comfortable lending to solar projects yet, with some banks reportedly even banning such loans as policy. This is evidenced not only from a speech of the NEA official, Liang Zhipeng, at a solar energy investment summit hosted in early 2014 which stated that many banks in China have restricted and even banned loans to distributed solar projects. At another conference when Chinese officials tried to matchmake between distributed solar developers and domestic banks, some bankers demanded the government first set up a safety net in case such investments turn into bad debts.

The attitude of bankers is evidenced by our interviews with two managers from the state-owned commercial banks. A manager interviewed said 'We bankers couldn't understand and see clearly the risks involved in the DSPV project. The best way for us at the moment is to wait and see.' Another manager interviewed said 'At the present stage, what we could evaluate is the eligibility of loan borrowers rather than DSPV projects per se when issuing loans. Large state-owned enterprises enjoying good credibility are surely our favourite customers'.

But the truth is in China most DSPV project developers are private businesses that lack the good credit to go to banks for loans. On top of that, loan terms in China are often short and interest rates high. After all, this is a country where real estate investments are supposed to offer quick returns of 10% per year and where factory owners like to see payback periods of 4 years or less before approving investments (Anders, 2014).

4. Recent policy changes since September 2014

According to the NEA's statistics, in the first half of 2014, the new installation of DSPV power was only 1 GW, achieving only 12.5% of the 8 GW target for the year (NEA, 2014c). Given the myriad constraints hampering a fast and smooth execution of distributed projects across China, the NEA published the Notice to Further Implement Relevant

Distributed Solar PV Policies on 2 September 2014, as a result of consultation with industry and government representatives. Subsequent to this, a few more documents were promulgated (Table 5.2).

Table 5.2: DSPV Policies passed between September 2014 and March 2015

Category	Time	Agency	Document
Scale and registration management	2014-09-02	NEA	Notice to further implement relevant distributed solar PV policies
	2015-03-16	NEA	Implementation scheme for the construction of solar PV projects
Tariff	2014-09-02	NEA	Notice to further implement relevant distributed solar PV policies
Market promotion	2014-09-11	NEA	Notice to speed up the construction of demonstration area of distributed solar PV power
	2014-11-05	NEA State Council	Notice to organise pilot solar PV projects for poverty alleviation
	2015-03-09	NEA State Council	Working scheme for the implementation of solar PV projects under poverty alleviation program

DSPV = distributed solar photovoltaic; NEA = National Energy Administration; PV = photovoltaic.
Source: Compiled by the author.

4.1. Motivate various DSPV project modes and coordinate rooftop resources

The notice states that measures suitable to local conditions to build DSPV stations are motivated by making use of waste land, barren hills and slopes, the construction of agricultural greenhouses, beaches, ponds, lakes, and other places to accommodate DSPV power on-site. With respect to rooftop resources, the document calls for the local governments to play their role in the coordination of the rooftop resources. The NEA has calculated that the rooftop area in the industrial areas at the provincial and above level amounts to 80 GW.

4.2. New 'pick one of two' policies

According to the notice, power generators when having their new projects registered, can choose from 'self-generation, self-consumption with excess sold to the grid' mode and 'all sold to the grid' mode. In addition, those which have already been registered as self-generation, self-consumption with excess sold to the grid mode can be changed to 'all sold to the grid mode in some circumstances. Under the 'all sold to the grid' mode, the on-grid tariffs for DSPV power are the FITs applied to LSPV projects registered after 1 September 2013, which are CNY0.90/kWh, CNY0.95/kWh, and CNY1.00/kWh depending on the location of the project, which are likely higher than the on-grid tariff plus CNY0.42/kWh.

4.3. Encourage all types of financing models

The notice stated that banks and other financing agencies are encouraged to provide preferential loans, to establish loan mechanisms based on the pledge of generation power and the property asset of DPSV projects, to build financing services platforms jointly with local government, and to provide preferential loans to poverty-relief DSPV projects, among others. Meanwhile, the provision of discount loan policies by local government and the adoption of all types of financing models such as leases, funds, individual credit, among others, are urged.

In response to the call from the central government, in addition to the CDB, other state-owned commercial banks that are unfamiliar with DSPV projects have progressively shown their interest in providing credit to DSPV projects. For instance, the Industrial and Commercial Bank of China and the China Merchants Bank (CMB) have both issued guidelines on providing credit to the solar industry. While the Industrial and Commercial Bank of China gives credit priority to rooftop DSPV systems, the China Merchants Bank provides moderate credit to the solar PV industry, leading electric power companies, the best DSPV projects, as well as grid-connect crystalline silicon PV projects in solar resources abundant areas.

4.4. Pilot DSPV projects under poverty alleviation programme

In October 2014, the NEA and the State Council Leading Group Office of Poverty Alleviation and Development unveiled a 6-year plan to use solar projects to provide power and income in poor regions. The first pilot projects were launched in 30 low-income counties in Anhui, Ningxia, Shanxi, Hebei, Gansu, and Qinghai provinces. The programme is to encourage solar power generating systems to be built on uncultivated hills and slopes, greenhouses, and agricultural facilities (NEA and SCLGOPAD, 2014; State Council and NEA, 2014).

On 9 March 2015, the NEA transmitted the Outlines for Compiling the Implementation Scheme of Solar PV Pilot Projects for Poverty Alleviation drafted by the China Renewable Energy Engineering Institute. The guidelines suggest three kinds of pilot solar PV projects under the poverty alleviation programme, namely, household PV projects, solar PV stations on barren hills and slopes, and agricultural facility PV projects. The business model suggested for rural residential and agricultural facility PV projects is that central and local governments provide subsidies to cover 70% of the upfront investment of the projects, while the remaining 30% is to be provided by 5-year term low-interest bank loans. For ground PV stations, the central and local governments provide subsidies to cover 40% upfront investment, the project developer bears 20% of the upfront investment, and the remaining 40% is to be supported by a 10-year term low-interest bank loan (CREEI, 2015).

4.5. Remove scale control on some DSPV projects

In the Implementation Scheme for the Construction of Solar PV Projects announced in March 2015, the NEA removed the scale cap on rooftop DSPV projects and on-ground DSPV projects, of which the power generated is fully self-consumed. This indicates that all generation produced by these projects will be eligible for the national government subsidy of CNY0.42/kWh.

4.6. Discussions

The recent policy changes could address some of the obstacles discussed in Section 3.

Firstly, with regard to rooftop resource problems, given that the rooftop ownership problem could not be addressed in the short run, the central government calls for the local governments to play their role in the coordination of the rooftop resources. This call was inspired by the Xiuzhou Model in Jiaxing city, Zhejiang province, a model recognised by the NEA. Under this model, at the initial stage of implementing DSPV programmes, the Xiuzhou District government investigated rooftop resources available in its jurisdiction, and established a rooftop resources database for DSPV projects. Meanwhile, by giving the rooftop owners preferential electricity prices, priority in access to new electricity capacity, priority in orderly power consumption, as well as in the assessment of DSPV application demonstration enterprises, the government managed to enter into agreements with these enterprises on the installation of DSPV systems on their rooftops.

In addition, the recently initiated pilot DSPV projects under the poverty alleviation programme are also an approach to address rooftop resource problems, not only because there are abundant rooftop resources in China's rural areas but also because the ownership of farmers' houses is clear. It was reported that during 1981–2000, the building space completed in rural areas reached 14.5 billion square metres, while the building space completed in cities was 20.1 billion square meters.

Secondly, as discussed in Section 3.2, one of the major barriers to DSPV deployment in China is the unattractiveness of the on-grid tariff for the excess DSPV power exported to the grid, and the unexpected low proportion of self-consumption. The new 'pick one of two' policy could help financing, causing fluctuations in on-grid tariffs. It is estimated that when the self-consumption proportion is lower than 30%, the 'all sold to the grid' mode has an advantage over the 'self-generation and self-consumption' mode when the commercial retail price is CNY0.90/kWh, the on-grid tariff for surplus DSPV power is CNY0.45/kWh, and the FIT applied to LSPV projects is CNY1.00/kWh.

Thirdly, it appears that the central government has increasingly been aware of the fact that access to financing is critical to the smooth development of DPSV in the country. Without project financing from banks or other financial institutions, the boom in DSPV will be slow to develop. However, Chinese commercial banks are cautious in financing DSPV projects. This probably arises from two reasons. Firstly, over the past decade these banks have provided a large number of loans to Chinese solar PV manufacturers, many of which went bankrupt due to the reduced overseas demand after the 2008–2009 global financial crisis. As a consequence, these banks may have lost confidence in this industry. Secondly, since China's DSPV market is still at its initial stage, banks are not familiar with it, particularly the risks involved in the development of DSPV projects.

It is in this context that Chinese policymakers are searching for financing sources other than bank loans. This is presumably helpful to solve the obstacles of obtaining upfront investment for DSPV projects.

5. Local policy incentives

Meanwhile, the NEA urges local governments at all levels to implement further financial support policies to stimulate the DSPV power market. According to incomplete statistics, as of May 2015, more than 100 government policy documents with regard to solar PV have been promulgated in at least 20 provinces, municipalities directly under the central government, as well as prefecture-level cities and county-level governments. The additional financial incentives are largely in the form of FIT, generation subsidy (an additional tariff per kWh), capital subsidies for the procurement of the hardware, or both (Table 5.3). Generally such additional incentives are designed specifically to promote DSPV. Hence, a DSPV project could possibly receive subsidies from four levels of administration. Take Yongjia County in Zhejiang Province as an example, the total subsidy for a demonstration DSPV project is CNY1.02/kWh from the central government: CNY0.42/kWh, CNY0.10/kWh from the provincial government, CNY0.10/kWh from the prefecture-level city government, and CNY0.42/kWh from the county government.

It is interesting to note that there are three types of provinces which provide relatively stronger incentives: (1) those which seek to absorb overcapacity of solar PV industry, for instance, Hebei and Jiangxi provinces; (2) those which are financially strong and have great power demand such as Guangdong, Shanghai, Shandong; and (3) those which seek to absorb overcapacity of the solar PV industry and have great power demand, such as Jiangsu and Zhejiang.

Table 5.3: DSPV Support Measures in Selected Provinces

Type	Province	Highlights
FIT	Hebei	CNY1.30/kWh for PV projects starting operating by the end of 2014, plus the size of the project is above 1 MW and without national subsidy; CNY1.20/kWh for similar PV projects which started operating by the end of 2015.
	Shandong	CNY1.20/kWh from 2013 through 2015
	Jiangsu	CNY1.30/kWh in 2012, CNY1.25/kWh in 2013, CNY1.20/kWh in 2014 and CNY1.15/kWh in 2015
	Guangdong	CNY1.00/kWh
Generation subsidy	Shanghai	Industrial and commercial customer: CNY0.25/kWh Resident and school: CNY0.40/kWh
	Zhejiang	CNY0.20/kWh
	Guangxi	For surplus generation power: CNY0.4552/kWh
	Jiangxi	CNY0.20/kWh for 20 years
	Hunan	CNY0.20/kWh for 10 years
	Jilin	CNY0.15/kWh
	Heilongjiang	CNY0.41/kWh
Capital subsidy	Shaanxi	CNY1.00/W
	Jiangxi	Under a special programme: CNY4.00/W for Phase I project; CNY3.00/W for Phase II project
	Hebei	CNY5.00/W (2014), CNY4.00/W (2015)

CNY = yuan; DSPV = distributed solar photovoltaic; FIT = feed-in tariff; kWh= kilowatt hour; MW = megawatt; PV = photovoltaic; W = watt.

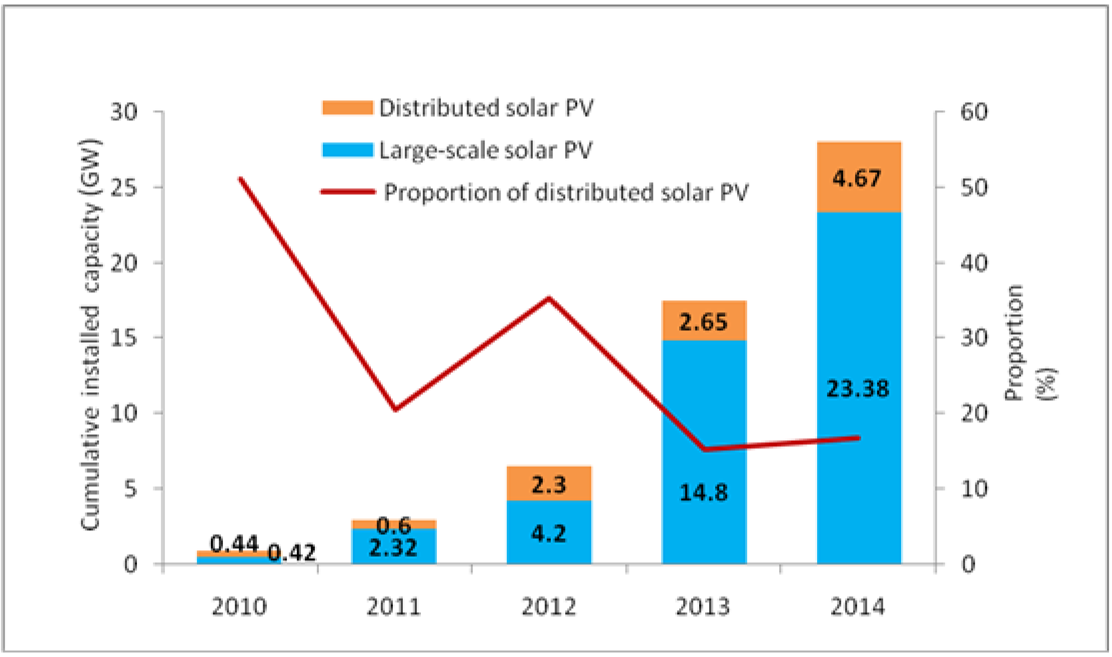
Note: While FIT here refers to the on-grid tariff (wholesale tariff) for DSPV power, generation subsidy is a grant

provided by the government based on the DSPV power generation.
Source: Compiled by author.

6. DSPV policy performance

As noted in Section 1, the performance of DSPV policies over the past 3 years falls below expectations. The share of DSPV in the total cumulative capacity of solar PV in the country was 35.38% in 2012, 15.19% in 2013, and 16.65% in 2014. In 2014 new installation of DSPV in 2014 was only 2.05 GW, lagging the target of 8 GW set by the government in the beginning of 2014 (Figure 5.2).

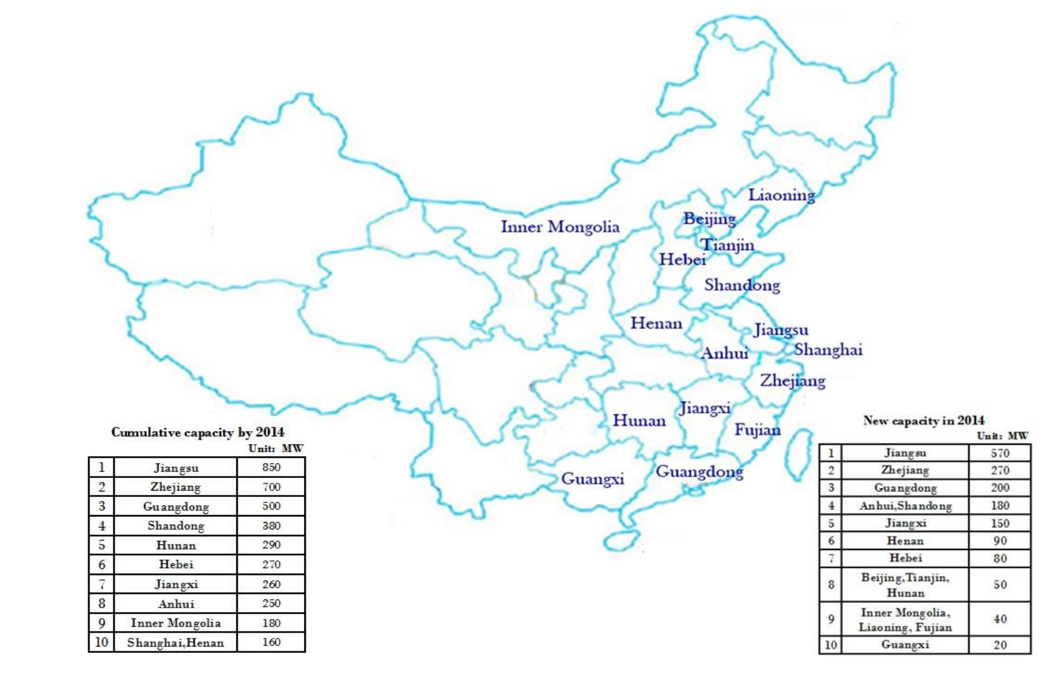
Figure 5.2: Installed Capacity of Solar PV in China, 2010–2014



GW = gigawatt; PV = photovoltaic.
Source: Author's compilation based on data from government websites.

The top three provinces in terms of cumulative installation are Zhejiang, Jiangsu, and Shandong (Figure 5.3), which accounted for 73% of the total in the country.

Figure 5.3: Cumulative and New Installed Capacity of DSPV in Leading Provinces, 2014



Cumulative capacity by 2014

Unit: MW

1	Jiangsu	850
2	Zhejiang	700
3	Guangdong	500
4	Shandong	380
5	Hunan	290
6	Hebei	270
7	Jiangxi	260
8	Anhui	250
9	Inner Mongolia	180
10	Shanghai,Henan	160

New capacity in 2014

Unit: MW

1	Jiangsu	570
2	Zhejiang	270
3	Guangdong	200
4	Anhui,Shandong	180
5	Jiangxi	150
6	Henan	90
7	Hebei	80
8	Beijing,Tianjin, Hunan	50
9	Inner Mongolia, Liaoning, Fujian	40
10	Guangxi	20

DSPV = distributed solar photovoltaic; MW = megawatt.
Source: Author's compilation based on data obtained from government websites.

7. Conclusions and policy implications

7.1. Conclusions

Since the second half of 2012, a series of policies have been put in place for DSPV deployment in China. Between the second half of 2012 and the first half of 2014, policies cover scale control and registration management, feed-in tariffs, subsidies, financing and fiscal incentives, market promotion by the establishment of demonstration areas for DSPV power generation, as well as power grid-connection, measurement, and settlement.

Unfortunately, the performance of these policies has not been satisfactory due to a number of constraints across the country. These include building (and/or rooftop) ownership problem, the unattractiveness of on-grid tariff, and the low proportion of self-consumption, the barriers to grid connection, and the difficulty in obtaining financing. Although new polices since September 2014 provided by the Notice to Further Implement Relevant Distributed Solar PV Policies issued on 2 September 2014 and subsequent documents do address some of the barriers and local governments have provided incentive measures, policy performance still fell short of expectations. Though the fact that new policies require time to bear fruit is part of the reason for the disappointing results, it is beyond doubt that many constraints on DSPV power deployment in the country still exist, which calls for further innovative policies.

7.2. Policy implications

7.2.1. Establish solar PV property registration system

In order to effectively protect the legal right of owners of solar PV systems or PV stations, a property registration system for solar PV needs to be established in the country. The owners of the solar PV property could either be the rooftop owners or any investment entities. In this way, the interests of the owners could be protected by China's Property Law. In this way, when urban reconstruction and enterprise transformation take place, the owners could be fully compensated. In the case where the government requires the enterprises to move to other locations, the owners of PV systems or PV stations could choose to require compensation for their economic losses from the government or to rebuild PV systems (stations) in new locations.

7.2.2. Increase subsidy for residential DSPV systems

As previously noted, contrary to market economies where residential and small commercial customers pay higher prices than larger commercial and industrial customers, in China commercial and some industrial customers pay high prices ranging from CNY0.80/kWh to CNY1.40/kWh, while residents pay lower, heavily subsidised prices ranging from CNY0.30/kWh to CNY0.50/kWh since the Chinese approach is intended to support key industries and maintain social stability rather than reflect costs as in market economies (Kahrl et al., 2011). Meanwhile, under the present subsidy policy, the subsidy for commercial and industrial solar projects is the same as for residential solar projects. That being said, it is not surprising that investors are more interested in commercial and industrial DSPV projects rather than residential ones.

A report issued by the Chinese Renewable Energy Industries Association (CREIA) in 2013 suggested that a typical residential building with a rooftop space of 1,000 square metres could set up an 80-kilowatt distributed solar system. Due to the small size of the system, installation costs would remain relatively high, around CNY720,000 ($116,000) in total. It was calculated that, with China's current electricity tariffs and subsidies, it would take about 11 years to generate enough power to recoup the initial investment, making the project economically unviable (CREIA, 2013). Given that the Chinese approach to retail electricity price will not be changed in the short run, it is recommended that higher subsidies or higher FIT for power exported to the grid be granted for residential PV projects.

7.2.3. Innovate grid connection mechanism

The existing grid connection process is built on a case-by-case basis. Grid utilities haven't yet built a proper grid-connection mechanism for DSPV power projects. It is suggested that a grid-connection licence mechanism similar to the network access mechanism in the mobile phone industry be employed. Under this mechanism, PV systems that meet the official quality requirements for grid connection will be issued a grid-connection licence. The users of such PV systems need to go through the registration process for grid connection of their PV systems. This innovative mechanism that shifts the grid-connection procedure from the PV power user side to the product side would undoubtedly help to address the grid connection barrier in the country.

7.2.4. Promote innovative business model and financing mechanism

The high upfront capital cost has been the major factor preventing a rapid market expansion of renewable energy market expansion, not only in developing economies, but also in developed economies. This is particularly true for DSPV projects, the growth of which has depended on strong government incentives. Currently the investment cost of a 1 MW size DSPV system for industrial and commercial customers is about CNY8 million, which is not a small amount for most companies.

The common business model for DSPV projects in China is the engineering procurement, and construction (EPC) model, under which at the construction stage of the projects, developers often lack funds and want to recover their investment as soon as possible. However, the core value of the DSPV project is at the operation stage when constant revenue streams could be generated. Therefore, for the long, healthy, and stable development of the Chinese PV market, it is necessary for the government to provide favourable policies for innovative business models and financing mechanisms for these projects.

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Chapter 6

Innovative Business Models and Financing Mechanisms for Distributed Solar Photovoltaic (DSPV) Deployment in China[17]

Sufang Zhang

Abstract

Following my report 'Analysis of Distributed Solar Photovoltaic (DSPV) Power Policy in China', this report looks into innovative business models and financing mechanisms for distributed solar photovoltaic power in China by reviewing existing literature and conducting interactive research, including discussions with managers from China's policy and commercial banks, and photovoltaic projects. It first provides a comprehensive review of literature on business models and financing mechanisms. Then, the paper looks into the rapidly evolving business models and financing mechanisms in the United States, one of the countries leading the deployment of DSPV. The emerging innovative business models and financing mechanisms for DSPV projects in China are next discussed. The report concludes that: (a) innovative business models and financing mechanisms are important drivers for the growth of DSPV power in the United States; (b) enabling policies are determinant components of innovative business models and financing mechanisms in the country; (c) innovative business models and financing mechanisms in the Chinese context have their advantages and disadvantages; and (d) support through government policies is imperative to address the challenges in the emerging innovative business models and financing mechanisms in China.

Keywords: Distributed solar photovoltaics, business model, financing mechanism, China, renewable energy policy

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1. Introduction

As discussed in my report entitled 'Analysis of Distributed Solar Photovoltaics (DSPV) Power Policy in China', China's government has put in place a number of incentives since the end of 2012 at both national and local levels, all of which have progressively addressed the constraints on DSPV's development. Nevertheless, there remain other constraints on DSPV power deployment. These, thus, require further innovative policies, particularly policies that support innovative business models and financing mechanisms for these projects.

The main questions addressed in this chapter are (a) What are the advantages and disadvantages of current business models and financing mechanisms for DSPV deployment in China? and (b) what types of government support should be provided to such models and financing mechanisms for DSPV deployment in China?

Towards this end, this chapter is structured as follows:

(1) Section 2 provides a comprehensive literature review on business and financing mechanism concepts, on the importance of business innovation and on DSPV-specific business model as well as DSPV-specific financing mechanisms.
(2) Given that the United States (US) is one of the countries that lead in DSPV deployment and has business models and financing mechanisms that have evolved rapidly over the years, Section 3 reviews business models and the financial mechanism in the US DSPV market.
(3) Section 4 turns to existing business models and financing mechanisms for DSPV project in China and discusses their advantages and disadvantages.
(4) Section 5 provides conclusions and policy implications.

In this research, a comprehensive literature study based on academic sources as well as non-academic sources such as sector reports, website articles, government documents, and presentations, attempts to set an initial overview of the different types of business models and financing mechanisms in both the United States and China. The author also attended several Chinese solar conferences and meetings.

2. Literature review

2.1. Business model and business model innovation

The first reference to the term 'business model' dates back to the 1950s (Bellman et al., 1957). Ever since the expansion of internet commerce in the mid-1990s, such a term has become a buzzword in media, business, and the sciences. Nevertheless, in theory and practice, there is yet no standard definition of the term. Literature has diverse interpretations and definitions of a business model, using it for a broad range of informal and formal descriptions to represent core aspects of a business.

A business model can be simple or complex. In the earlier days, a business model merely described the way a company makes money, or the means and methods used to earn revenue. In the last decade, the understanding of business models has become more complex. For example, Amit and Zott (2012) defined a business model as a system of interconnected and interdependent activities that determines the way the company 'does business' with its customers, partners, and vendors. In other words, a business model is a bundle of specific activities—an activity system—conducted to satisfy the perceived needs of the market, along with the specification of which parties (i.e., a company or its partners) conduct which activities, and how these activities are linked to each other. Osterwalder et al. (2005) maintained that a business model describes the rationale of how an organisation creates, delivers and captures value.

Whatever the definition, 'business model innovation' is considered to be a source of competitive advantage for companies. At its simplest, it demands neither new technologies nor the creation of brand-new markets. It is about delivering existing products that are created by existing technologies for existing markets. Because business model innovation often involves changes invisible to the outside world, it can bring advantages that are hard to replicate. As noted by a chief executive officer from IBM: 'In the operation area, much of the innovation and cost savings that could be achieved have already been achieved….It's not enough to make a difference on product scale or delivery readiness or production scale. It's important to innovate in areas where our competition does not act' (Amit and Zott, 2010).

2.2. DSPV-specific business model

Distributed solar photovoltaics power development has attracted the attention of academics given that there is a need for innovative business models to overcome the high upfront capital costs.

Richter (2013) argued that innovative business models for DSPV could drive the transformation of the electric power industry from one characterised by a small number of large projects to that consisting of a large number of small projects. Also, utilities can greatly benefit if they treat photovoltaics (PV) as a strategic gateway into the emerging distributed generation and service market. In addition, Richter argued that strengthening the business model innovation capabilities of a company is crucial to mastering changes in the external environment.

Huijben and Verbong (2013) examined the reasons for the rapid growth of DSPV power in the Netherlands. One reasons behind the PV breakthrough in the Netherlands, results show, has been the development of new business models where there is financial support---for example, in the form of tax deduction after investment---from both local and national governmental bodies. The link between institutional factors (regulation) and business models is very clear. The three main types of business models identified in the study are customer-owned, community shares and third-party models.

Asmus (2008) discussed the ‘community solar’ or ‘solar shares business model’. Under this model, multiple users can draw from a single solar PV array or a series of arrays on different buildings but operated as a single system, supplying clean electricity to community institutions (e.g., fire stations, community centres, among others) as well as residents. Participants, in essence, purchase shares of solar systems’ total output without ever having to pay the upfront costs or deal with technical installation challenges. Through collective participation, larger and more efficient projects can be done, leading to cost efficiencies.

According to Graham et al. (2008), current DSPV business models principally revolve around the ownership of PV systems by individuals and increasingly by third parties, rather than by utilities. However, they argued that as PV market penetration accelerates, utilities will become critical stakeholders, driven primarily by concerns about grid operation, safety, and revenue erosion.

Drury et al. (2012) found that third-party business models that started to appear in the United States in 2005 and have been operating in 20 states, are attracting new customers who are younger, less educated, and have a lower income than those investing in PV systems themselves.

2.3. Innovative financing mechanism for DSPV

2.3.1. Financing mechanisms for DSPV

Financing mechanisms for DSPV projects are means to raise funds from investors. Investors are buyers of real and financial assets and may be government, state-owned, or private sector entities. Examples of private sectors are corporations (electric utilities), retail investors (individuals), investment partnerships (hedge funds, private equity firms), financial intermediaries (banks, insurance companies, pension funds), and endowment (foundations and universities) (Donovan, 2015).

Private sector investors in DSPV power projects are *strategic investors* consisting of companies with an existing presence in the energy sector, or newly established with DSPV as their core activity. Unlike strategic investors, *financial investors* usually have no specific impetus for getting involved in the industry. The key difference between strategic investors and financial investors is their preference for real assets (physical properties such as solar PV systems) versus financial assets (less tangible than real assets such as a certificate of deposit at a savings bank). Financial investors typically maintain a portfolio of investments in more than one asset, including equities, fixed income, and real estate.

Investments in solar PV sector span multiple asset classes. Investors may, for example, buy shares in publicly traded solar PV companies (equities), lend directly to solar PV projects (fixed income), or have ownership in production facilities (real estate) (Donovan, 2015). Strategic investors do not have much financial resources at their disposal to scale up investments in DSPV project.

There is a growing awareness that more funding from financial investors will be necessary to meet DSPV investment goals. Many large, regulated financial intermediaries, however, prefer financial assets, as these assets tend to offer important benefits to investors---namely, scale (the capacity to absorb sizable capital inflows/outflows) and liquidity (frequent trading that allows securities to be bought or sold immediately) (Donovan, 2015).

2.3.2. Innovative financing mechanisms

The term ‘innovative financing mechanism’ can mean different things to different people. Broadly speaking, innovative financing mechanisms include not only mechanisms designed to raise funds but also mechanisms that improve the use of those funds (Gargasson and Salomé, 2010). They should involve a creative idea — the process of conceiving and implementing a new way of mobilising and channelling financial resources. This could be, for example, through the incorporation of new elements, a new combination of existing elements, or a significant change or departure from the traditional way of doing things.

2.4. Summary

The literature review demonstrates that the concept of business model varies in different contexts and for different people. However, what remains is that innovation in a business model is a source of any company's competitive advantage. Along this line, innovative business models for DSPV are an important driving force for the DSPV industry.

The literature review also shows that investors in DSPV projects consist of government, state-owned and private sector entities such as strategic investors, which prefer real assets such as solar PV systems; and financial investors, which prefer financial assets such as a certificates of deposit in savings banks. Investments in the solar PV sector span multiple asset classes.

There is a growing awareness that financial investors' funding is important in increasing DSPV investments. An innovative financing mechanism may take the form of new marketable funding instruments that can be used to attract public and private investment, and may make improvements in revenue and spending policies (UNEP, 2007).

3. Business models and financing mechanisms for DSPV projects in the United States

Based on the literature reviewed earlier, this study defines the *business model for DSPV* as the ownership structure of the DSPV project. Meanwhile, *financial mechanisms for DSPV* refer to the ways of mobilising and channelling financial resources during the construction phase of DSPV projects.

This section specifically looks at business models and financing mechanisms for DSPV projects in the United States.

3.1.Business models

3.1.1. Enabling legislation for business models

National legislation has enabled the development of particular types of business model in the United States, particularly the federal *solar investment tax credit* (ITC), the *modified accelerated cost recovery system* (MACRS), and *net-metering policy*.

(1) **Federal solar investment tax credit.** The ITC is one of the most important federal policy mechanisms to support the deployment of solar energy in the United States. It is a federal tax credit worth 30% of the cost for both commercial solar developers and residential consumers who install on-site solar systems. To take advantage of the credit, solar developers must have some tax liability. However, most of these solar developers lack sufficient tax liability to fully utilise the credit (SEIA, 2015; Mendelsohn and Kreycik, 2012; Burns and Kang, 2012).

The ITC was first applied between 1 January 2006 and 31 December 2007. In December 2006, the ITC was extended for one more year. The US Emergency Economic Stabilization Act of 2008 included an 8-year extension of the commercial and residential solar ITC. This suggests that unless modified, the 30% ITC will remain in effect until the end of 2016. The ITC has driven the growth of annual solar installation by over 1,600% since its implementation in 2006 – a compound annual growth rate of 76% (SEIA, 2015; Mendelsohn and Kreycik, 2012; Burns and Kang, 2012).

(2) **Modified accelerated cost recovery system (MACRS).** In the United States, businesses investing in solar projects may also claim accelerated depreciation deductions. Under the MACRS, businesses may recover investments in solar energy property through depreciation deductions on an advanced 5-year schedule (SEIA, 2015; Mendelsohn and Kreycik, 2012; Burns and Kang, 2012).

The ITC and MACRS can provide a tax benefit that amounts to more than half of the upfront installed cost of a solar system. Furthermore, a variety of state-level incentives exist to assist homeowners with upfront installation costs, such as renewable portfolio standards, cash or tax incentives, and favourable regulatory environments. With few exceptions, the states with significant solar markets were found to be the ones that offer meaningful solar policies.

(3) **Net-metering policy.** Net metering is a service to electric consumers wherein electric energy generated by electric consumers from an eligible on-site generating facility and delivered to the local distribution facilities is used to offset the electric energy provided by the utility to electric consumers. As a result, customers are only billed for their ‘net’ energy use.

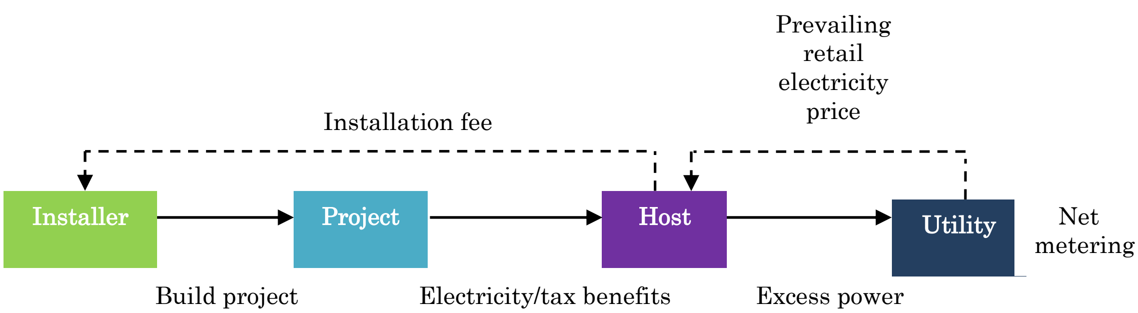
Currently, 43 states, Washington DC, and four territories are adopting a net-metering policy. The net-metering policy varies significantly between states (SEIA, 2015; Mendelsohn and Kreycik, 2012; Burns and Kang, 2012).

3.1.2. Business models for DSPV in the United States

(1) **Host-owned model.** In this model, the project is owned by the host – i.e., the owner of the property on which the projects sits (e.g., rooftop or adjoining land) – and the electricity the project produces is primarily for the said host. The system owner receives credit for any excess generation the solar system sends into the grid.

Figure 6.1 shows the tax benefits enjoyed by the host (Frantzis et al., 2008). On the other hand, this model's disadvantages include (a) high upfront and maintenance costs; (b) the risk of poor system performance, depending on what the engineering, procurement, and construction (EPC) contractor offers to guarantee the systems' performance; and (c) transaction costs associated with grid interconnection.

Figure 6.1: Host-owned Model

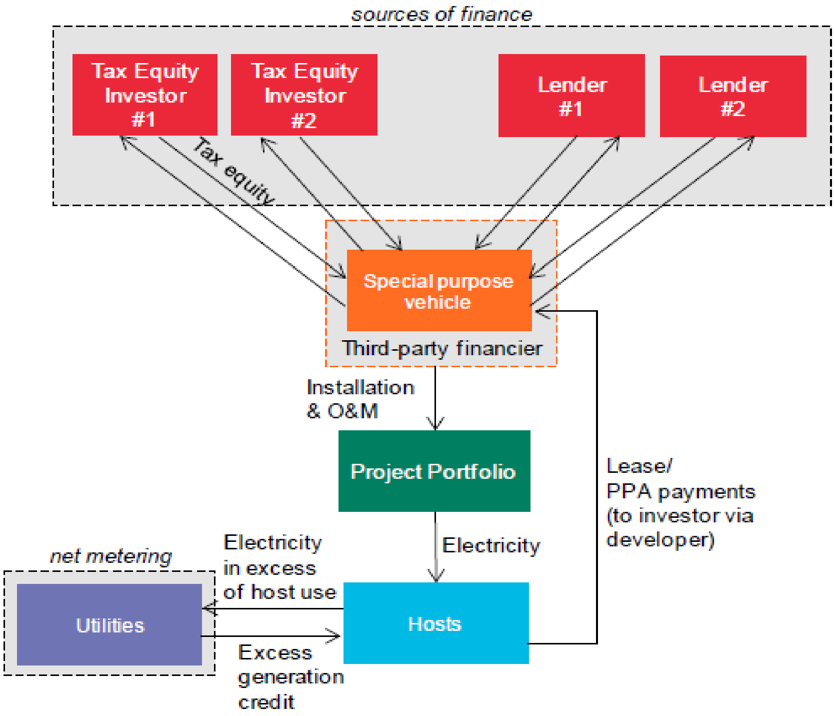


Source: Compiled by the author.

(2) **Third-party ownership model (SolarCity model).** Due to high upfront and maintenance costs, many residential and commercial users may not be able to afford the upfront cost of a solar system, do not want to assume risks associated with ownership, or prefer a low down payment option. The third-party ownership model (also called third-party financing model, or SolarCity model) offers customers the benefits of a solar system without the upfront cost.

In this model (Figure 6.2), a system owner (the third-party financier) handles customer origination, installation, engineering, maintenance and financing services for the PV system on the host customer's properties via a 10- to 25-year solar lease or a power purchase agreement (PPA).

Figure 6.2: Third-party Ownership Model



O & M = operation and maintenance; PPA = power purchase agreement.
Source: BNEF (2012).

In a solar lease, the host customer pays a specified amount every month regardless of the system's energy production. In a solar PPA, the customer pays a specified amount per kWh of generation; thus, the amount paid varies monthly as a function of power generation. Regardless of the type of contract, host customers typically pay a one-time, upfront down payment and monthly payments (BNEF, 2012; Davidson et al., 2015).

The advantage of this model is that third-party financiers could pool multiple leases and PPAs from multiple systems into investment portfolios to attract larger outside project investors (project finance lenders and tax equity[18] providers) who would not otherwise be interested in such small projects on a one-off basis.

Use of third-party ownership model for PV has increased over the past years from an estimated 10% to 20% in large US markets in 2009, to an estimated 65% of the US market

[18] 'Tax equity' is a term that is used to describe a passive ownership interest in an asset or a project, where an investor receives a return based not only on cash flow from the asset or project but also on a federal and state income tax benefits (tax deduction and tax credits).

in 2013 (GTM Research, 2013; GTM Research, 2014). Solar leases and PPAs are widely available in markets with: (a) favourable interconnection and net-metering policies; (b) legal or regulatory clarity for third-party solar ownership models; and (c) local financial incentives (Speer, 2012).

(3) **Community-shared model**. In this model, a solar garden (solar PV array or solar farm) with multiple subscribers is connected to the utility grid. Subscribers may purchase a portion of the power produced by the array of PV panels and receive a credit on their electricity bill. Utility customers within the solar garden's service area can include residences, businesses, local governments, non-profit organisations, and religious groups. Management of solar gardens' subscribers can either be via a limited liability corporation, a cooperative, or any for-profit or non-profit entity, including but not limited to solar developers, municipalities or other organisations in the community. An example of a solar garden programme managed by a limited liability corporation is that undertaken by the Clean Energy Collective (CEC), which has Xcel Energy as its utility partner (Monica Oliphant Research, 2012).

The CEC provides a member-owned model that enables individuals to directly own panels in community-shared solar projects that deliver reliable, commercial-scale renewable energy to an electric utility's grid. The utility's customers, including residences, businesses, and tax-exempt entities, can own or lease solar panels in the array without having to install panels on their own rooftop or property. Clean Energy Collective is responsible for subscriber management, where they sign up scribing customers and interface with them. Customers will receive a credit on their electricity bill for the energy produced by the PV system less a charge to deliver the energy to the subscribers' location (Funkhouser, 2015).

A CEC-developed metre, RemoteMeterTM, automatically transfers PV data to the utility's billing system to ensure appropriate metre crediting directly on the customer's monthly utility bill. Confirmation and reconciliation reports are provided to the utility and the subscriber to assure proper crediting and to permit historic tracking and auditing (Monica Oliphant Research, 2012).

3.2.Financing mechanisms

Financing mechanisms currently available to homeowners in the United States are grouped into three categories (Table 6.1): (a) traditional self-financing; (b) third-party ownership financing; and (c) utility and public financing. In addition, financing mechanisms available for DSPV project developers – such as crowdfunding – are emerging.

Table 6.1: DSPV Financing Mechanisms in the United States

Traditional Self-financing	Third-party Ownership Financing	Utility and Public Financing	Crowdfunding
• Cash purchase • Home equity loan (HEL) • Home equity line of credit (HELOC) • Cash-out mortgage refinancing (COMR)	• Model1 • Model 2 • Model 3	• Utility financing • Credit-enhanced and revolving loans • Property-assessed clean energy (PACE) financing • Crowdfunding	• Mosaic loan • SolarCity bonds

DSPV = distributed solar photovoltaic.
Source: Compiled by the author.

3.1.1. Traditional self-financing

Traditional self-financing options are widely available across the United States. They include cash purchase, home equity loans (HEL), home equity lines of credit, and cash-out mortgage refinancing.

Cash purchases are the least expensive option in terms of total dollars spent to acquire PV, as these do not incur any financing costs or solar financing company fees. However, the upfront cost of a PV system is significant and a likely barrier for most households. In addition, homeowners will need a sufficient federal tax liability to take full benefit of the federal ITC (Speer, 2012; PWC, 2011; Sanders, 2013).

Home equity loans, home equity lines of credit, and cash-out mortgage refinancing are provided by banks and credit unions across the United States and are likely to be the most available option for homeowners. However, accessing these financing options requires homeowners to have good credit, enough equity in their home to finance the system and, preferably, a home in an area with stable property values. Similar to cash purchases, homeowners must also determine whether they can take full benefit of the federal ITC (Speer, 2012; PWC, 2011; Sanders, 2013).

3.1.2. Third-party ownership financing (SolarCity financing)

Third-party ownership business model and *third-party ownership financing* are sometimes used interchangeably. Indeed, the third-party ownership business model embraces elements of third-party ownership financing; for instance, the host customer is financed through PPA/lease. However, the third-party ownership financing discussed in this paper refers to the financing mechanism in the development stage of a DSPV project rather than its operations stage.

The third-party ownership financing is also known as SolarCity financing as it was first created by SolarCity. In this model, SolarCity designs, finances and installs solar energy systems. It partners with banks, large corporations including Bank of America, Merrill Lynch, Citibank, Morgan Stanley, National Bank of Arizona and US Bancorp, among others, to create solar funds so as to finance its lease and PPA options. Among SolarCity's more well known financing partnerships was a USD 280 million fund created with Google in June 2011 to finance residential solar installations.

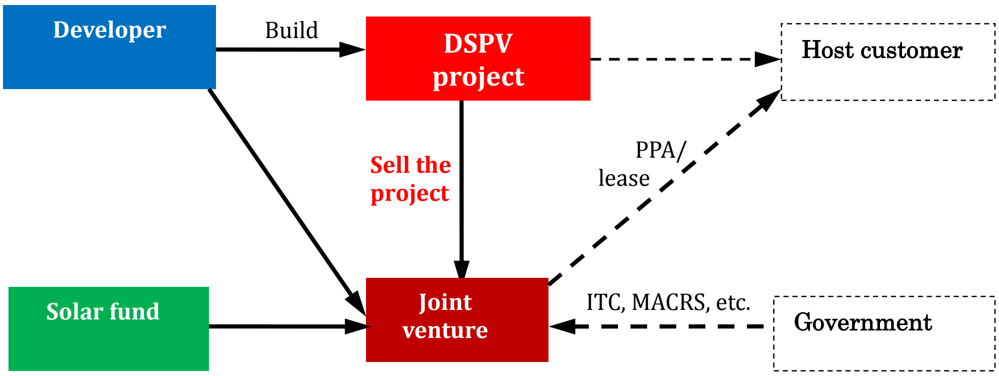
There are three models in the SolarCity's solar funds mechanism: joint venture model, sublease model, and sale leaseback model (SLSE, 2014).

Under the *joint venture model*, the developer (e.g., SolarCity) builds the project and sells it to the joint venture of the developer and the solar fund. The joint venture then signs a PPA or lease contract with the host customers (Figure 6.3). Under this model, the developer shares the upfront cost, the government subsidy, and tariff revenue with the Fund.

Under the *sublease model*, the developer builds and leases the project to the solar fund, which then subleases it to the host customers and transfers the lease rental to the developer (Figure 6.4). This suggests that the developer needs to bear the upfront cost alone. While the developer obtains the tariff revenue alone, the solar fund gets the benefits from the ITC and MACRS.

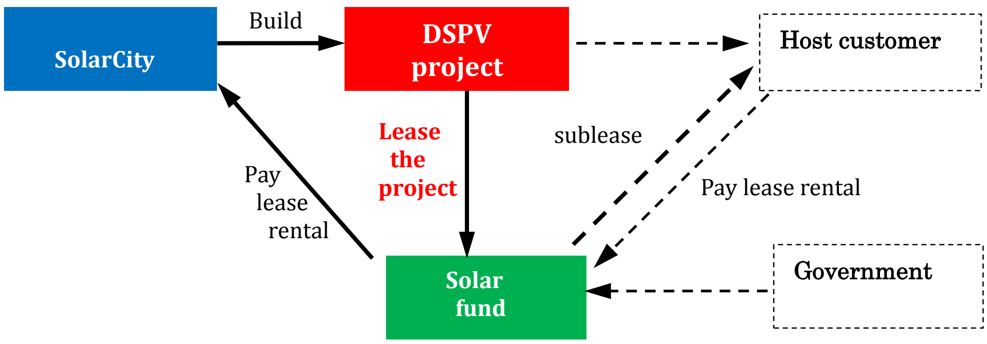
Under the *sale leaseback model*, the developer sells the project it built to the solar fund and then leases it back (Figure 6.5). Thus, the developer can recover its investment quickly and gain from power revenues, but cannot benefit from the government's subsidy (Liu, 2014).

Figure 6.3: Solar Fund/Joint Venture Model



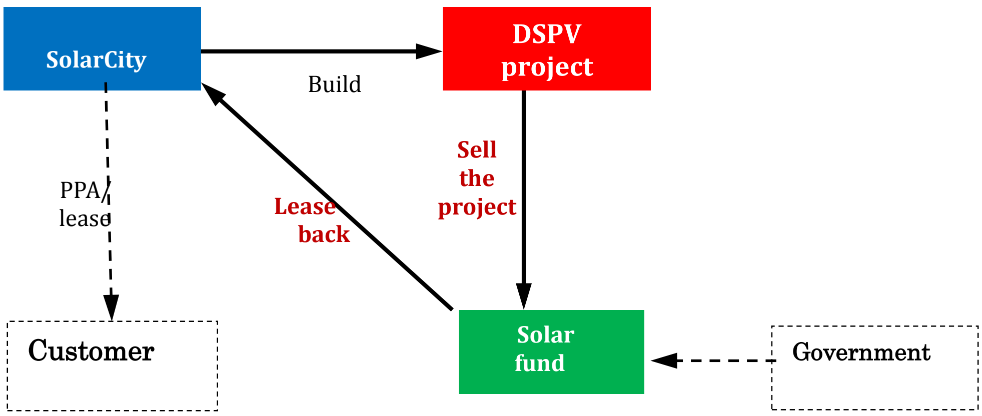
DSPV = distributed solar photovoltaic; ITC = investment tax credit; MACRS = modified accelerated cost recovery system; PPA = power purchase agreement.
Source: Compiled by the author.

Figure 6.4: Solar Fund/Sublease Model



DSPV = distributed solar photovoltaic.
Source: Compiled by the author.

Figure 6.5: Solar Fund/Sale-leaseback Model



DSPV = distributed solar photovoltaic; PPA = power purchase agreement.
Source: Compiled by the author. ‘

3.1.3. Utility and public financing

State and local governments, and utilities' three primary types of financing options are: utility financing (utility loans), public financing (i.e., credit-enhanced and revolving loans), and property-assessed clean energy (PACE) financing.

(1) **Utility financing**. Utility financing comes in two primary forms: *on-bill financing*, where customers repay the principal and interest on their electricity bill (or on a separate bill); and *metre-attached financing*, where the loan is tied to the metre/property. Because an on-bill loan is tied to the borrower, the homeowner must repay the loan when they move out of the property. In contrast, a metre-attached loan is underwritten to the property. Thus, if the property is sold, the buyer could potentially take over the loan payments. Only homeowners who are customers of utilities that provide or participate in financing programmes can access these loans (Speer, 2012; Sander, 2013).

(2) **Credit-enhanced and revolving loans**. Credit-enhanced loans are loans provided by either the state or local government, wherein it can, for example, offer a revolving loan on a portion of the principal as well as a credit enhancement for the private lender-provided portion of the loan. The state or local government portion often subsidises the net cost of the loan by providing a reduced interest rate. By dividing up the loan, the state or local government and lender share in the risk of default. Credit-enhanced programmes include loan loss reserves, subordinated debt, and interest rate buy-down (Speer, 2012; Sander, 2013).

Revolving loans, on the other hand, are loans to the homeowner that ideally replenish a pool of funds over time as the principal and interest is repaid. Revolving loans may be initially funded (and/or continually supported) by different methods, including appropriations, public benefit funds, alternative compliance payments, environmental non-compliance penalties, bond sales, and tax revenue. These loans can be combined with the credit enhancements (Speer, 2012).

(3) **Property-assessed clean energy.** Property-assessed clean energy financing is a public financing mechanism that has been utilised by state and local governments in the United States to fund PV projects since the 1990s. In areas with PACE legislation in place, governments offer a specific bond to investors and then turn around and loan the money to property owners for financing energy efficiency upgrades or renewable energy installations for buildings. The loans are repaid over the assigned term (i.e., somewhere

between 5 and 25 years) via an annual assessment on their property tax bill. One of the most notable characteristics of PACE programmes is that the loan is attached to the property rather than to an individual. Like other financial options introduced above, the primary benefit of PACE financing is the removal of significant upfront cost. This allows property owners to begin saving on energy costs while they are paying for their systems. On the other hand, the biggest challenge for PACE financing is that it is only available to a very few due to federal mortgage regulations and other concerns (Kaatz and Anders, 2014).

3.1.4. Solar crowdfunding

Solar crowdfunding is a new financing mechanism in the United States as well as in other countries. In solar crowdfunding, investment funds in solar systems are raised from individual investors through the internet. The companies that run solar crowdfunding platforms pool small investments from many individual investors, and the individual investors receive interest and are paid back in full over a specified number of years (Tongsopit, et al., 2013).

Mosaic is the company that pioneered solar crowdfunding platforms in the United States when it launched its online platform in January 2013, inviting individuals to invest as little as US$25 in specific solar projects while earning a 4.5% annual return on their money. The money pooled from investors serves as loans to small- and medium-scale project developers of commercial scale rooftop solar system at a 5.5% interest rate. Mosaic takes a 1% fee, while investors can expect a full return on their investment in 9 years.

In 2014, SolarCity, the country's leading installer of rooftop solar systems, began selling bonds online to ordinary investors. SolarCity would pay these investors with its income from the monthly solar electricity payments made by its customers (composed of homeowners, schools, businesses, and government organisations) in 15 states and Washington, DC (Cardwell, 2014).

3.3. Summary

The business models and financing mechanisms for DSPV power reviewed above, among others, have helped spur the solar industry's growth in the United States. Tax equity financing has significantly driven the expansion of US renewable energy over the past decade. Because most developers cannot utilise the tax credits and depreciation benefits themselves, they must incorporate third-party investors into the deals. This tax equity financing is primarily provided by banks, insurance companies, and a few large corporations. These provide the upfront capital in exchange for the tax credits and depreciation deductions associated with the development of solar energy projects.

Although each country has its own DSPV incentives, financial institutions and regulations, and electricity market structure, the business models and financing mechanisms in the United States may provide insights and lessons for China. Indeed, some of the emerging business models and financing mechanisms in China were drawn from the US experience, as will be presented in the next section.

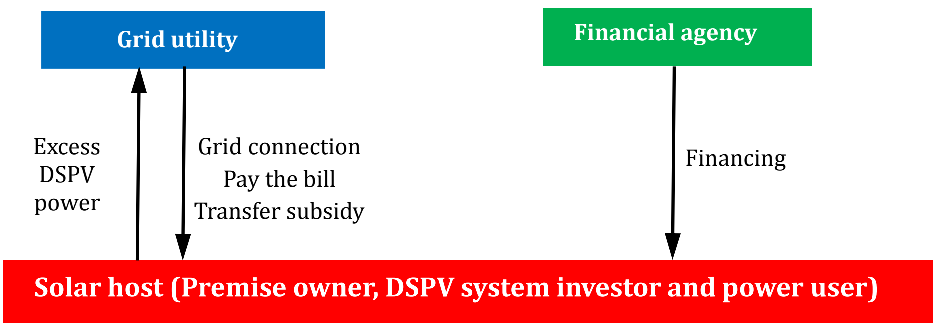
4. Existing business models and financing mechanisms for DSPV projects in China

4.1. Business models

4.1.1. Host-owned model

China's host-owned model is the simplest business model and is similar to that of the United States. In this model, the solar hosts purchase the solar system, have it installed on their rooftops or other solar sites, and use the power that the system produces, selling the excess power to the grid utility (Figure 6.6). In China, pioneer homeowners such as solar PV engineers and environment protection advocates are adopting this model.

Figure 6.6: Host-owned Model



DSPV = DSPV = distributed solar photovoltaic.
Source: Compiled by the author.

Box 6.1

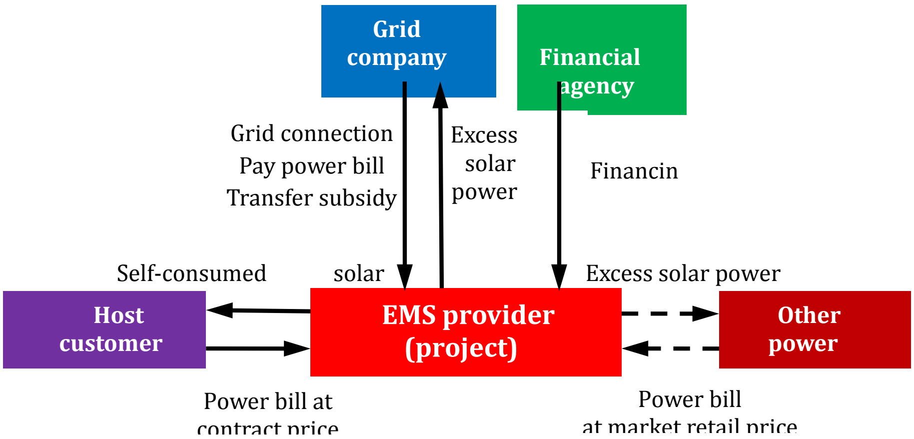
Case study: In October 2012, Ren Kai was the first in Beijing to install a solar system on the rooftop of his house. He paid CNY40,000 for his solar PV system and installed it himself. In 2014, the system generated 3,700 kWh in total, of which 80% was self-consumed and 20% was sold to the grid company. Subsidy from the state for this 3,700 kWh was CNY1,554 (CNY0.42/kWh), while the power revenue from the grid company was CNY300. Thus, the power bill saved was CNY2300, while the net income from the solar installation was CNY4,200. Payback time was 6 to 8 years (Source: Author's interview with Ren Kai).

The advantages of the host-owned model are: (a) The host customer saves on the electricity he uses; (b) The host customer gets the government subsidy of CNY0.42/kWh for all the power his PV system produces. Meanwhile, the disadvantages are: (a) the host customer has to pay the upfront cost, about 80% of which is the cost of the PV system (CNY40,000 or roughly $6,500); (b) the host customer has to look for an EPC contractor (solar PV developer) to design, procure, and install the solar PV system as well as provide a comprehensive O&M support, and runs the risk of poor system performance; and (c) the host customer has to bear the transaction costs associated with the grid interconnection.

4.1.2. Solar energy management service model

The *solar energy management service* (EMS) model is similar to the US third-party ownership model, and is also composed of the PPA model and lease model. Under the PPA model, the EMS provider owns and installs the PV system on the host customer's rooftop. The rooftop is offered to the EMS provider for free, and in return, the host customer receives solar power supply at a price 80% to 90 % lower than the market retail price. Thus, the host customer's revenue is in the form of savings on his electricity bill. Meanwhile, the EMS provider's revenue is composed of three parts: the discounted sales of the solar power to the host customer, the sales of the excess solar power to the grid and/or other end users at the local benchmark on-grid price for desulfurised coal-fired power, and the government subsidy (Figure 6.7).

Figure 6.7: The PPA Model



EMS = energy management service; PPA = power purchase agreement.
Source: Compiled by the author.

The second model, the lease model, is one where the host customer leases the PV system from the EMS provider and makes fixed monthly payments. Thus, the host customer's revenue under this model is the electricity bill saved, the sales of excess solar power to the grid, and the government subsidy minus the lease rental.

Table 6.2 shows the revenue model of the EMS provider and the host customer under the PPA model and lease model. Currently, the host customer prefers PPA over the lease model for two reasons:

(a) The PPA model is simpler than the lease model. In the PPA model, the host customer does not need to deal with grid connection or power sale issues.

(b) The PPA model provides a definite benefit to the host customer. In this model, the host customer's revenue is the discounted power supply (i.e., the saved electricity bill), which is relatively definite.

Table 6.2: Revenue Models Under PPA Model and Lease Model

ASSUMPTIONS	
Power generation in a specified month	100 kWh
Industrial and commercial power price	CNY0.85/kWh
Proportion of self-generation and self-consumption	80%
Government subsidy	CNY0.42/kWh
On-grid benchmark price for desulfurised coal-fired power	CNY0.40/kWh
Discount rate of sale price for host customer	90%
PPA MODEL	
EMS provider's revenue (①+②+③)	CNY111.2
① Sales of solar power to the host customer	100*80%*0.85*90% = CNY61.2
② Sales of excess solar power to the grid and/or end users	100*20%*0.40=CNY8.0
③ Government subsidy	100*0.42=CNY42.0
Host customer's revenue	100*80%*10%*0.85 =CNY6.8
LEASE MODEL	
EMS provider's revenue (lease rental)*	CNY111.2
Host customer's revenue (①+②+③-④)	
① Power bill saved	CNY6.8
② Sales of excess solar power to the grid and/or end users	100*80%*0.85= CNY68.0
③ Government subsidy	100*20%*0.40= CNY8.0
④ Lease rental	100*0.42=CNY42.0
	CNY111.2

EMS = energy management service; PPA = power purchase agreement.
Note: *Assumes that the lease rental under the lease model is equivalent to the revenue of the EMS provider in the PPA model.
Source: Compiled by the author.

However, several challenges exist for the EMS providers:

(1) **Liquidity risks.** Under the current on-grid tariff and subsidy policy, the payback time is generally 6 to 8 years for commercial and industrial PV projects and more than 10 years for residential PV projects. On the other hand, commercial banks tend to provide short-term (1–5 years) loan financing. Therefore, liquidity risks are present for EMS providers who rely on long-term returns to cover short-term loan expenses.

(2) **Risk of non-performance on the part of host customers.** In cases where the power generated by the solar PV system accounts for a very small amount in the total power consumption of host customers (industrial and commercial customers in particular), non-performance on the part of host customers (i.e., non-payment of the discounted solar PV power tariff) would have little impact on the revenue of these

customers. This suggests that the probability of non-performance of contract on the part of host customers could be great.

(3) **Other risks**. As discussed in the paper, 'Analysis on Distributed Solar PV (DSPV) Policy in China', although many incentive policies have been put in place, some of the policies that pertain to grid-connection services have not been well implemented. As such, there exist risks of non-grid connection of DSPV projects.

All in all, while the solar EMS model seems attractive to the host customer, it brings about many challenges to the EMS provider, who faces greater risks than the EPC company in the host-owned model.

4.2. Financing mechanisms

This section presents the main financing mechanisms for DSPV projects in China, with a particular focus on recently evolving financing mechanisms, and identifies the key challenges or problems under these mechanisms.

4.2.1. Conventional bank loan

On 22 August 2013, the National Energy Administration (NEA) and the China Development Bank (CDB) jointly promulgated the 'Opinions on Financial Services to Support Distributed Solar PV', which calls for China's policy and commercial banks, and other financing agencies to provide preferential and pledge loans, and to establish financing platforms for DSPV projects, while encouraging local governments to provide discounted loans (NEA and CDB, 2013).

A bank loan provided by Chinese policy banks such as the CDB, and the commercial banks is the main financing mechanism for DSPV projects in China. In response to the government's call and along with the growing confidence in China's DSPV industry, the CDB and other state-owned commercial banks have progressively shown interest in DSPV projects. For instance, both the Industrial and Commercial Bank of China and China Merchants Bank issued guiding opinions on providing credit to solar industry. While the Industrial and Commercial Bank of China is committed to give loan priority to rooftop DSPV system, China Merchants Bank is committed to provide appropriate loans to the best DSPV projects.

Nevertheless, as discussed in 'Analysis of Distributed Solar PV (DSPV) Power Policy in China' in this special issue, the complex sources of risk have created confusion among

Chinese banks regarding the predictability of risk and return on DSPV investments. This has greatly constrained the availability of bank loans. The current conventional bank loans are in the form of mortgages based on the borrower's credit, real estate or negotiable security, and normally short term (1–5 years) for DSPV. This appears to be not good enough for DSPV projects that derive their revenues from power generation during their operation period and have a life of 20–25 years. Also, the majority of the DSPV investors in China are private companies whose credibility is not as good as that of state-owned enterprises.

4.2.2. Local financing platforms

Due to the constraints on bank loans for DSPV projects, particularly for non- state-owned enterprises, the NEA and CDB jointly promulgated the establishment of local financing platforms where the CDB provides credit lines to finance eligible loan borrowers.

The platform is presumed to play the role of small credit provider and offers credit endorsements---an ideal financing form for medium- and small-sized companies (mainly non-state-owned enterprises) and individuals who cannot get access to bank loans due to limited credibility or financing capability.

However, a survey report issued by the Energy Research Institute under the NEA shows that this financing mechanism has not been performing well, as seen in the Sanshui case.

Along with two other enterprises, the management committee of Sanshui Solar PV Demonstration Area in Guangdong Province established a limited liability company to act as a financing platform for DSPV projects in the demonstration area. However, the CDB required the local government to provide financial guarantees to the loans the platform provided. Given that the requirement would undoubtedly put financial burden on the local government, the local government rejected CDB's request. As a consequence, the limited liability company had no other option but to require the shareholders of the company to provide financial guarantees in proportion to their shareholdings in the company (Xie and Gao, 2015). This suggests that no breakthrough in financing mechanism innovation has been achieved.

In addition, in 2014 the Chinese government initiated three types of solar PV projects under a national poverty alleviation programme; namely, household DSPV projects, solar PV stations on barren hills and slopes, and agricultural facility DSPV projects.

Meanwhile, the government has proposed that 5-year low-interest bank loans should be provided to rural residential and agricultural facility DSPV projects, and 10-year low-interest bank loan to ground PV stations in rural areas (CREEI, 2015).

4.2.3. Solar PV industry investment fund

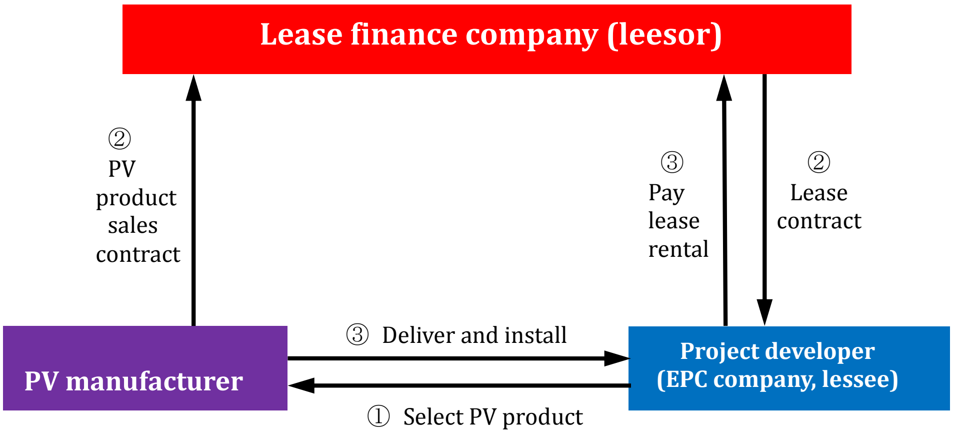
The solar PV industry investment fund is the fund set aside for the construction of solar PV projects. On 17 April 2014, the Beijing Guolin Harlyn Solar PV Industry Investment Fund was jointly initiated by Harlyn Capital and the PVP365.com website as originators, and several well-known enterprises such as limited partners at CNY 500 million. This fund not only makes equity investment in large-scale PV stations and DSPV projects but also provides value-added services along the whole PV supply chain, including coordinating relevant PV parties, introducing insurance, as well as searching for PV project buyers, among others.

To date, the fund has built cooperative relationships with several local governments, strategic buyers, policy banks, commercial banks as well as third-party asset management agencies; has completed the first phase of financing amounted to CNY 500 million; and has provided start-up capital to the best PV projects currently available. The capital will be withdrawn with an expected rate of return of between 10% to 20% once the PV projects are built. As such, the fund is expected to leverage CNY10 billion if it operates smoothly. Evidently, this financial mechanism helps to mitigate the problem in obtaining start-up capital for PV projects in China. Its major drawbacks, though, are its high financing cost, limited fund sources as well as risks involved.

4.2.4. Lease financing

As one of the most popular financing tools in modern business world, *financial leasing service* uses finance leases to leverage assets. A *finance lease* (or capital lease) is a method of raising finance to pay for assets, rather than a genuine rental. Lease financing is emerging for DSPV projects in China. For instance, the Ronglian Lease Company, a subsidiary company under the China Power Investment Corporation, provided financing lease to China Power Investment Corporation’s Yunnan Branch in the development of its 20MW DSPV project in 2014. In this model, the lessee (the project developer) selects the PV product (type, size, price, quantity, etc.), and the lessor (finance company) purchases the required PV product and leases it to the lessee, who then pays lease rentals for the use of the PV system (Figure 6.8).

Figure 6.8: Lease Financing/Direct Lease Model



EPC = engineering, procurement, and construction; PV = photovoltaic.

Source: Compiled by the author.

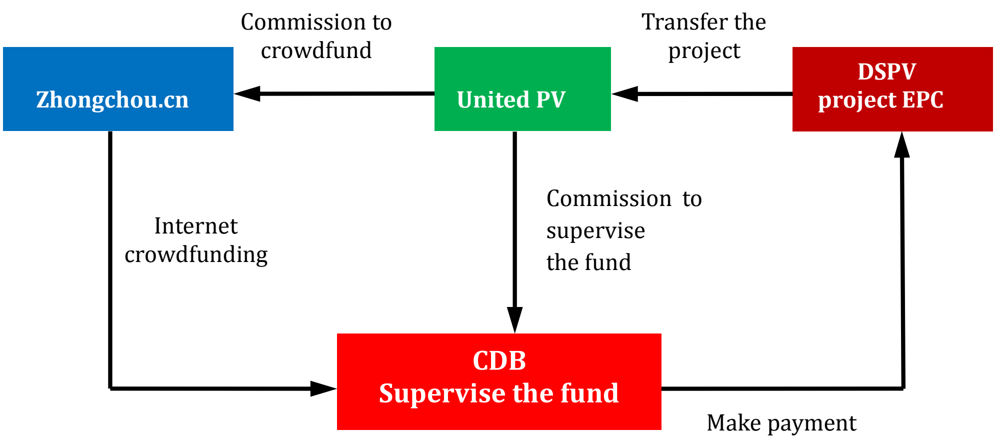
In this model, whether the lease rental could be duly paid is determined by several factors including the lessee's credibility, the PV system's quality, and the sale revenue of the PV system, which depends on grid connection and the host customer's credibility, among others. The problem is some of the well-designed policies have not been well implemented as discussed in 'Analysis of Distributed Solar PV (DSPV) in China'.

4.2.5. Internet financing

(1) **Equity crowdfunding.** United Photovoltaics Group Limited (United PV), a leading Chinese solar power plant investor and operator, pioneered solar crowdfunding in China. In February 2014, United PV raised CNY 10 million to develop the world's first megawatt-level distributed solar power project in Qianhai, Shenzhen, in cooperation with its two strategic partners through China's most influential internet crowdfunding platform – zhongchou.cn – a website that raises capital from the public.

As shown in Figure 6.9, United PV commissions zhongchou.cn to launch a crowdfunding activity and the CDB to supervise the fund. The CDB makes regular payments to the DSPV project constructor (the EPC contractor), who will then transfer the DSPV project to United PV once the project is completed.

Figure 6.9: United PV's Internet Fundraising Model



CDB = China Development Bank; DSPV = distributed solar photovoltaic; EPC = engineering, procurement, and construction.
Source: Compiled by the author.

However, there is concern about the legality of the United PV's equity financing. In March 2014, an official from China Securities Regulation Committee gave positive comments on United PV, but this does not suggest that this model has no legal problem. According to a report of T*he Diplomat*, Liu Zhangjun of the China Banking Regulatory Commission noted that crowdfunding and peer-to-peer lending are potential illegal fundraising models of particular concern. In these models, lenders often do not know their borrowers, and borrowers do not know their lenders. The internet funding companies are often unauthorised to engage in lending practices. Risk control and truth in advertising may be abandoned in some cases, leading to consumer fraud (Hsu, 2014).

(2) **SPI Solarbao: An innovative internet financing scheme**. In January 2015, Solar Power, Inc. (SPI), a vertically-integrated PV developer that focuses on the downstream PV market (including the development, financing, installation, operation and sale of utility-scale and residential solar power projects in China, Japan, Europe, and North America), launched the innovative online platform Solarbao.com in mainland China.

Under the SPI Solarbao model (Figure 6.10), the investor buys solar PV panels on the Solarbao's investment platform and then leases them to Solarbao. The minimum investment is as little as CNY 1,000. The panels bought by the investor will be installed in the power station for power generation via Solarbao. The then investor receives a monthly rental payment, which is technically from the value of the electricity produced by the investors' panels. He/she can retain ownership of the solar PV panels or choose to sell the panels to Solarbao after the lockup period, during which the he/she receives payback for the investment (Solarbao, 2015).

Figure 6.10: Simplified SPI's Solarbao Model

Source: Solarbao (2015).

Solarbao was reported to successfully raised CNY200 million for one of its wealth investment products named 'Orange No. 1' in just two months through its online platform and proved extremely popular with investors. Nevertheless, industry insiders, financial experts, or lawyers have raised certain concerns about the scheme (Yu, 2015).

The first concern is about its high rate of return. For one, the rate of return for its first two product series (one for pipeline PV projects; the other for completed projects) is around 10%. In financial experts' view, the rate is too high, as the internal rates of return for PV projects are 12% to 14% at most. They therefore cast doubt on the model's profitability.

The stability of the cash flow from its projects is also put to question since not all DSPV projects in China could be effectively connected to the grid, and government DSPV subsidies may not be appropriated in time (Solarzoom, 2015).

The second concern is about the investment's security. According to the Solarbao.com website, the investment is put into the company's account rather than into a third-party account (Solarzoom, 2015).

The third concern is about its legality. In the Solarbao model, Solarbao appears to be a leasing company that leases panels on behalf of investors. Theoretically, under a financing lease contract, the lessor's (principal's) income comes from the lease rental minus the charges and taxes paid by the leasing company (Solarbao). In the case of Solarbao, what the lessor receives is a monthly rental, which is technically the value of the electricity generated by the investors' panels. In this sense, Solarbao's products are financial rather than physical products. As such, it is an effective crowdfunding that has obscured the legality problem, as noted above (Solarzoom, 2015).

5. Conclusions and policy implications

Based on the literature review and the analysis of business models and financing mechanisms for DSPV in both the United States and China, this paper concludes that: (a) Enabling policies are determinant components for innovative business models and financing mechanisms in the United States; (b) Innovative business models and financing mechanisms drive the rapid growth of DSPV power in the United States; (c) While innovative business models and financing mechanisms for DSPV are emerging in China, there are challenges; (d) Government policy support is imperative to address these challenges.

5.1. Policy implications

5.1.1. Incentivise innovative bank loan mechanism

The prevailing bank loans in China still largely take the form of conventional mortgages based on the borrower's credit rating, real estate, or negotiable security. Also, banks usually provide short-term rather than long-term loans to PV project developers. This has greatly constrained the availability of bank loan financing. It is suggested that based on the very nature of PV projects, loans mortgaged on power bill and project assets as well as long-term bank loans be provided to DSPV projects. So as to incentivise banks to do this, tax incentives similar to the US tax credits needs to be provided. In addition, bank loan subsidies may also be provided to drive banks to provide lower interest loans.

5.1.2. Improve the regulation of solar PV internet financing

Internet financing provides an excellent channel for the public to make indirect investment in solar PV projects. However, since internet financing in China is at its early stage, it has been viewed with negativity or suspicion over the years. As a new concept in China, internet financing is neither regulated nor well defined. As a result, it operates on unclear legal boundaries that have prompted Chinese internet financing platforms to be cautious amid the government's strong stance against illegal fundraising (China Impact Fund, 2014).

Nevertheless, what is worth noting is that on 18 July 2015, 10 regulatory agencies jointly issued the 'Guidelines on Promoting the Healthy Development of Internet Finance'. These are the most formal and comprehensive guidelines issued by high-level Chinese state authorities in the area of Internet finance and is the first time central Chinese authorities have supported internet financing.

While the guidelines encourage innovation and support the steady development of internet finance, there are a few unresolved issues that must be clarified. For instance, the guidelines only mention equity crowdfunding, but do not address other forms of crowdfunding that have arisen in the market such as product and income rights crowdfunding. The guidelines state that unless otherwise specified, internet finance enterprises shall select qualified banking financial institutions as the depository entities that will manage client funds and the enterprise's proprietary funds under separate accounts. However, most internet finance enterprises currently use third-party payment institutions as their funds' depository. It is unclear whether 'qualified financial institutions' include these third-party payment institutions or not. If these are not, it is also unclear how one can bring the current market practice into compliance (Han Kun Law Office, 2015).

5.1.3. Push the implementation of direct power sale policy

The pilot programme of direct power sale to large users was implemented in limited areas in China after the electricity market reform in the early 2000s. The recent power sector reform launched in March 2015 will further open up the retail market, leading to the growth of direct sales deals between generators and large users. This would undoubtedly benefit distributed generators, including DSPV producers.

The low proportion of self-generation and self-consumption of DSPV power, and the low on-grid tariff policy for DSPV power have lowered the internal rates of return of DSPV projects. This, in turn, has undermined the enthusiasm of the DSPV project investors. Direct sale of DSPV power to end users, particularly to industrial and commercial end users whose power prices are much higher than the on-grid price of DSPV power, could increase the internal rates of return for PV project developers. This suggests that the Chinese government needs to come in and help open up the power retail market.

5.1.4. Push the implementation of the existing DSPV policies

Over the past years, many incentive policies have been promulgated both at central and local government levels. However, some of these policies have not been well implemented. This underscores the need for the government to give more importance to the implementation of existing policies as well as to address these implementation problems.

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Chapter 7

Exuberance in China's Renewable Energy Investment: Rationality, Capital Structure, and Implications with Firm Level Evidence

Dayong Zhang[19], Hong Cao[20] and Peijiang Zou[21]

Abstract

The 21st century has already witnessed phenomenal worldwide growth in renewable energy investments. China has been especially remarkable, surpassing both the US and the EU in 2013. Some recent facts, however, have raised the question of whether China's exuberant investment in renewable energy sector is rational. This study aims to contribute to the literature and to the debate in two ways. First, it tests the over-investment hypothesis based on the mainstream finance methodology (the Q model); second, it analyses the role of capital structure in the performance of China's renewable energy firms. Empirical results could then provide recommendations for policymakers on how to prompt sustainable growth in the renewable energy sector. Although based on China, this study's main findings could also contribute to policy design for emerging economies.

Keywords: Renewable energy, over-investment, Tobin's Q, capital structure, China

JEL: Q20, G11

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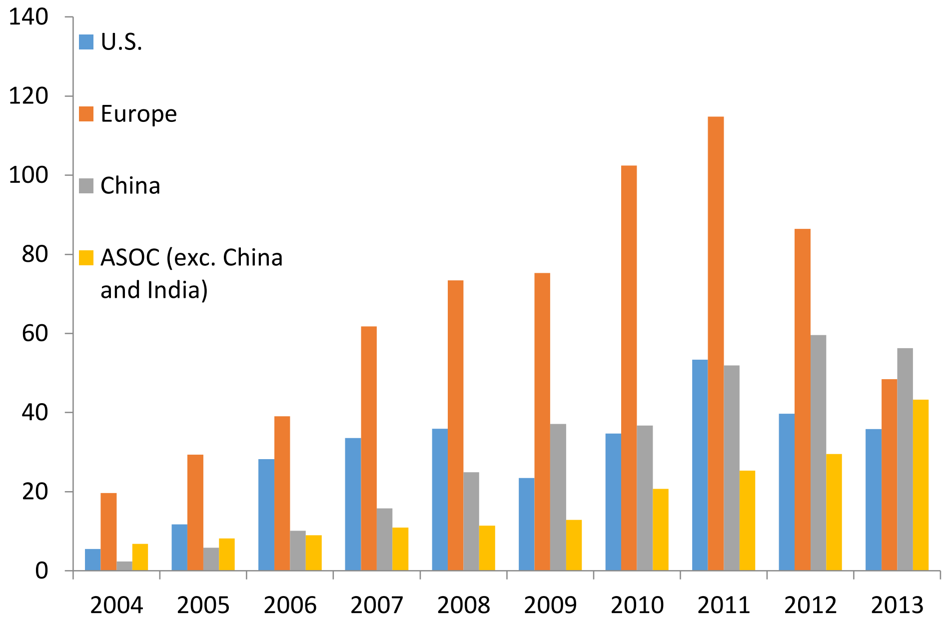
1. Introduction

Since the start of the new century, the world economy has been facing an ever-increasing demand for energy and the challenges of climate change. Although opinions still differ, the international community generally believes that global warming is a real threat and that reducing greenhouse gas emissions is necessary. This provides a natural demand for the development of the new energy sector (or clean/renewable energy) in place of traditional forms of fossil fuel energy.

The increasing demand for clean energy has led to a phenomenal growth in global investments in the renewable energy sector (Figure 7.1) over the last 10 years. As reported by Bloomberg New Energy Finance (2014), its average annual growth rate from 2005 to 2013 was approximately 24%. The growth pattern has clearly been more volatile since the 2008–2009 global financial crisis. Although developed countries are still the major contributors to renewable energy investments, developing countries have higher growth rates (27% vs. 15%) and have begun to catch up. In fact, China surpassed both Europe and the US and became the world’s top renewable energy investor in 2013. While European and American investments have been falling since 2011, the continuous growth of China and Asian and Oceanian countries (ASOC), excluding China and India) have shown strong potential.

As one of the biggest energy consumers in the world, China has been active in developing its renewable energy sector. In 2005, the National People's Congress of China passed the Renewable Energy Law (REL). The introduction of REL marked China's renewable energy development moving into the fast lane. Several supporting measures and regulation guidelines have been introduced to stimulate renewable energy development (see Wang et al., 2010; Shen and Luo, 2015; Zhao et al., 2014, for more information). Since then, the total investments in the renewable energy sector have grown rapidly, from $2.4 billion in 2004 to more than $59.6 billion in 2012 (Bloomberg New Energy Finance; UNEP). According to the International Renewable Energy Agency (IRENA, 2014), the expansion of China's renewable energy sector has been very aggressive. Apart from its already largest installed capacity of wind and hydroelectric power, China installed more solar photovoltaic (PV) capacity than the whole Europe in 2013.

Figure 7.1: Global Trend of New Investment in Renewable Energy: 2004–2013 (US$ billion)



ASOC = Asia and Oceania countries (excluding China and India); US = United States.
Sources*:* UNEP; Bloomberg New Energy Finance.

The enthusiasm for new energy investments in China has also been driven by mounting environmental pressures. China's greenhouse gas emissions have often been criticised for being one of the primary drivers of the world's increasing aggregates level of emissions (Peters et al., 2013). Policymakers in China have set up clear goals to reduce emissions. However, the size of its economy and its aim for high-speed growth have created a dilemma for the government and made it harder to achieve desired emission levels. Besides, the excessive use of coal (which comprises approximately 70% of China's energy use) has made the country one of the most polluted areas in the world. Nationwide air quality has continued to worsen, in turn leading to calls for improvements and action against further deterioration.

Another motivation for developing China's renewable energy sector is to ensure energy security (IRENA, 2014a). Behind China's fast economic growth in the last three decades is an increasing demand for energy. China has already become a net energy importer, depending heavily on the international market. Taking crude oil as an example, more than half of the oil that China consumes is imported. Discovering how to meet the increasing energy demand and ensure sustainable growth is of great strategic importance. The increasing needs for energy in the modern society and the exhaustible nature of most fossil fuels mean that developing the renewable energy sector and utilising alternative sources of energy are inevitable. In fact, China has abundant renewable energy resources (Shen and Luo, 2015), including hydro, wind, solar, biomass, and geothermal resources, which offer clean power sources and alternatives to fossil fuels. Developing the renewable energy sector is therefore necessary and also feasible to provide stable energy supply to the growing Chinese economy.

Recognising the strategic importance of the renewable energy sector, policymakers in China strongly support the development of renewable energy and have set clear targets. For example, China's 12th Five-Year Plan states that by 2015 and 2020, non-fossil fuel energy should account for 11.4% and 15% of the total primary energy consumption, respectively. Investment in the renewable energy sector will continue thriving with government support and subsidies.

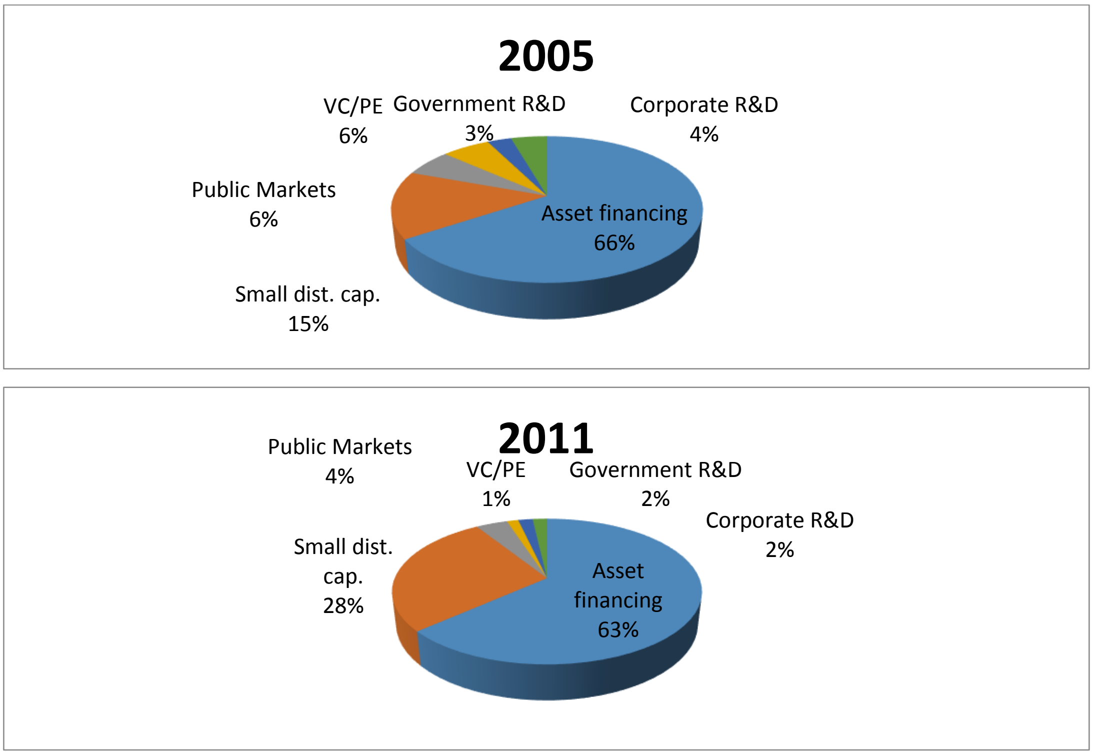
Although there is evidence (Zhao et al., 2014) of its many benefits, the boom in renewable energy investments is not without problems. Fast expansion can induce misallocation of resources and unbalanced industrial structure, which exposes the whole sector to high risks. For example, China's solar photovoltaic (PV) industry has experienced rapid growth since 2008 and China is now the world’s largest manufacturer of PV products. In 2011, China accounted for approximately 60% of global PV production. The industry is mainly export driven and depends heavily on the demand of the EU and North American markets. Policy changes in the EU and the US between 2011 and 2012 (reducing subsidies by the EU and imposing anti-dumping tax by both parties) caused sharp drops in market demand and clearly surplus of China’s PV industry. It eventually led to a substantial decline in the price of PV products. Similar issues also occurred in the wind power sector in China. Some recent dramatic increases of China’s wind power capacity may also be the consequence of possible overinvestment (Liu, 2013).

Investment in the renewable energy sector is risky, as this is a relatively new industry. This is probably why the global trend has been more volatile since the 2008 global financial crisis, potentially causing higher uncertainties in the market. Government subsidies and support can only provide the industry with short-run motivation, but not replace market mechanisms. It is observed that China's energy firms tend to invest irrationally (Tan, 2013). Similar concerns can also be extended to the fast-growing renewable energy sector. If overinvestment exists in this sector, it can cause a significant waste of resources and also do harm to the industry's development. Therefore, it is necessary to empirically investigate the story behind China's exuberance towards renewable energy investments.

The first goal of this chapter is therefore to empirically test for the rationality of renewable energy investments in China. 'Irrational exuberance', a phrase used by Greenspan (1996) in a speech given at the American Enterprise Institute during the dotcom bubble of the 1990s, is also used by Shiller (2000) to warn that the market might be overvalued. We borrow the concept here and extend the existing literature on testing for the free cash flow problem (Jensen, 1986) in China's renewable energy sector. Specifically, we use data from listed firms and adopt a standard finance methodology to investigate the overinvestment problem.

The Economic Research Institute for ASEAN and East Asia (2012) estimated that about US$1.5 trillion would be needed from 2009 to 2035 for investment in renewable energy in the East Asia Summit (EAS) region, providing a very positive outlook on the future of the renewable energy industry's development. The International Renewable Energy Agency (IRENA, 2014b) argues that financing renewable energy is getting easier and cheaper, but still with variations. Figuring out how to finance renewable energy investments at firm level is important not only to the managers, but also to the policymakers. Figure 2 compares new global investments in renewable energy by asset class in 2005 and 2011 (before and after the global financial crisis, respectively). Asset financing remains the major source of investment, accounting for around two-thirds of total investment. This number gets much higher in China where it shows more than 90% of asset financing (i.e., 95% in 2013, UNEP, Bloomberg New Energy Finance) and almost no public market and venture capital/private equity (VC/PE) investments in the renewable energy sector.

Figure 7.2: New Global Investments in Renewable Energy by Asset Class, 2005 and 2011



PE = private equity; R&D = research and development; VC = venture capital.
Sources: UNEP; Bloomberg New Energy Finance.

Zeng et al. (2014) provide a detailed overview of China's renewable energy investment structure and financing channels. They show that bank loans are the main financing channel with a total of CNY300 billion issued by banks by the end of 2011. Equity financing in the stock market has been popular since 2009, and by the end of June 2012 more than CNY20 billion had been raised by listed firms in this sector. The evolving of financing structure has brought an additional question: does capital structure matter in the renewable energy sector? If yes, what is the best form of financing in this industry? Answering these questions is the second main objective of this paper.

The remainder of this chapter is organised as follows. Section 2 provides a brief survey of relevant literature with more focus on introducing the background of renewable energy investments in China. Section 3 introduces the methods used in our empirical studies. Section 4 describes the data and Section 5 reports empirical results and discusses potential implications. The last section concludes.

2. Literature review

2.1. Renewable energy investment: a financial perspective

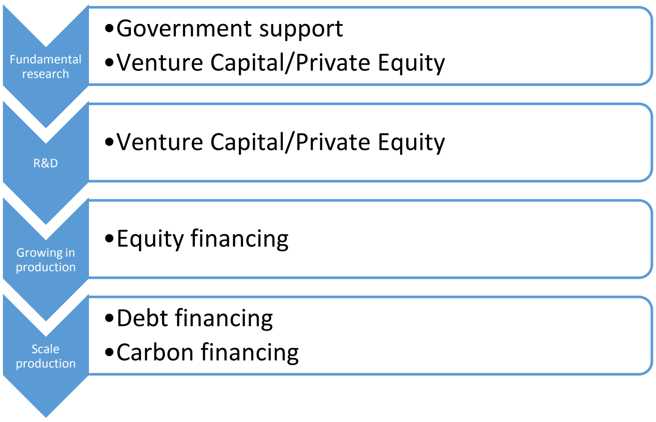
The significance of developing the renewable energy sector has attracted intensive attention in the literature. The world needs to invest heavily in renewable energy development[22] to reduce emissions and control global warming. The sustainability of such investments requires policymakers and firms to act optimally. Wustenhagen et al. (2007) introduce the concept of social acceptance of renewable energy, pointing to the needs to explore the factors that affect the financial community's acceptance of renewable energy innovation.

Wustenhagen and Menichetti (2012) propose a conceptual framework for renewable energy investment and emphasise the importance of this issue in the background of finance theory. Their starting point is that risk, return, and policy jointly decide the current investment levels. Understanding the market mechanism, especially from the investors' perspective (Dinica, 2006; Hamilton, 2009), is crucial to successful renewable energy investment. One of the key messages from these authors is incorporating financial principles to investigate issues in renewable energy investment. Common factors in finance theory, such as the risk-return relationship, diversification, heterogeneous investors, behavioural finance, and bounded rationality, are all important aspects alongside with policies driving renewable energy investment.

Given the environmental externalities of renewable energy in comparison to other conventional forms, policymakers need to be involved (IPCC, 2011); however, policy alone cannot secure sustainable renewable energy development. Subsidies and support from policymakers may change the risk-return relationship in the renewable energy investment sector and affect investors' behaviour as a result (e.g., De Jager and Rathmann, 2008; Burer and Wustenhagen, 2008). Banerjee (1992) introduces the notion of herding in financial markets. Subjecting investors in the renewable energy sector to herding can result in overinvestment/underinvestment. Due to agency problems (Jensen, 1986), investors and managers may have conflicts of interest, especially when there is policy intervention (which also may result in overinvestment).

[22] In 2009 the International Energy Agency (IEA) estimated that around US$400–500 billion annually in renewable energy investments would be needed until 2020.

Figure 7.3: Source of Financing in Different Stages of Renewable Energy Development



R&D = research and development.
Source: Complied by the authors.

Another interesting aspect of renewable energy investment is the source of financing. Different sources of financing may be applied to various stages of renewable energy development (Figure 7.3). Grubb (2004) suggests that public funds are needed in the early stages of clean innovation. Private sources are more likely to invest in firms with imminent profitability (Popp, 2010). Olmos et al. (2012) discuss the issue of supporting clean energy innovation via main financing instruments. They suggest that financing options may differ for different stages of innovation.

Different sources of financing raise the important question of whether capital structure matters to renewable energy firms. In the traditional financial theory, Modigliani and Miller’s (1958) theorem suggests that capital structure does not matter, meaning that the source of financing cannot affect the firm’s value. This relies on a series of strong assumptions, such as market perfection, no taxation, etc. The reality can be more complicated and especially relevant for the renewable energy sector. In fact, different financial instruments have been used in development stages because of financial motivations.

A recent study by Corsatea et al. (2014) on the financial sources and their impacts on Europe’s wind energy sector finds that the three main sources of finance are public support for research, development, and demonstration (RD&D), incentives for the production of wind energy, and access to credit. Their empirical results suggest that corporate debt is the primary factor supporting both wind technology research investments and wind turbine sales (with other sources playing more limited roles). Their study also suggests that compared to financial risks, regulatory risks are more influential.

2.2. Renewable energy investment in China

The recent surge in renewable energy investment in China and the strong government support for the sector's development have drawn considerable attention in the literature. Most of these works focus on one field, such as wind energy (for example, Wang, 2010; Zeng et al., 2013; Liu, 2013; Caralis et al., 2014) or solar energy (Zhao et al., 2011; Zhang et al., 2014; Zhao et al., 2015).

Liu (2013) builds a simple model to explore why firms may overinvest in wind power capacity. Firms have incentives to invest more since the additional (overinvested) part has value for holding scarce resources for future purposes. Zhao et al. (2011) provide an overview of the development of the solar PV industry in China. This industry has grown rapidly due to strong support from both the central and local governments. Expansion and speed may result in overinvestment. Caralis et al. (2014) evaluate the profitability of wind energy investment in China through Monte Carlo simulation. Lin and Yang (2014) measure the efficiency of the power industry in China and suggest that this industry's investment structure reform can improve efficiency. Zhang et al. (2014) evaluate the renewable energy policies of China's solar PV power generation sector via a real option model. Their results show an imbalance between government subsidies and investors' interests.

Wang et al. (2010) analyse China's renewable energy policies since the passing of REL in 2005. One of their concerns is that the current renewable energy generators have a low level of efficiency and a significant amount of waste. Zeng et al. (2014) provide a detailed overview of the current status of China's renewable energy investments and financing. They describe the current situation of general investment in renewable energy, investors, financing sources, and channels. Their study also discusses investment and financing issues and countermeasures via a comparative analysis based on the wind and photovoltaic power sector. In general, most of these existing studies about China are descriptive, providing readers with very important information and raising a series of interesting research questions.

3. Methodology

To answer the aforementioned questions, namely overinvestment and the role of capital structure, we take an empirical approach that follows mainstream financial literature. To avoid data availability constraints that negatively impact proper empirical research, we use publicly listed firms' information in our econometric models. Although publicly listed firms only reflect a fraction of the renewable energy industry, their size and importance are more relevant to policymakers. The development of the renewable energy industry will inevitably go through a process of restructuring and consolidation. Those key players will dominate the market and steer the direction of this industry. Therefore, evaluating the performance of these listed firms can provide critical information. Furthermore, regulations require these firms to make their financial and operational information publicly available, which is essential to our empirical modelling. The econometric models are given as follows.

3.1. Testing for overinvestment

A firm's decision to invest in a project often depends on its future profitability. Standard financial theory suggests that a rational investment decision requires that the project offers a future stream of cash flows that will generate positive net present value (NPV). Due to agency problems or other irrational managerial behaviour, especially when firms have free cash flows (FCF(Jansen, 1986), however, they tend to invest in negative NPV projects or overinvest. In other words, managers have strong incentives to invest rather than distribute the FCF as dividends, even when the investment opportunities are poor (with negative NPV).

Since the return on investment will be lower than the cost of capital, these investments will be at the expense of the shareholders. The rise of the FCF problem was against the backdrop of the 1970s oil crisis. Radical changes in crude oil prices generated significant free cash flows in the oil industry. As Jensen (1986) points out: 'The 1984 cash flows of the ten largest oil companies were US$48.5 billion, 28% of the total cash flows of the top 200 firms in Dun's Business Month survey.' The managers of these firms did not pay dividends to the shareholders; instead, they spent heavily on exploration and development (E&D) as well as diversification programmes to invest outside of the oil industry. McConnell and Muscarella (1986) find that these expenditures reduced firms' stock prices. It is also shown that the recovery rates for these investments only ranged from 60% to 90%.

To test the FCF hypothesis, it is important to first justify the firms' future investment opportunities. Empirically, Lang and Litzenberger (1989) propose to use Tobin's Q, the ratio of the market value of the firm's assets to their replacement cost, to distinguish between good and bad investment opportunities. The good opportunities also refer to projects with positive NPV. It is often said that a higher Tobin's Q indicates good opportunities and more productive investments, thus increasing market value. The model can be set as:

$$I_{i,t}/K_{i,t-1} = \beta_1 TQ_{it-1} + \beta_2 \left(CF_{i,t}/K_{i,t-1}\right) + \mu_i + \gamma_t + \varepsilon_{i,t} \quad (1)$$

Where $I_{i,t}/K_{i,t-1}$ stands for the investment divided by the beginning-of-period capital stock, $(CF_{i,t}/K_{i,t-1})$ stands for the cash flow scaled by the same capital stock, and TQ_{it} is the proxy for investment opportunities. This model also allows for the firm-specific and time-specific fixed effects through μ_i and γ_t. According to the above specification, Lang et al. (1991) propose using Tobin's Q as a proxy for investment opportunities and they set unit value as a threshold to test for the overinvestment (or free cash flow) hypothesis. For firms with a high Tobin's Q (TQ > 1), they are considered to be good investment opportunities. Adding more control variables Z, the empirical model can be set up:

$$I_{i,t}/K_{i,t-1} = \beta_1 TQ_{i,t-1} + \beta_2 \frac{CF_{i,t}}{K_{i,t-1}} + \beta_3 \left[\frac{CF_{i,t}}{K_{it-1}} \times I(TQ_{it-1} < 1)\right] + \delta Z_{it-1} + \mu_i + \gamma_t + \varepsilon_{it} \quad (2)$$

Where I(·) is a function that equals unit when the statement in the brackets is true and zero otherwise. The key indicator here is β3. If positive, it means that firms with lower investment opportunities will invest their cash flows; this suggests FCF problems or general irrational investments in China's renewable energy sector. Since there are lagging dependent variables, the dynamic panel data model (DPD) estimation (developed by Arellano and Bond [1991], Arellano and Bover [1995], and Blundell and Bond [1998]) will be adopted and estimated through the system GMM method.

One challenge for this test is finding the right proxy for future growth opportunities. Although TQ is a simple choice, it has been criticised (by Gilchrist and Himmelberg, 1995, for example) for being an inappropriate proxy. In our data, the average is 1.9 and majority of firms have TQs higher than 1. The renewable energy sector has probably been considered as having potential to grow, and the market prices are abnormally high (overvaluation). In this sense, using Tobin's Q is not feasible. To solve this problem, we use the growth rate of operational income as an alternative proxy, and consider the last period of operational income growth as a future growth opportunity. Similar proxies can also be found in Ding et al. (2010), who use sales growth in their empirical model.

3.2. The role of capital structure

Deciding how to finance renewable energy projects is also an important issue for policymakers. It is worth examining whether different sources of finance can have an impact on the success of investments. According to standard financial theory (Moligliani and Miller, 1958), capital structure does not matter. This result relies on the strong assumption of a perfect market, something that remains elusive in the real world. The source of financing (or capital structure) can also affect renewable energy investments and performance (see Corsatea et al., 2014, for example). Our study will follow this basic idea, but focus more on the renewable energy sector where firms' capital structure and other factors will be included in our regression analysis to identify their relative roles.

The main measure of a capital structure is the debt-to-asset ratio (total liabilities divided by total assets). To further investigate the detailed structure, we consider current liabilities and non-current liabilities separately, and the sources of debts (e.g. bank loans, corporate bonds) separately. The impact of capital structure on a firm's profitability results in the following econometric model:

$$\mathrm{ROA}_{it} = \beta_1 D_{it} + \delta Z_{it-1} + \mu_i + \gamma_t + \varepsilon_{it} \tag{3}$$

where ROA denotes return on assets, which measures a firm's profitability; D is the measure of capital structure, for example, the debt asset ratio; Z is a vector of control variables; firm-specific and time-specific fixed effects are captured by μ_i and γ_t.

4. Data

The data in this study were collected from the RESSET financial research database.[23] Using information from the three main financial media collections[24] and checking them carefully (similar to Broadstock et al, 2012), we have identified a total of 106 firms, which

[23] http://www1.resset.cn.
[24] They are Sina finance, Ifeng finance, and http://www.china-nengyuan.com/ssgs/, respectively.

got listed between 1990 and 2012, specialising in four fields (wind, nuclear,[25] biomass, and solar energy). Studying listed firms may limit the implications of our results, but the benefits are clearly significant. First, there is very intensive information available for this empirical study. Second, these firms represent the main players in the development of China's renewable energy sector and their behaviour can have profound impacts on the industry relative to other smaller firms.

The distribution of these firms and years of their initial public offering (IPO) are reported in Table 7.1. Given other financial variables and our sample size, the effective sample in our study spans 13 years, from 2001 to 2013 (unbalanced panel). These firms are further divided according to their main business' stage of production (position in the industrial chain). Seventy-one of them specialise in producing materials and equipment (upstream), 17 are generators/final users (downstream), and the remaining 18 firms have both businesses (mixed).

Table 7.1: Distribution of Renewable Energy Firms

Listed Time	Number of Firms	Wind	Nuclear	Biomass	Solar
1990–1999	38	15	8	10	9
2000–2005	26	9	10	2	9
2006–2010	34	8	12	2	13
2011–2012	8	1	0	1	6
Total	106	33	30	15	37

Note: Due to duplicate operations, the total number of firms is smaller than the aggregate number in each field.
Sources: RESSET database and authors' calculation.

Following the explanation in section 3, we have constructed key explanatory variables and reported them in Table 7.2. The construction of these variables and their definitions are similar to Lang et al. (1991). More descriptive statistics for firms in each field/stage of their main business are provided in the appendix.

[25] Nuclear is not normally considered as renewable energy source. However, our paper adopts a more general concept of renewable energy as compared to the traditional fossil fuel energy sector and therefore includes nuclear sector. We thank the comments and concerns raised by the ERIA work group meeting.

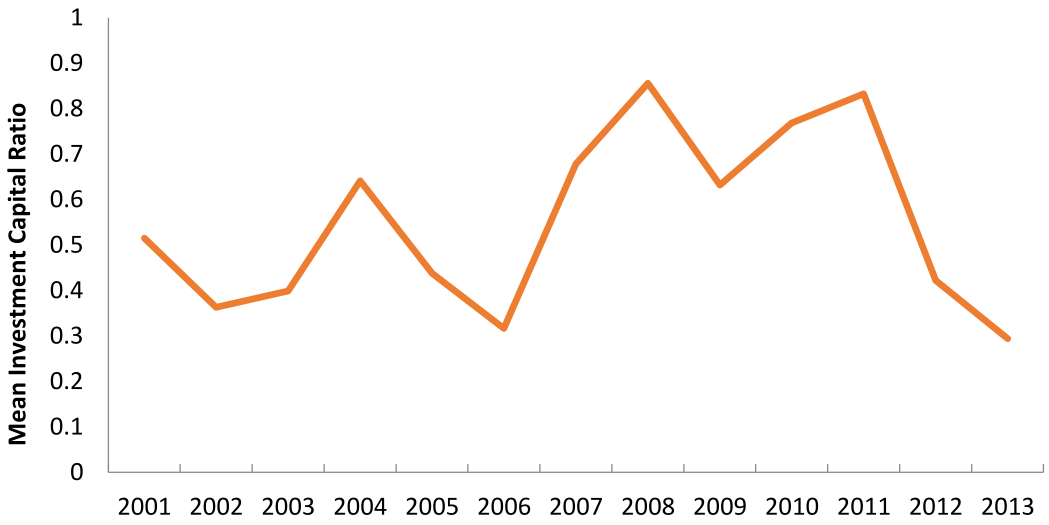
Table 7.2: Variable Definition and Descriptive Statistics

Variable	Description	Mean	SD.	Min	Max
IK	Investment capital (fixed assets) ratio	0.53	1.25	0.00	17.27
CFK	Cash flows scaled by fixed assets	0.43	0.84	-1.85	10.88
OCF	Operation net cash flow scaled by fixed assets	0.13	1.05	-12.47	9.73
DTA	Total liabilities divided by total assets	0.62	0.30	0.08	3.00
CTA	Current liabilities divided by total assets	0.47	0.25	0.07	2.88
NCTA	Non-current liabilities divided by total assets	0.15	0.18	0.00	1.59
SLTA	Short term loan divided by total assets	0.18	0.14	0.00	0.72
LLTA	Long term loan divided by total assets	0.12	0.17	0.00	1.59
BTA	Bond divided by total assets	0.02	0.05	0.00	0.58
CRTA	Commercial credit divided by total assets	0.20	0.20	0.00	2.65
SZ	Natural logarithm of total assets (RMB Yuan)	21.97	1.23	19.20	26.21
ROA	Net profit divided by total assets	0.03	0.05	-0.37	0.35
OIG	Growth rate of operational income	0.15	0.32	-1.56	2.20
AGE	How long the firm has been listed (years)	8.69	4.94	1.00	24.00
State	Shares owned by state (%)	16.49	23.77	0.00	88.58
FOWN	Shares of the largest shareholder (%)	36.96	15.50	3.62	73.67

Note: Investment is defined as cash paid for the construction of fixed assets, intangible assets, and other long-term assets. Cash flow is defined as operating profits plus depreciation of fixed assets. Sources: RESSET database and authors' calculation.

Figure 7.4 plots the annual average of investment capital ratio (IK) across sample firms. It is clear that the passage of REL in 2005 (actually implemented in 2006 in conjunction with a series of favourable policies) marked a booming period of investment starting in 2007. Although the global financial crisis depressed the investment capital ratio shortly thereafter, it remained at a relatively high level until 2012 when both the international environment and domestic development cooled down. The question here was whether this booming period indicated overinvestment in China's renewable energy sector; in other words, were these firms being rational?

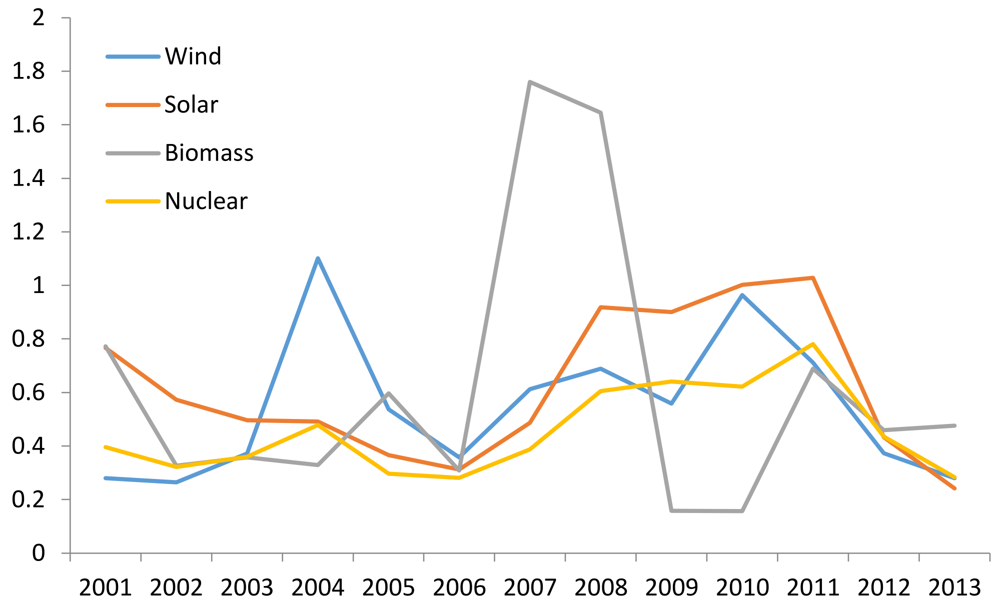
Figure 7.4: Investment Trend of Sample Firms (Annual Average Scaled by Capital, IK)



Sources: RESSET database and authors' calculation.

Further information from the four sectors (Figure 7.5) shows that the investment trend differs significantly. For example, in 2007 the biomass sector experienced a significant increase in investment capital ratio. Such dramatic changes may not reflect the market dynamics; rather they may signal that government policies have a strong influence on firms' investment decisions. Since the REL, an intensive set of policies related to the bio-energy sector in China were introduced in 2006 and 2007. For example, China's Department of Agriculture introduced the Agricultural Biological Mass Energy Industrial Development Program (2007–2015) in 2007 (see Zhang et al., 2009; Qiu et al., 2012, for more information). Of course, more formal analysis is needed to provide further information.

Figure 7.5: Trend of Investment (Annual Average Scaled by Capital, IK) in Sample Firms of Each Sector



Sources: RESSET database and authors' calculation.

5. Empirical results and implications

5.1. Testing for the overinvestment hypothesis

Given the econometric model setup discussed in section 3, we report the results for testing the overinvestment hypothesis in Table 7.3. All regressions are estimated using the system Generalized Method of Moments (GMM) method. There are six models listed for comparison, including industrial dummies and time dummies. The first interesting points across all models are the time dummies. They are roughly consistent with the illustrations in Figures 7.4 and 7.5.

Table 7.3: Testing for Overinvestment Hypothesis

	Model (1)	Model(2)	Model(3)	Model (4)	Model (5)	Model (6)
IK(t-1)	0.1936**	0.4175***	0.4071***	0.3358***	0.3351***	0.3481***
	(0.0885)	(0.0981)	(0.1384)	(0.0708)	(0.0842)	(0.0729)
CFK	-0.1128	0.1388	0.1947	0.1632	0.0900	-0.0062
	(0.1371)	(0.2482)	(0.3816)	(0.2077)	(0.1007)	(0.0886)
OIG(t-1)				-0.3954	-0.2766	0.1048
				(0.2955)	(0.2338)	(0.2472)
CFK*I(OIG(t-1)<0)					0.5051***	
					(0.1824)	
Inter_Nuclear						-0.4840
						(0.8954)
Inter_Biomass						2.8229*
						(1.4968)
Inter_Solar						-0.9100
						(2.0167)
Inter_Wind						0.8376***
						(0.2606)
SZ(t-1)		0.2731	0.3903	0.1495	0.1191	0.1644
		(0.2069)	(0.4320)	(0.2458)	(0.1835)	(0.1585)
DTA(t-1)		-1.2498***	-1.4225**	-1.0725	-0.8225	-1.1648
		(0.4712)	(0.6373)	(1.0791)	(1.0257)	(0.8036)
YD_2002	0.0420	0.2936	0.3025	0.1664	0.2244	0.1605
	(0.1030)	(0.2586)	(0.6806)	(0.2566)	(0.2537)	(0.3280)
YD_2003	0.1495	0.4650**	0.4567	0.3285	0.3369	0.2279
	(0.1371)	(0.2367)	(0.7025)	(0.2627)	(0.2420)	(0.3069)
YD_2004	0.2807	0.5848**	0.5170	0.4901	0.4488	0.3515
	(0.2482)	(0.2416)	(0.9594)	(0.3420)	(0.2794)	(0.4331)
YD_2005	0.0731	0.3710	0.4762	0.2615	0.2211	0.0595
	(0.1085)	(0.2775)	(0.4735)	(0.2846)	(0.2000)	(0.2563)
YD_2006	-0.0114	0.3311	0.3400	0.2246	0.1651	0.1028
	(0.1166)	(0.2504)	(0.4632)	(0.2881)	(0.1820)	(0.1999)
YD_2007	0.4010	0.7542**	0.6949	0.6075	0.5026	0.4504*
	(0.2882)	(0.3653)	(0.5985)	(0.5362)	(0.3551)	(0.2431)
YD_2008	0.5597**	0.6594**	0.5832	0.5515*	0.5012**	0.5182**
	(0.2342)	(0.2602)	(0.4789)	(0.3145)	(0.1997)	(0.2023)
YD_2009	0.3581*	0.3475	0.3167	0.2809**	0.2735*	0.2178
	(0.2145)	(0.2139)	(0.2821)	(0.1209)	(0.1456)	(0.2568)
YD_2010	0.4042***	0.4657***	0.4300*	0.3188**	0.2655**	0.3206**
	(0.1234)	(0.1532)	(0.2496)	(0.1533)	(0.1184)	(0.1341)
YD_2011	0.3544***	0.4806***	0.4362*	0.4174**	0.3380***	0.2942**
	(0.1177)	(0.1544)	(0.2343)	(0.1657)	(0.1110)	(0.1247)
YD_2012	0.0549	0.1565	0.1199	0.2195	0.2312**	0.0671
	(0.0457)	(0.1076)	(0.1381)	(0.1347)	(0.0975)	(0.1278)
Constant	0.2078***	-5.3988	-8.1331	-2.7043	-2.2471	-3.2175
	(0.0773)	(4.4208)	(9.8943)	(5.2837)	(3.8947)	(3.5819)
Industrial dummy			Y	Y	Y	Y
Observations	763	763	763	708	708	708
Number of firms	105	105	105	103	103	103
Sargan test	48.09	57.58	50.47	75.83	75.09	64.56
Sargan_pvalue	0.0194	0.0127	0.0264	0.0172	0.0157	0.0555

Note: Robust standard errors are in brackets. *** denotes 1% significance, ** for 5% and * for 10%. It is worth noting that our sample is unbalanced. Some variables (especially financial variables) are missing for some firms, therefore, the effective sample (and number of firms) used in each regression differ from each other. YD refers to year dummies. Please refer to table 7.2 for the definition of other variables.
Source: Prepared by the authors.

Clearly, investments in the renewable energy sector were significantly higher between 2007 and 2011. The second consistent finding across all models is the positive first-order autoregressive component. The coefficients on lagged investment capital ratio are all positive and significant at 1% level. It suggests that investment in China's renewable energy sector had very strong momentum during the sample period. This is, of course, consistent with the fact that China's overall investment in the renewable energy sector has been continuously increasing.

Debt ratio has been negatively related to firm investments as given in models (2) and (3), indicating a potential constraint to firms' investment decisions as the liability level increases the risk of insolvency. This effect disappears after growth opportunity is controlled. Firm size is positively associated with investment, though the coefficients are generally not significant.

The main testing results on overinvestment hypothesis can be found in models (5) and (6). Lagged OIG (representing growth opportunities) are generally insignificant, but the coefficients on interaction term CFK*I(OIG(t-1)<))[26] are significant and positive. The positive autoregressive part of investments may contribute to the insignificant relationship between growth opportunities and investment, but the significant positive coefficient on the interaction term clearly indicates that firms with fewer opportunities (but positive cash flows) tend to invest more. Consistent with Jensen's (1986) free cash flow hypothesis, firms tend to overinvest when the project they have may not be profitable, corresponding to the irrational behaviour of managers.

When we dissect the interaction term according to sectors, namely nuclear, wind, biomass and solar, the results show clear evidence that overinvestment differs significantly across sectors. The biomass coefficient is 2.8229 and the wind coefficient is 0.8376, both of which are statistically significant. Overinvestment and irrationality exist in these two sectors and are supported by our results. The conclusion of the nuclear and solar sectors is not so obvious.

It is important to be cautious when interpreting these results. Those interaction terms correspond to testing for free cash flow hypothesis; this means that firms with free

[26] We have also performed similar analysis using Tobin's Q. The results, as expected due to the limited number of Q being smaller than unit, are generally not significant and uninformative. Therefore, we do not report those results in this study.

cash flows but bad investment opportunities are still willing to invest. It is certainly irrational that managers should represent shareholders' best interests. Even without free cash flow problems (such as solar/nuclear), these firms can still aggressively invest as the industry shows strong upward trends (justified by the positive autoregressive term). The annual dummy effects have also shown a strong investment trend, generally in the renewable energy sector.

5.2. The role of capital structure in profitability

We have learned from financial theory that capital structure is relevant in a world with frictions such as the tax benefits of debt over equity, cost of bankruptcy, etc. It is therefore important to study how capital structure in China's renewable energy sector affects its performance. This part studies a series of financing instruments and their relative importance to a firm's capital structure. Starting from the standard debt equity ratio, or debt-to-asset ratio, as the total value of a firm's assets equals debt plus equity, we also studied the impacts of other forms of debts, such as current liabilities, non-current liabilities, total loans, corporate bonds, commercial credit, short-term loans, and long-term loans. The estimation results of a series of alternative models are reported in Table 7.4. All these models are estimated using fixed effect specification with yearly dummies included. To control for other firm-specific effects, the growth rate of operational income, size of the firm, and age of the firm are also included. The main explanatory variables have been delayed one period to reflect the fact that the previous period's decisions can affect this period's output. Using time delays also enables us to avoid endogeniety.

Table 7.4: The Role of Capital Structure

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
DTA(t-1)	0.0145			0.0133		
	(0.0095)			(0.0093)		
CTA(t-1)		0.0101			0.0085	
		(0.0116)			(0.0108)	
NCTA(t-1)		0.0246			0.0240	
		(0.0166)			(0.0161)	
BTA(t-1)			0.0143			0.0140
			(0.0381)			(0.0378)
CRTA(t-1)			0.0597**			0.0589**
			(0.0239)			(0.0245)
SLTA(t-1)			-0.0467**			-0.0489**
			(0.0228)			(0.0212)
LLTA(t-1)			0.0190			0.0192
			(0.0152)			(0.0144)
OIG(t-1)	0.0306***	0.0310***	0.0255***	0.0303***	0.0308***	0.0249***
	(0.0076)	(0.0077)	(0.0080)	(0.0076)	(0.0077)	(0.0079)
Age	0.0025*	0.0024*	0.0022	0.0032**	0.0031**	0.0030**
	(0.0014)	(0.0014)	(0.0014)	(0.0013)	(0.0013)	(0.0013)
State				0.0001	0.0001	0.0001
				(0.0002)	(0.0002)	(0.0002)
FOWN				0.0003	0.0004	0.0004
				(0.0005)	(0.0005)	(0.0005)
SZ	-0.0221***	-0.0224***	-0.0234***	-0.0228***	-0.0232***	-0.0244***
	(0.0061)	(0.0062)	(0.0062)	(0.0062)	(0.0063)	(0.0061)
YD_2003	0.0136	0.0135	0.0149	0.0130	0.0129	0.0143
	(0.0104)	(0.0104)	(0.0101)	(0.0107)	(0.0107)	(0.0104)
YD_2004	0.0064	0.0064	0.0045	0.0059	0.0059	0.0040
	(0.0115)	(0.0115)	(0.0116)	(0.0118)	(0.0118)	(0.0119)
YD_2005	-0.0078	-0.0076	-0.0076	-0.0079	-0.0076	-0.0074
	(0.0113)	(0.0113)	(0.0113)	(0.0115)	(0.0114)	(0.0114)
YD_2006	0.0154**	0.0154**	0.0149**	0.0164**	0.0166**	0.0165**
	(0.0069)	(0.0070)	(0.0068)	(0.0074)	(0.0074)	(0.0072)
YD_2007	0.0272***	0.0279***	0.0275***	0.0283***	0.0292***	0.0291***
	(0.0090)	(0.0089)	(0.0087)	(0.0087)	(0.0084)	(0.0082)
YD_2008	0.0019	0.0024	0.0042	0.0026	0.0033	0.0055
	(0.0093)	(0.0090)	(0.0085)	(0.0099)	(0.0096)	(0.0090)
YD_2009	0.0163**	0.0165**	0.0167***	0.0173***	0.0176***	0.0180***
	(0.0065)	(0.0064)	(0.0062)	(0.0066)	(0.0065)	(0.0062)
YD_2010	0.0267***	0.0266***	0.0253***	0.0278***	0.0277***	0.0265***
	(0.0069)	(0.0070)	(0.0068)	(0.0071)	(0.0072)	(0.0069)
YD_2011	0.0105	0.0105	0.0100	0.0115	0.0116	0.0111
	(0.0078)	(0.0078)	(0.0078)	(0.0080)	(0.0079)	(0.0079)
YD_2012	-0.0100	-0.0100	-0.0082	-0.0098	-0.0098	-0.0080
	(0.0069)	(0.0069)	(0.0065)	(0.0069)	(0.0069)	(0.0066)
Constant	0.4599***	0.4684***	0.4965***	0.4567***	0.4653***	0.4940***
	(0.1226)	(0.1241)	(0.1218)	(0.1213)	(0.1234)	(0.1201)
Observations	843	843	843	843	843	843
R-squared	0.1287	0.1294	0.1502	0.1314	0.1323	0.1539
No. of firms	103	103	103	103	103	103

Note: Robust standard errors are in brackets. *** denotes 1% significance, ** for 5% and * for 10%. YD refers to year dummies. Please refer to table 7.2 for the definition of other variables.
Source: Prepared by the authors.

Given that the measurements of the capital structure may overlap, we have constructed three alternative models. The overall debt-to-asset ratio is not significant and shows that capital structure may not be relevant. When we further divide the gross debt, there are some interesting results. Short-term loans are not good for ROA, but commercial credit has a significantly positive impact on the profitability of firms. Firms which rely more on short-term loans may suffer from stronger constraints and be more affected by interest rate volatility. Given that short-term loans normally require longer periods to realise their full potential, firms may have to give up more profitable projects. Commercial credit is mainly credit between firms. For example, one firm may delay payments to another firm or collect received deposits. It reflects not only a firm's credibility, but also its long-term profitability; therefore, the positive relationship with ROA is not surprising.

It also suggests that the government has a strong influence on the decision-making of state-owned firms or those with a strong state presence in their ownership structures. Therefore, the shares of state ownership have also been included in Figures 7.4 to 7.6 to check this issue. The results are generally positive but insignificant; this indicates that state ownership does not necessarily have any significant impact on the renewable energy sector's performance even though it might have strong influence on the industry's general development. An additional variable related to the ownership structure is also included, representing the importance of the first biggest shareholder. The impacts are also insignificant across all model specifications.

The important things affecting the profitability of China's renewable energy firms are growth potential (measured by the last period growth rate of operation income), the age of the firms listed in the stock market, and the individual firm's size. Firms with better growth potential tend to make more profit; newer listed firms tend to make less profit; and smaller firms tend to make more profit[27]. These results are intuitively sensible. In order to be listed in the stock exchange, firms must show strong potential and this momentum may continue, especially with more capital available when getting listed. Smaller firms with growth potential may be more risky, but they can generate higher returns for investors. Furthermore, significant positive coefficients have been seen in the year dummies in 2006–2007 and 2009–2010. The first two years positive coefficients are obviously due to the

[27] It is worth noticing that the interpretation of the size effect only applies to the listed firms. Smaller unlisted firms may behave differently. We thank a referee for this important comment.

passage of REL in 2005. China's stimulus packages in response to the 2008–2009 global financial crisis, which emphasise the role of the renewable energy sector (Zhang, 2008), contribute to the positive coefficients in 2009–2010.

5.3. Firms' position in the industrial chain

Arguably, downstream firms should behave differently from upstream firms.[28] China's renewable energy firms, as described in Table A2 (appendix), mainly concentrate on raw materials and equipment manufacturing (upstream). There are 71 firms in this group, accounting for around two-thirds of all renewable energy firms. If we add those with mixed production lines, this share increases to about 88%. The distribution of these firms creates trouble when negative shocks arrive. For example, the anti-dumping duty and decreased demand from the EU and the US in 2012 have significantly shaken the renewable energy sector. If we consider China's non-listed firms (which are generally smaller and more likely to concentrate on upstream of the industrial chain) the significant negative impact of the international shock is not surprising at all. Developing the renewable energy sector following this strategy may also be problematic since the upstream firms normally have lower levels of technology and thus lower profit margins (relative to the downstream firms). The lower entry barrier to this group can easily cause irrational overinvestment or intensive competition, essentially squashing out the profit.

In this subsection, we test the overinvestment hypothesis and role of capital structure following exactly the same strategy as the previous two subsections. Similar to model (6) in Table 7.3, we replace the industrial dummies in the interaction terms with upstream dummies, mixed dummies, and downstream dummies. All other control variables and econometric setups remain the same. The interaction term coefficients of these new dummy variables with CFK*I(OIG(t-1)<0) are 0.4344 (0.4122), 0.2927 (0.9133) and 0.5287***(0.1943)[29] for upstream, downstream, and mixed, respectively. The fact that the mixed coefficient is the only significant one suggests that only mixed firms (with materials, equipment, and appliance production) have irrational expansion (overinvestment even when there are no clear growth opportunities when free cash flows are available). The

[28] We would like to thank the participants of the ERIA work group meetings for their invaluable comments and suggestions for dividing firms according to their positions in the industrial chain. This enables us to provide more insightful information to the questions in this paper.
[29] The robust standard errors are in brackets and *** represents a 1% level of significance.

interesting result is that neither the downstream firms nor the upstream firms have overinvestment problems. Firms that tend to have overinvested problem if their business cover both upstream and downstream in the industrial chain.

Table 7.5 reports the role of capital structure in upstream, mixed, and downstream firms’ positions in the renewable industrial chain. It is clear that we can see quite significant differences between these three types of firms. The results of these upstream firms are very similar to the general conclusions in the previous section; the short-term loan is shown to be negative but insignificant. For the other two groups of firms, however, capital structure (or more specifically, the source of financing) matters. For mixed firms, commercial credit is no longer significant. These firms have combined the upstream and the downstream into one group. Commercial credit, which normally applies to firms trading with their partners either upstream or downstream, is now within the firms and therefore has no significant impact.

The role of capital structure for downstream firms is statistically significant. There are more factors shown to have significant impacts on firms' profitability. First, higher levels of debt financing (relative to equity financing) can increase profitability. In examining subcategories of debt financing, we find that the impacts from current liabilities and short-term loans are insignificant, whereas others are all significantly associated with higher ROA levels. This information provides important policy implications for Chinese policymakers. The accessibility to various channels of debt financing can improve the profitability of downstream firms, consequentially benefiting the development of these firms. Therefore, it is necessary for the authorities to provide supporting financial policies when restructuring China's renewable energy industry towards a more balanced and advanced status.

Table 7.5: The Role of Capital Structure in Different Firms' Positions

	Upstream			Mixed			Downstream		
	Model (u1)	Model (u2)	Model (u3)	Model (m1)	Model (m2)	Model (m3)	Model (d1)	Model (d2)	Model (d3)
DTA(t-1)	0.0272			-0.0120			**0.0382***		
	(0.0167)			(0.0080)			(0.0200)		
CTA(t-1)		0.0289			**-0.0386****			0.0110	
		(0.0174)			(0.0145)			(0.0174)	
NCTA(t-1)		0.0165			0.0123			**0.0792****	
		(0.0406)			(0.0167)			(0.0273)	
BTA(t-1)			-0.0335			-0.1171			**0.1213*****
			(0.0970)			(0.0916)			(0.0376)
CRTA(t-1)			**0.0689***			-0.0278			**0.0624*****
			(0.0367)			(0.0394)			(0.0166)
SLTA(t-1)			-0.0254			**-0.0606***			-0.0236
			(0.0385)			(0.0320)			(0.0294)
LLTA(t-1)			0.0104			0.0106			**0.0505****
			(0.0331)			(0.0164)			(0.0232)
OIG(t-1)	0.0330***	0.0329***	0.0269**	0.0119	0.0140	0.0124*	0.0170	0.0185	0.0162
	(0.0097)	(0.0098)	(0.0109)	(0.0082)	(0.0081)	(0.0070)	(0.0251)	(0.0253)	(0.0274)
Age	0.0037*	0.0038*	0.0036*	-0.0017	-0.0016	-0.0015	0.0014	0.0005	0.0014
	(0.0022)	(0.0022)	(0.0021)	(0.0018)	(0.0018)	(0.0017)	(0.0022)	(0.0023)	(0.0021)
SZ	-0.0233***	-0.0232***	-0.0245***	0.0002	-0.0031	0.0008	-0.0206	-0.0212	-0.0300**
	(0.0084)	(0.0083)	(0.0083)	(0.0103)	(0.0102)	(0.0095)	(0.0135)	(0.0143)	(0.0125)
YD_2003	0.0260	0.0260	0.0263	0.0002	0.0010	0.0033	0.0006	-0.0010	-0.0036
	(0.0190)	(0.0190)	(0.0188)	(0.0063)	(0.0060)	(0.0056)	(0.0146)	(0.0147)	(0.0163)
YD_2004	0.0292*	0.0291*	0.0274	-0.0083	-0.0095	-0.0092	-0.0460	-0.0443	-0.0482
	(0.0167)	(0.0168)	(0.0168)	(0.0079)	(0.0081)	(0.0093)	(0.0392)	(0.0380)	(0.0392)
YD_2005	0.0013	0.0010	0.0019	-0.0123	-0.0142*	-0.0133	-0.0268*	-0.0209	-0.0253*
	(0.0205)	(0.0203)	(0.0204)	(0.0078)	(0.0075)	(0.0087)	(0.0133)	(0.0124)	(0.0137)
YD_2006	0.0303**	0.0301**	0.0287**	0.0016	0.0012	-0.0002	-0.0027	0.0010	-0.0022
	(0.0116)	(0.0115)	(0.0114)	(0.0073)	(0.0075)	(0.0078)	(0.0121)	(0.0114)	(0.0103)
YD_2007	0.0387**	0.0381**	0.0368**	0.0014	0.0024	-0.0004	0.0176	0.0226**	0.0253***
	(0.0151)	(0.0148)	(0.0147)	(0.0092)	(0.0094)	(0.0091)	(0.0115)	(0.0098)	(0.0082)
YD_2008	0.0234*	0.0231*	0.0237*	-0.0602***	-0.0567***	-0.0583***	0.0130	0.0177	0.0176
	(0.0132)	(0.0129)	(0.0120)	(0.0113)	(0.0108)	(0.0109)	(0.0117)	(0.0112)	(0.0104)
YD_2009	0.0254**	0.0252**	0.0233**	-0.0104	-0.0086	-0.0096	0.0197*	0.0220**	0.0221**
	(0.0102)	(0.0101)	(0.0099)	(0.0068)	(0.0067)	(0.0066)	(0.0097)	(0.0094)	(0.0082)
YD_2010	0.0371***	0.0374***	0.0345***	-0.0163	-0.0140	-0.0160	0.0421**	0.0450**	0.0459**
	(0.0088)	(0.0091)	(0.0088)	(0.0128)	(0.0125)	(0.0122)	(0.0170)	(0.0177)	(0.0172)
YD_2011	0.0208*	0.0207*	0.0194*	-0.0203	-0.0200	-0.0232*	0.0069	0.0094	0.0133
	(0.0108)	(0.0107)	(0.0106)	(0.0136)	(0.0135)	(0.0120)	(0.0198)	(0.0197)	(0.0203)
YD_2012	-0.0065	-0.0066	-0.0051	-0.0057	-0.0055	-0.0048	-0.0289	-0.0283	-0.0260
	(0.0081)	(0.0081)	(0.0075)	(0.0087)	(0.0088)	(0.0086)	(0.0278)	(0.0272)	(0.0267)
Constant	0.4514***	0.4477***	0.4844***	0.0661	0.1394	0.0522	0.4304	0.4596	0.6420**
	(0.1676)	(0.1646)	(0.1619)	(0.2155)	(0.2133)	(0.2002)	(0.2719)	(0.2915)	(0.2522)
Observations	515	515	515	185	185	185	143	143	143
R-squared	0.1703	0.1705	0.1849	0.3511	0.3790	0.4051	0.2424	0.2542	0.2697
No. of firms	69	69	69	17	17	17	17	17	17

Note: Robust standard errors are in brackets. *** denotes 1% significance, ** for 5% and * for 10%. It is worth noting that our sample is unbalanced. Some variables (especially financial variables) are missing for some firms, therefore, the effective sample (even with the same number of firms) used in each regression differ from each other. YD refers to year dummies. Please refer to table 7.2 for the definition of other variables.
Source: Prepared by the authors.

6. Conclusion and policy implications

China's investment in the renewable energy sector has grown rapidly since 2006 when REL was implemented. Motivated by the desire to solve its long-standing environmental problems and energy security concerns, the Chinese government in recent years has strongly encouraged the development of the renewable energy sector and is now the world's top investor in this area. When the EU and the US, the market leaders, began to slow down and implement a series of new policies in recent years, especially towards products from China, China's growth has slowed down. Problems have arisen as a consequence of fast expansion.

Despite the setback of global investment in renewable energy, this sector still has a promising future. Based on the estimations of most major agencies (for example, IEA, 2009), the total investment in the renewable energy sector across the world has the potential to be worth billions or even trillions of dollars over the next couple of decades. As China determines to keep the pace of its rapid growth in the renewable energy sector, it is important to evaluate this industry's efficiency and problems, especially from a micro perspective. This paper adopts the standard finance approach to investigate the problem of firms overinvesting in the renewable energy sector.

Our results show that overinvestment in the renewable energy sector exists. It was first captured by the positive and significant autoregressive investment coefficients, indicating strong momentum that exists in this industry. Secondly, the investment in renewable energy sector has shown to have patterns over our sample period. The passage of REL and other favourable policies in China has indeed triggered a significant desire for investment in this sector. The effects mainly occurred between 2007 and 2011, consistent with the changing international environment. The key results based on the Jensen's (1986) free cash flow hypothesis demonstrate that firm managers may act irrationally when free cash flows are available. They tend to invest even when future growth opportunities are not positive and their investment decisions are at the cost of shareholders' benefits. Among all four sectors, this kind of irrational overinvestment has been more significant in the biomass and wind sectors.

Consistent with the Modigliani and Miller (1958) theorems, capital structure does not seem relevant to the renewable energy sector if we use the aggregate debt-to-asset ratio as the measure. Categorising debt according to its different forms reveals more interesting information. Capital structure does matter, such as commercial credit and short-term loans.

Given the concerns over environmental changes and the responses from firms in different positions on the renewable energy industrial chain, our empirical results are based on categorising firms into upstream, downstream, and mixed groups. Our results show that one's position in the industrial chain matters both in terms of overinvestment and the role of capital structure. In the transition process, mixed firms tend to experience overinvestment or irrational expansion, clearly requiring policymakers to intervene or provide proper guidance. Capital structure turns out to be more important to those downstream firms, indicating that policymakers may provide further financial support that enables these firms to finance their investments through corporate bonds, commercial credit, or long-terms debts.

Both investment in the renewable energy sector and returns have shown clear cyclical behaviour. For example, after the 2008 global financial crisis, renewable energy sector in China has become a new concept of potential driving forces for its economic growth. The consequence of policy supports and investors' interest has brought significant increase in the renewable energy investment. However, our data have shown that the rapid progress of China's renewable energy sector mainly concentrates in the upstream (raw material and equipment manufacturing). The unbalanced industrial structure and potential internal over-competition have resulted in clear vulnerability against outside shocks. Policy supports should aim to encourage structural reform of the renewable energy sector, which shifts the industry towards high-end technological advance and development.

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Appendix

Table A1: Descriptive Statistics for Four Sub-sectors

	Wind		Nuclear		Biomass		Solar	
Notation	**Mean**	**SD.**	**Mean**	**SD.**	**Mean**	**SD.**	**Mean**	**SD.**
IK	0.4443	1.1342	0.4656	0.6452	0.6236	2.1708	0.6052	0.8612
CFK	0.3913	0.6760	0.6519	1.2312	0.3411	0.5611	0.3114	0.4444
OCF	0.1266	0.9668	0.0918	1.4869	0.3069	1.1000	0.1193	0.4861
DTA	0.6528	0.3335	0.6234	0.3163	0.6044	0.2525	0.6154	0.2866
CTA	0.4540	0.2783	0.5199	0.3042	0.4380	0.2226	0.4773	0.2222
NCTA	0.1989	0.2205	0.1035	0.1175	0.1664	0.1693	0.1381	0.1481
SLTA	0.1535	0.1270	0.1534	0.1371	0.1968	0.1511	0.2244	0.1419
LLTA	0.1650	0.2142	0.0698	0.1097	0.1375	0.1585	0.0969	0.1335
BTA	0.0170	0.0425	0.0092	0.0361	0.0188	0.0467	0.0177	0.0557
CRTA	0.2102	0.2670	0.2860	0.2778	0.1612	0.1622	0.1818	0.1278
TQ	1.7136	0.8632	2.1254	1.2258	1.6088	0.6688	1.9459	1.0272
SZ	22.470	1.3954	21.826	1.3903	22.159	1.2136	21.904	0.9307
ROA	0.0294	0.0528	0.0386	0.0441	0.0260	0.0501	0.0180	0.0640
OIG	0.1626	0.3189	0.1755	0.2904	0.1341	0.2677	0.1480	0.3742
AGE	9.9245	5.3409	8.5105	4.9971	9.5580	4.6056	7.6382	4.4634
State	21.074	27.006	18.585	25.357	22.241	24.281	11.798	20.343
FOWN	39.464	16.746	40.810	16.229	36.156	15.176	35.284	14.470

Sources: RESSET database and authors' calculation. Please refer to table 7.2 for the definition of other variables.

Table A2: Descriptive Statistics for Three Stages of Production

	Material & Equipment (No. of Firms = 71)		Generator/Final Users (No. of Firms = 17)		Mixed (No. of Firms = 18)	
Notation	**Mean**	**SD.**	**Mean**	**SD.**	**Mean**	**SD.**
IK	0.5669	1.3025	0.4117	1.3176	0.5775	0.9567
CFK	0.4728	0.9713	0.3251	0.5143	0.3911	0.6186
OCF	0.0848	1.2891	0.2386	0.4034	0.1562	0.5803
DTA	0.5928	0.2943	0.6819	0.3224	0.6295	0.2658
CTA	0.4999	0.2632	0.3498	0.1899	0.4943	0.2142
NCTA	0.0928	0.1077	0.3320	0.2371	0.1352	0.1488
SLTA	0.1891	0.1453	0.1446	0.1224	0.2224	0.1386
LLTA	0.0608	0.0955	0.3008	0.2279	0.0871	0.1277
BTA	0.0094	0.0341	0.0234	0.0498	0.0299	0.0750
CRTA	0.2361	0.2154	0.0948	0.1001	0.2137	0.1644
TQ	1.9980	1.0231	1.5564	0.7421	2.0265	1.3199
SZ	21.6413	1.0855	22.8666	1.2960	21.9971	1.0114
ROA	0.0229	0.0570	0.0391	0.0440	0.0223	0.0563
OIG	0.1361	0.3395	0.1984	0.2581	0.1513	0.3306
AGE	7.8537	4.6212	10.258	4.8527	9.6912	5.4874
State	15.062	22.892	24.311	26.378	11.423	20.887
FOWN	37.431	15.441	37.830	16.166	34.121	14.575

Source: RESSET database and authors' calculation. Please refer to table 7.2 for the definition of other variables.

Chapter 8

The Impacts and Interaction of Upstream and Downstream Policies for the Solar Photovoltaic Industries of China

Wang Hongwei[30], Zhang Kai[31], and Vanessa Yanhua Zhang[32]

Abstract

In this chapter, we provide a research framework on the industrial structure of solar photovoltaic (PV) industry in China and aim to study the incentive correlation and interaction between upstream and downstream firms. We first draw a picture of Chinese solar PV industry and go through the literature to lay out the history and existing policies of the industry and current issues that companies in different positions in the industry chain have to face. Secondly, we use industry data and apply unit root test, Johansen co-integration analysis, Granger causal test, and Directed Acyclic Graph test. With these econometric methods, we study the long-term relationship between the polysilicon price, government subsidies on polysilicon plants, the solar cell price, the solar power price, and government subsidies on solar power. Our analysis shows that the policy-conducting effects from upstream PV firms to the downstream products are smaller than that coming from the downstream PV firms to the upstream products. Policy implications are discussed. We recommend that the Chinese government should issue policies to facilitate coordination between the central government and local governments on the development of PV industry in China. The government should encourage indigenous innovations in the PV industry and improve its competitiveness. Policies on electricity pricing and cost allocation should also be improved to ensure the steady growth of the solar PV industry in China.

Key words: Upstream and downstream policies, solar photovoltaic industries, interaction, China.

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1. Background

China has issued a series of policies to support the development of the solar photovoltaic (PV) industry and to help domestic solar PV enterprises. The fiscal subsidy, financial support, and research and development support policies for the polysilicon and solar cells enterprises (the upstream) help expand the scale of manufacturing and speed up the technological progress of the downstream industry and reduce the costs and change the structures of end-products. Electricity subsidies, trade remedies, and financial support policies for the Solar Roof Plan and the Golden Sun Demonstration Project (the downstream) will help expand market demand and size, that should conduct to upstream industry, and strengthen competition, promote economy of scale, and technological progress of front-products. We use the model of demand price elasticity of producer and user to study the impact and interaction of upstream and downstream policies for solar PV industries. This study further calculates the shadow demand and predicts possible development scale of solar PV industry in China under different scenarios in the future. Based on this, we put forward sound policy improvement suggestions for the solar PV industry including technical support, tax preferential policies, fiscal and financial support policies, access policies, and electricity price subsidies for the upstream and downstream industries.

Shenghong Ma (2010) and Molin Huo (2012) explore the current technological level of PV industry in China and the cost competitiveness of PV power generation. They find that even though the cost of PV power generation is gradually declining, it is still far from realising the cost-effective power generation of traditional fossil energy. Junfeng Li (2011), Semiconductor Equipment and Materials International (SEMI) and China Photovoltaic Industry Alliance (CPIA) (2012), and Lifang Guo (2012) make a comprehensive analysis of the flagging situation of China's PV development, and its favourable and unfavourable prospects. Chuanggui Wang (2010), Zhou Deng (2012), and Li Ju (2012) probe into the underlying causes of the difficulties facing China's PV industry under the new situation. Sicheng Wang (2011), Qingzhen Li (2011), Lifang Guo (2011), Yuyang Li(2013), Guoxing Xie (2013), and Xiaolan Wang (2013) suggest that it is imperative to accelerate activation of domestic PV market, concentrate on the development of rural and urban distributed PV power generation, and work out a clear development plan for the PV industry.

Lei Li (2011), Zhou Deng (2012), and Jinwei Zhu (2012) analyse relevant policies set by the Energy Administration of the National Development and Reform Commission and their roles in PV development. They also put forward future policies and recommendations to promote the healthy development of the PV industry.

Section 2 reviews the history of China's PV industry. Section 3 and 4 identify the main issues and challenges facing this industry. Sections 5 and 6 review the policies for this industry. Sections 7 and 8 analyse the impacts of these policies and Section 9 conducts a quantitative analysis on this issue. Section 10 concludes and draws policy implications.

2. The development of China's photovoltaic industry

The PV industry's upstream produces high-purity silicon of the highest technology, the greatest profits, and the highest price and cost proportion. The industry's midstream produces batteries, cell components, and related products. The downstream is an integration of the PV installation system.

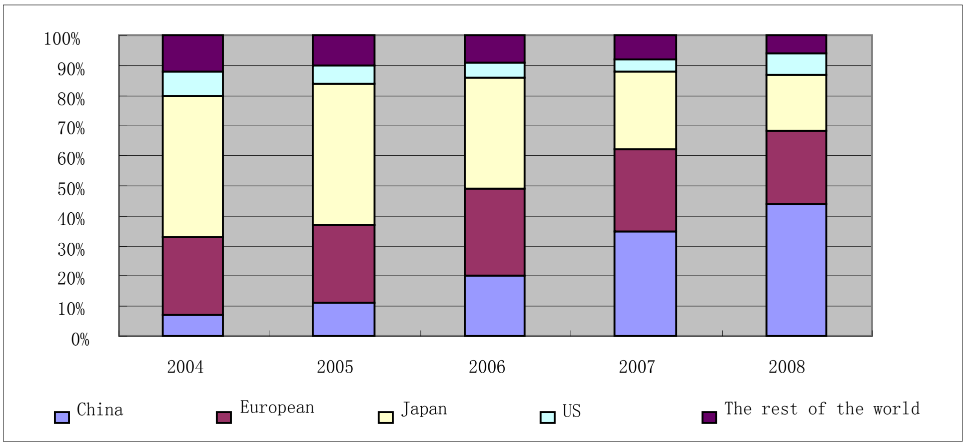
China's PV industry that produces silicon of high purity relies on foreign countries for raw materials, key technology and equipment, and market demand. The industry chain is not balanced; China's PV industries are mainly concentrated in the midstream with lower value, such as piece-cutting of silicon, production of batteries and cell components, and systems-supporting industries. The production in the upstream of polysilicon of high purity is mainly done in the US, Japan, Europe, and other developed countries.

(1) There has been a dramatic growth in the production of high-purity silica.

This is a result of the spurt in polysilicon prices around the world in early 2008 and the policy support of the National Development and Reform Commission.

China produced 20,000 tonnes of polysilicon in 2009, and 82,000 tonnes in 2011. In 2012, however, China's production of polysilicon was reduced to about 69,000 tonnes. Because of the great technological gap between China and the more advanced countries, high production costs, and predatory pricing of the United States (US), South Korea, and Europe, more than 90% of Chinese polysilicon companies had to stop production or cut output.

Figure 8.1: Global Market Shares of Cells



US = United States.
Source: China Merchants Securities.

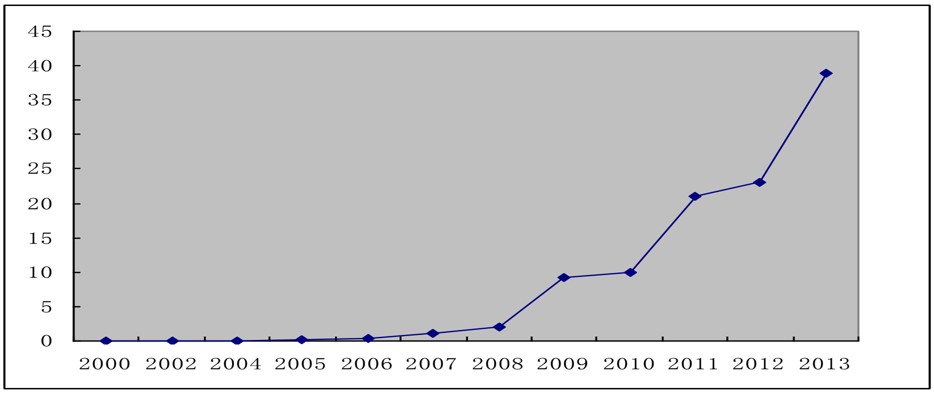
(2) China’s solar cell production is growing rapidly and has ranked top in the world (Figure 8.1).

Since 2002, China's production capacity of PV cells has improved rapidly and has made significant achievements. As a result, a large number of assembling and packaging companies have emerged. China is rapidly moving as an international manufacturing power in the PV industry in terms of production scale of batteries and components.

In 2002, China's production of cells and cell components ranked seventh in the world. In 2005, its manufacture of PV cells and components ranked seventh in the world. In 2008, China became the world's largest producer of solar cells, with total capacity of about 3.3 gigawatts (GW), total output of more than 2 GW, and market share of over 30%. In 2009, China’s production of solar cells reached 4.3 GW or 40% of the global outputs. In 2010, China’s production of solar cells reached 9 GW, or more than 50% of the global outputs. In 2013, China’s production of solar cells was up to 40 GW (Figure 8.2).[33]

[33] The upstream of photovoltaic industry produces high-purity silicon is characterized with the highest technology and the greatest profits. The prices are accountable for more than 70% of the costs; the midstream produces batteries, cell components and other related products; the downstream is an integration of photovoltaic installation system.

Figure 8.2: China's Production of Cells, 2000–2013 (in GW)



GW = gigawatt.

Sources: European Photovoltaic Industry Association; BP Statistical Review of World Energy (2012).

(3) China's total installed capacity of PV power generation now accounts for a small part of global output and its new installed capacity is rising markedly.

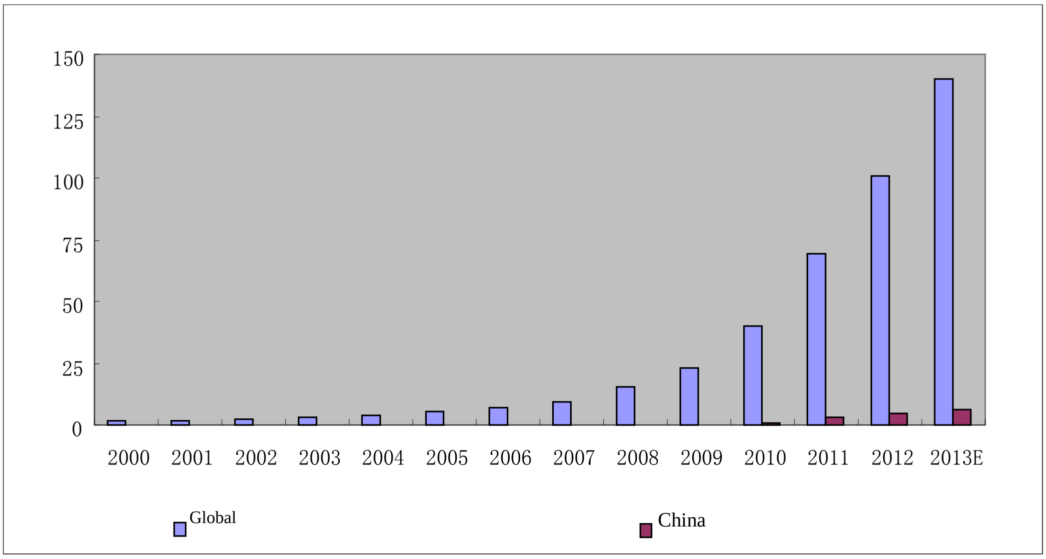
In 2007, China's PV installed capacity was only 0.1 GW. In July 2009, the Golden Sun Demonstration Project was officially launched and China's PV market has since then sustained high growth with an average annual growth rate of over 200% (Table 8.1). In 2013, its new installed capacity was 11.3 million kilowatts or three times higher than in 2012. Thirty percent of the world's new capacity is now concentrated in China and its total is more than that of the whole Europe (10.25 million kilowatts).

Table 8.1: China's Installed Capacity of Photovoltaic Power Generation from 2002 (MW, %)

Year	Installed Capacity	Increase Over the Previous Year	Accumulated Installed Capacity
2002	20	250	45
2003	10	-50	55
2004	10	0	65
2005	5	-50	70
2006	10	100	80
2007	20	100	100
2008	40	102	140
2009	160	297	297
2010	500	212	797
2011	2900	480	3697
2012	1190	-59	4887

MW = megawatt.
Sources: National Energy Administration; Silicon Industry of China; Nonferrous Metals Industry Association.

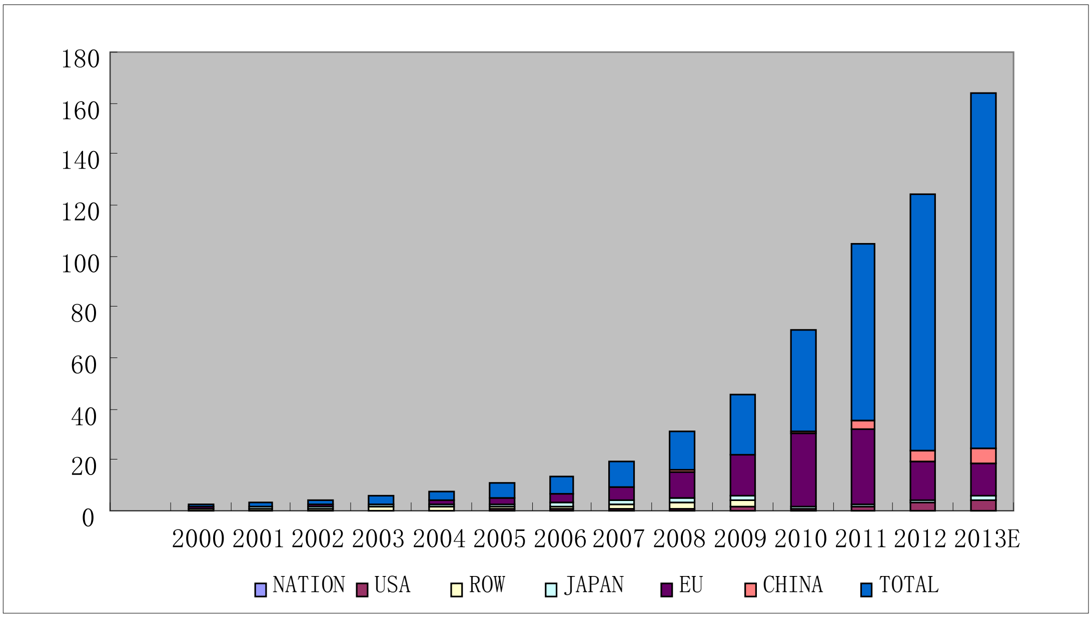
Figure 8.3: Accumulated Installed Capacity, Global and China



Sources: European Photovoltaic Industry Association; BP Statistical Review of World Energy (2012).

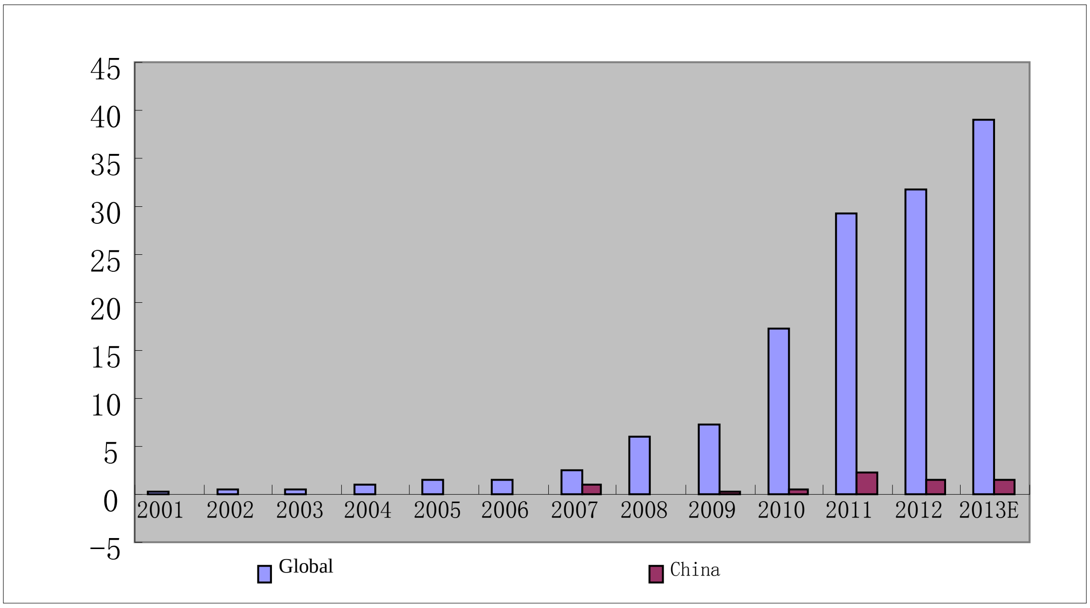
Figure 8.4: Global Accumulated Installed Capacity of Photovoltaic Power Generation

（GW）



EU = European Union; ROW = Rest of the World; USA = United States of America .
Sources ：(European Photovoltaic Industry Association; BP Statistical Review of World Energy (2012).

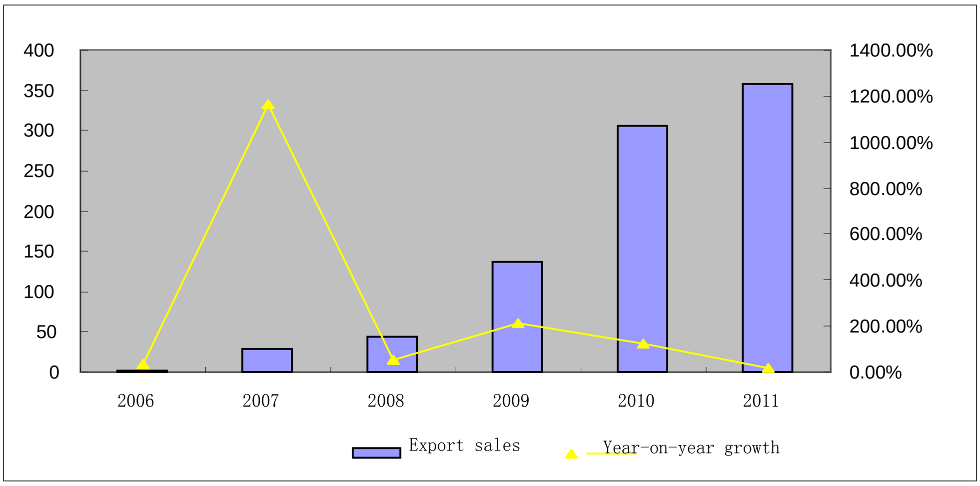
Figure 8.5: New Installed Capacity of Photovoltaic Power Generation, Global and China



(4) China's solar PV industry depends heavily on foreign markets.

Since China’s domestic PV market started late and small in scale, its PV industry relies heavily on foreign markets (Table 8.2).

Figure 8.6: China's Exports of Photovoltaic Products, 2006–2011 (10,000 billion, %)



Source: Report of Global Photovoltaic Industry (2012).

Table 8.2: China's Photovoltaic Industry's Independence from Foreign Markets

	2006	2007	2009	2010（predicated）
Output /MW	400	1088	4011	8000
Export /MW	390	1068	3851	7600
Domestic Installs/MW	10	20	160	400
Export Percentage %	97.5	98.2	96.0	95.0

MW = megawatt.

Sources: Wang Sicheng. Speed﹣up development of PV to ensure sustainable energy supply in China. Engineering Sciences, 2011(9), 51–61.

(5) Despite a short-term downturn, China's solar PV industry has a promising prospect in the long run.

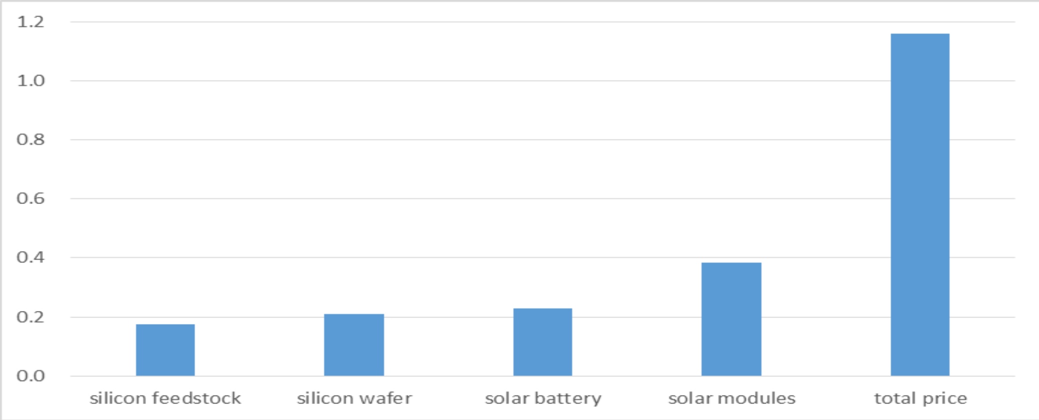
At present, the PV market is facing weak demand, with the double strikes of domestic overcapacity and under-expectation demands greatly aggravating the rapid price decrease of every chain in the PV industry. At present, the PV industry chains, (e.g., raw materials of polysilicon, silicon, cells, and modules) are earning small profits and some are even suffering losses.

Still, China's PV industry has enormous potential in the long run. The continuous improvement of PV industry is a prerequisite for the great development of the domestic market; the growing contradiction between energy supply and energy demand, and the changes in the energy structure point to the development of PV application market.

The relative cost ratio of module production and processing technology is quite high, while slicing techniques are faced with price cuts. Improvements in the conversion efficiency of PV products can directly reduce system-balancing costs. A 1% increase in the efficiency of components decreases the system-balancing costs by 5% to 7%. But for the price, a one-level increase in the conversion efficiency of components its price can go up by CNY0.1974/W. A one-level increase in cell efficiency raises its price by 3% to 5%.

Promoting technological progress and technological innovation of domestically produced equipment are the potential and decisive factors to lower costs.

Figure 8.7: Cost Structure of Polycrystalline Solar Cells



Sources: Semiconductor Equipment and Materials International's reports.

3. Main problems of China's solar photovoltaic industry

3.1. Low industry-chain concentration and lack of obvious scale effects

China leads in total output of solar products. However, some links in the industry chain have low industrial concentration and suffer from lack of obvious scale effects. Especially in the low sections of the industrial chain that have low entry barriers, the largest number of firms concentrate, which greatly impact the industrial concentration and scale benefits. As a result, their products have low added value, lack competitiveness, and earn weak profits.

3.2. Obvious technological gap in the entire industry

Although China has become a global manufacturing country in PV industry, it is far from being a great manufacturing power. To begin with, its basic research is weak and it lacks key technology and equipment.

Secondly, technological advances mainly take place in the manufacturing process, which lacks innovation and invention.

Thirdly, China's research institutes work inefficiently and the industry-academia-research collaboration has yet to take effect. The main innovating bodies of the solar PV industry are private firms. Research institutes show low R&D efficiency and week applicability.

Fourthly, although the PV industry has low technological barriers and high liquidity, its intellectual property protection is quite weak.

3.3. The development of photovoltaic application market greatly lags behind the development of the photovoltaic industry

The domestic PV market shows slow development and low application levels of PV products. Although China has become the world's largest manufacturer of PV products, the prices of its products and market spaces are greatly limited.

3.4. Serious overcapacity and heavy dependence on the international markets

In 2012, the domestic PV trade was greatly limited by the decline in market demand, overcapacity, and anti-dumping and anti-subsidy strategies of Europe and the US. Profits of domestic PV industry fell sharply and the whole industry faced operational difficulties. Many small and medium firms stopped production. In 2012, the operating rate of China's PV firms was less than 70%. Suntech, once an industry leader, declared bankruptcy in 2013.

3.5. Lack of industry standards and the need for government regulations

At present, China has no uniform standard in its PV industry and PV firms differ a lot in their manufacturing standards. It is thus necessary to speed up the establishment of technical standards and quality certification system for PV products and power generation system, change the standards of industry leaders into national mandatory standards, and actively participate in setting relevant international standards.

3.6. Industrial development disorder and serious blind investments

Currently, a lot of investors poured capital into the PV market due to low entry barriers in some of the links in the industry chain and local government’s support, resulting in serious blind investments, redundant construction, overcapacity, unhealthy competition, waste of resources, and environmental pollution.

4. Critical obstacles to the development of the domestic photovoltaic application market

Despite the decline in exports, industrial policies and corporate strategies have shifted focus to the domestic PV market and, as a result, its application market starts to rise rapidly. However, problems remain: small quantities, large obstacles, slow development, indefinite directions, and unclear policies. The domestic market shows different short-term and long-term trends.

(1) Regarding government guidance, not enough strategic emphasis is laid on the PV industry, and long-term development planning is lacking. Once faced with growth spurt, the government merely supported the expansion of production scale and took few effective measures to promote market development.

(2) Regarding economic benefits, the costs of PV applications remain very high and, as a result, limit market competitiveness. Economic efficiency is a deceptive factor, whether in centralised large-scale PV power plants or in distributed roof power plants. In China, PV power generation can only take 1,300 hours on the average. In areas with enough sunshine (1,500 hours the whole year), the PV cost is around one yuan per kWh, which is higher than the on-grid price of thermal power and wind power, both of which have hindered the development of centralised PV power plants. Small distributed power plants have to deal with the problem of high initial investment.

(3) Regarding the system, it is difficult to coordinate the interests of all stakeholders. The main stakeholders in constructing and using PV power stations are roof owners and grid companies. The first obstacles to the installation of power plants are the roof owners. Property owners and property companies are unwilling to install PV solar power plants because of costs, safety, aesthetics, and other considerations.

There are also difficulties in determining property rights, identifying the one responsible for the operation and management of power plants, and distributing benefits after completion. The second obstacles are the grid companies. The generating capacity of distributed PV power stations is limited and most of the generated power is used by the owners, so there is little impact on the grid system and small profit for grid companies after connection. So far, there have been some relevant requirements that grid companies need to follow, such as providing appropriate ports and devices for distributed power plants. However, due to lack of technical standards covering grid systems and subsidies, grid companies are unwilling to accept PV electricity.

(4) Regarding supporting policies, these lack implementation details and their supporting effects are limited. The main policies supporting domestic PV application markets are the Golden Sun Project and subsidies for distributed power generation plants from the National Energy Administration.

(5) Excessive growth leads to serious production backlog, and price wars result in the abnormal development of the market. On the one hand, since 2000, the wealth effect of domestic PV industry has stimulated a large number of private capitals to invest in the PV industry. On the other hand, under pressure to contribute to GDP growth and because of structural adjustment assessment, the solar PV industry or related industries were to be developed as key directions of strategic emerging industries in almost all provinces, municipalities, and autonomous regions. In 2011, because of the excessive concentration of private capital and government resources, China's PV manufacturing suffered industry-wide losses. Small-scale companies and those with weaker risk tolerance started clearing inventory and reclaiming funds, resulting in a disastrous decline of prices of PV products. Vicious price competitions not only deteriorated further the development of domestic PV enterprises but also affected the healthy development of the applications market.

5. Background of industry policies for solar PV

When cost per kWh is higher than price of local electricity, mere reliance on the market is not cost-effective and government subsidies are needed. Thus, PV demands are greatly influenced by adjustments of government subsidy policies at this stage. When cost per kWh is lower than price of local electricity, or the consumers' grid parity is realised, the market will drive the demand of PV power generation.

At present, the cost of PV power generation is still higher than the power generation cost of conventional energy. Thus, the end demand for PV industry is still not fully market-oriented. The demand fluctuates depending on the changes in the nation's industry policies.

Germany, Spain, Italy and other countries have launched feed-in tariff, a subsidy policy that has stimulated the rapid growth of installed capacity in the European market. In 2004, Germany modified the Renewable Energy Laws so that the on-grid prices of different application types and scales, and the yearly decrease of on-grid price were clarified, which contributed to a dramatic increase in PV installed capacity in the country. In 2005, Spain launched its fit-in tariff policy, which greatly promoted the development of its PV market, with new installed capacity reaching 2.5 GW in 2008. The drop in polysilicon's prices in 2009–2010 caused the cost of PV installation to fall sharply. In Germany and Italy, a short-term 'predatory' phenomenon appeared in the market under expectations of subsidy cuts. The PV manufacturing chain started a new round of capacity expansion. Influenced by the European debt crisis, a sharp fall in component prices, and other factors in 2010–2012, the countries with great growth of installation quantity, such as Germany, United Kingdom, France, Australia, etc., gradually reduced feed-in tariffs to curb excessive investment.

Because of subsidy cuts, Europe's new installed capacity in 2012 fell by 22 % to 17.58 GW for the first time in nearly a decade and further declined by 42% to 10.25 GW in 2013. Falling demand and excess capacity of the whole manufacturing chain led to the industry bottoming in 2011–2012.

Benefiting from direct subsidies on investment, tax relief, accelerated depreciation, green power certificate, and other policy supports, the US photovoltaic market has grown rapidly. In 2013, the country's new PV installed capacity increased by 41% compared to the previous years and reached 4.75 GW. In 2013, solar energy became America's second largest new power source, accounting for 29% of the total new installed electricity capacity and only behind the new installed capacity of gas (46%).

The vigorous development of Japan's PV market is also due to policy incentives. After the Fukushima Daiichi nuclear disaster in 2011, Japan has implemented renewable energy subsidies starting July 2012 and that would last for 20 years. It was the most generous subsidy in the world. In 2013, Japan's new PV installed capacity was 6.9 GW, second only to China's installed capacity.

5.1. Background and goals of China's policies

（1）The laws and policies issued from 2006 to 2008 to encourage the development of renewable energy. These policies set the supporting rules of cost allocation, full acquisition, and cap-and-trade. The solar PV power generation also benefited from them.

（2）The policies launched between 2007 to 2011 to solve the solar PV industry's prominent problem of overdependence on foreign markets. These preferential policies played positive roles in starting the domestic PV market and other aspects.

（3）The policies to solve the problems of serious overcapacity of the solar PV industry, overdependence of domestic market on external demands, and the common operational difficulties facing firms since 2012. China launched a number of emergency policies and tried to expand domestic demands of PV products by starting domestic distributed PV market. These emergency measures brought in hopes to the domestic PV industry.

6. Industry policies for solar photovoltaic industries

Since 2005, China has successfully issued a series of policies and strategies to support the development of the PV industry and help domestic PV firms freed themselves of difficulties （Table 8.3). These policies can be divided into five types: fiscal subsidy, electricity price subsidies, research and development support, industry entry, and trade remedy.

Table 8.3: China's Policies for Solar PV, 2005–2014

Policy	Time	Main Content
Renewable Energy Law	February 2005	Encourages and supports grid-connected power generation of new energies, such as solar energy. Sets corresponding policies on incentive price and cost allocation. Sets up special funds for renewable energy development. Supports technology research and development, system construction and demonstration projects, etc.
Interim Measures for the Management of Pricing and Cost Sharing of Electric Power from Renewable Energies	January 2006	Project pricing: reasonable cost + reasonable profits
Measures for the Control of Renewable Energy Fund	August 2006	A special fund to support the spread and application of solar energy in architecture, and solar power. Formulates rules for application and approval process of the fund. Special funds include unpaid subsidies and preferential loans.
Mid and Long-Term Development Plan for Renewable Energy	September 2007	Objectives for planned PV installed capacity are 300 MW for 2010 and 1800 MW for 2020. The Planning gives priority to the development of strategic reserves of solar technology and the construction of several PV power generation demonstration plants and solar heat power generation demonstration plants
The 11th Five-Year Plan for the Renewable Energy Development	March 2008	A plan for key areas of PV solar power to carry out power construction in areas without electricity, start application projects in PV cities, and support PV power station pilots. It also plans to conduct R&D work, equipment-manufacturing work, and to construct PV industry system.
Implementing Opinions on Expediting the Application of Photovoltaic Energy in Buildings	March 2009	Supports demonstration projects of PV application in buildings, implements 'Solar Power Rooftop Initiative', and encourages the combination between PV modules and buildings; implements fiscal support policy and develops the mechanism and model of government guidance and market-based implementation; enhances policy support in construction areas.
*I*nterim Measures for the Management of Fiscal Subsidy Fund for the Application of Photovoltaic Energy in Buildings	March 2009	Prescribes the scope and qualification requirements for the use of subsidy fund; encourages local governments to issue and implement supporting policies for PV development; sets the subsidy standard in 2009 to be in principle CNY20/Wp, with specific standards to be determined according to the level of integration with buildings and technology sophistication of PV products.
Provisional Rules on the Financial Subsidy Management of the Golden Sun Demonstration Project	July 2009	Specifies the key supporting objects of the Golden Sun Demonstration Project and the subsidy standards. Those listed in the grid-connected PV power generation projects of the Golden Sun Demonstration Project can get 50 % of the total investment in PV

		power generation systems and supporting projects from government as subsidies. In remote areas without electricity, independent PV power generation systems can get subsidies as high as 70% of the total investment.
Amendment to the Renewable Energy Law	December 2009	The state guarantees the purchase of electricity generated by using renewable energy resources.
Notice on Strengthening the Management of Golden Sun Demonstration Project and the Building Integrated Photovoltaic Application Demonstration Project	October 2010	Central finance proportionally provides price subsidies on key equipment of the demonstration projects per bidding agreement. Quota subsidies are used for other fees of the demonstration project construction.
Polysilicon Industry Access Requirements	December 2010	Specifies construction conditions, production layout, production scale, technical equipment, resources recycling, energy consumption, environmental protection, product quality, safety, health, and social responsibility of polysilicon projects.
Circular on the Implementation of the Golden Sun Demonstration Project in 2012	January 2012,	The total capital is not less than 30% of the project investment. The demonstrative projects about centred application of PV power generation should apply as a whole. The total installed capacity is not less than 10 MW. The installed capacity of scattered constructed users' power generating project that is not less than 2 MW.
The 12th Five-Year Plan for the Solar Photovoltaic Industry	February 2012	By 2015, the costs of PV components will decrease to CNY7,000/kW, system costs to CNY0.8//kWh, the average comprehensive power consumption of polysilicon production is lower than 120 kWh/km. The efficiency of monocrystalline silicon solar cells and polycrystalline silicon solar cells will reach 21% and 19%, respectively.
Circular on the Application for the Large-Scale Demonstration Areas of Distributed PV Power Generation	Septembe r 2012	The government will introduce a quota subsidy policy for power generation from PV projects in the demonstration areas and implement unified subsidy standards for the self-use of power generation and grid connection of redundant power generation.
Circular on the Implementation of Grid Connection Services for Distributed Photovoltaic Power Generation	October 2012	Provide grid connection for power generation of voltage less than 10kV with the total installed capacity of each grid connection node no more than 6MW; system backup fee is exempted for distributed PV and wind projects; grid connection authority is delegated to local prefecture-level companies with the cycle of grid connection procedures roughly 45 working days; all costs related to public power grid renovation arising from the connection of distributed PV and connection into public power grid shall be borne by the State Grid.
Circular on the Implementation of Grid Connection Services for Distributed Photovoltaic Power Generation	October 2012	Provide grid connection for power generation of voltage less than 10kV with the total installed capacity of each grid connection node no more than 6MW; system backup fee is exempted for distributed PV and wind projects; grid connection authority is delegated to local prefecture-level companies with the cycle of grid connection procedures roughly 45 working days; all costs related to public power grid renovation arising from the connection of distributed PV and connection into public power grid shall be borne by the State Grid.
Notice of Implanting Subsidy Policy Based on the Power in the Distributed Photovoltaic Power Generation and Other Related Problems	July 2013	Specifies the subsidy based on power.
Notice of National Development and Reform Commission that Makes Best of Price Lever to Promote the Healthy Development of Photovoltaic Industry	August 2013	Identified benchmark tariffs and their timeline, benchmark feed-in-tariffs for distributed PV subsidies (three types of solar energy resource regions to respectively follow the standards of CNY0.9/kWh, CNY0.95/kWh and CNY1/kWh for a duration of 20 years; for distributed PV power generation, tariff subsidy standard is CNY0.42/kWh according to the policy of full power generation subsidy.

Notice on Constructing Demonstration Areas of Distributed Photovoltaic Power Generation Application	August, 2013	According to the implementing scheme for demonstration areas submitted by relevant provinces (municipalities and autonomous regions), 18 industrial parks have been identified as the first batch distributed PV application demonstration areas, including Zhongguancun Haidian Industrial Park in Beijing.
Announced the First Demonstration Areas of the Distributed Photovoltaic Power Generation	August 2013	Clarifies that distributed PV power generation adapts the mode of 'use own power generating, excessive power are on grid and power regulation'.
Comments on the Financial Services of Supporting the Development	August 2013	Financial innovation. Establishes local investment and financing institutions. Unified-borrowing and Unified-lending Model.
Notice on the Issues About Adjusting the Additional Criteria of Renewable Energy Power Prices and the Green Prices	August 2013	Additional tariff for renewable energies is increased from 0.8 cents to 1.5 cents for each kilowatt hour.
Guides Further Supporting the Development of Photovoltaic and Other New Energies	August 2013	Fully supports the orderly and coordinated development of new energies by grid-connected services, power purchase services, grid-connected dispatch management, etc.
Soliciting Opinion on Manufacturing Specifications of Photovoltaic Industry	Septembe r 2013	Sets up industry rules and guides the transformation and upgrading of the industry.
Notice on the Value-added Tax Policy of Photovoltaic Power Generation	Septembe r 2013	Adopts drawback policy of value-added tax (50%) to PV power generation.
Circular and the Promotion of Banking Sector Support to the Healthy Development of PV Industry	October 2013	Encourages banks to support the development of PV industry.
Letter for Soliciting Public Opinions on the Scale of PV Construction in 2013 and 2014	October 2013	In 2014, installed capacity is planned to increase by 12GW, including 8GW of distributed PV.
Announcement of the First Batch of Compliant PV Enterprises	November 2013	Outputs and product quality are strictly required. Enterprises excluded in the list cannot enjoy bank credit and export rebates.
Provisional Measures for the Management of Distributed Photovoltaic Power Generation Projects; Provisional Measures for Operation Regulation of Distributed Photovoltaic Power Generation	November 2013	General provisions of distributed PV, capacity management, project record filing, construction conditions, power grid connection and operation, metering and settlement.
Notice on Exemption from Government Funds to the Distributed Photovoltaic Power that Used its Generators	November 2013	Self-generation and self-use of distributed PV are exempted from the payment of renewable energy tariff surcharge, national major water conservancy project construction fund, mid-and large reservoir resettlement support fund and rural power grid loan repayment fund.
Detailed Regulations on the Business Services of Distributed PV Power Generation (for Trial Operation)	February 2014	Prescribed detailed regulations on the grid connection of distributed PV power generation.
Credit Policy of 2014	February 2014	Requires banking and financial institutions to support the development of emerging strategic industries, such as information consumption, integrated circuit, new energy vehicles, and PV industry, etc.
Notice on Recommending Key Projects of Photovoltaic Industry of 2014	February 2014	The Ministry of Industry and Information Technology sets the recommended key projects of the photovoltaic industry. The China Development Bank will provide comprehensive financial services to projects that are elected and conform with the relevant

		conditions of the China Development Bank.
Circular on the Implementation of Grid Connection Services for Distributed Photovoltaic Power Generation	October 2012	Provide grid connection for power generation of voltage less than 10kV with the total installed capacity of each grid connection node no more than 6MW; system backup fee is exempted for distributed PV and wind projects; grid connection authority is delegated to local prefecture-level companies with the cycle of grid connection procedures roughly 45 working days; all costs related to public power grid renovation arising from the connection of distributed PV and connection into public power grid shall be borne by the State Grid.
Announcement of the Second Batch of Compliant PV Enterprises	April 2014	Further strengthens the management of PV manufacturing industry, keeps the industrial orders, raises the levels of industry development, accelerates the transformation and upgrading of the PV industry.
Suggestions of the National Energy Administration (NEA) on the Implementation of Relevant PV Power Generation Policies	April 2014	Vigorously promotes the diversified development of PV industry and expedited the expansion of PV market.
Circular of the National Energy Administration (NEA) on Accelerating the Fostering of Distributed PV Application Demonstration Areas	April 2014	Fosters a series of distributed PV power generation demonstration areas on the existing basis.

Source: Prepared by the authors.

(1) Fiscal subsidy policies

At present, there are six types of fiscal subsidies on PV industry in China: special fund for renewable energy development, special fund for renewable energy constructing application, fiscal subsidy fund for PV constructing application, fiscal subsidy fund for demonstration cities of renewable energy constructing application, fiscal subsidy fund for countryside of renewable energy constructing application, fiscal subsidy fund for the Golden Sun Demonstration Project.

(2) Electricity price subsidies

To speed up the application of PV industry in the power generation terminal, China created, in 2012, network subsidy tariff that established service work pinions on distributed PV power generation and network, and allowed distributed PV dispersive access to low-voltage distribution network .

In August 2014, the National Development and Reform Commission specified CNY0.42/kWh as the national subsidy standard for the PV industry. It was the first time the on-grid electricity price was categorised into three levels according to regions: CNY0.9/kWh, CNY0.95/kWh, and CNY1.0/kWh (Table 8.4 and Table 8.5).

Table 8.4: National PV Power Plant Network Power Price

Resources Regional Division	Network Power Price	Regions
Class Ⅰ Resource Area	CNY0.9 /kWh	Ningxia; Haixi; Jiayuguan; Weiwu, Zhangye, Jiuquan, Dunhang and Jinchang of Qinghai; Hami, Tacheng, Alatai, Kelamayi of Xinjiang; Except Chifeng, Tongliao, Xinganmeng, Hulunbeier of Inner Mongolia Autonomous Region
Class Ⅱ Resource Area	CNY0.95/kWh	Beijing; Tianjin; Heilongjiang; Jilin; Liaoning; Sichuan; Yunnan; Chifeng, Tongliao; Xinganmeng, Hulunbeier of Inner Mongolia Autonomous Region; Chengde, Zhangjiakou, Tangshan and Qinghangdao of Shanxi; Datong, Suozhou, and Xinzhou of Shanxi; Yulin and Yanan of Shanxi; Qinghai; Gansu; Except class I resource area of Xinjiang
Class Ⅲ Resource Area	CNY1.0/kWh	Except class I, Ⅱ resource area

kWh = kilowatt-hour.
Source: State Development and Reform Commission.

Table 8.5: Price of National Residents Distributed Photovoltaic Electricity

	Resident Electricity Price	Price of National Residents Distributed Photovoltaic Electricity
Guangdong	0.61 yuan/kWh	1.01 yuan/kWh
Shanghai	0.62 yuan/kWh	1.01 yuan/kWh
Hainan	0.61 yuan/kWh	1.00 yuan/kWh
Jiangxi	0.60 yuan/kWh	1.00 yuan/kWh
Hunan	0.59 yuan/kWh	0.99 yuan/kWh
Hubei	0.57 yuan/kWh	0.97 yuan/kWh
Anhui	0.57 yuan/kWh	0.96 yuan/kWh
Henan	0.56 yuan/kWh	0.96 yuan/kWh
Shandong	0.55 yuan/kWh	0.95 yuan/kWh
Zhejiang	0.54 yuan/kWh	0..95 yuan/kWh
Guangxi	0.53 yuan/kWh	0.94 yuan/kWh
Jiangsu	0.53 yuan/kWh	0.93 yuan/kWh
Sichuan	0.52 yuan/kWh	0.93 yuan/kWh
Chongqing	0.52 yuan/kWh	0.93 yuan/kWh
Hebei	0.52 yuan/kWh	0.92 yuan/kWh
Jilin	0.53 yuan/kWh	0.92 yuan/kWh
Xinjiang	0.55 yuan/kWh	0.91 yuan/kWh
Heilongjiang	0.51 yuan/kWh	0.91 yuan/kWh
Liaoning	0.50 yuan/kWh	0.90 yuan/kWh
Shanxi	0.50 yuan/kWh	0.90 yuan/kWh
Gansu	0.51 yuan/kWh	0.89 yuan/kWh
Tianjin	0.49 yuan/kWh	0.89 yuan/kWh
Beijing	0.49 yuan/kWh	0.89 yuan/kWh
Shanxi	0.48 yuan/kWh	0.88 yuan/kWh
Yunnan	0.48 yuan/kWh	0.88 yuan/kWh
Fujian	0.45 yuan/kWh	0.87 yuan/kWh
Guizhou	0.46 yuan/kWh	0.86 yuan/kWh
Neimeng	0.47 yuan/kWh	0.85 yuan/kWh
Ningxia	0.45 yuan/kWh	0.84 yuan/kWh
Qinghai	0.43 yuan/kWh	0.83 yuan/kWh

kWh = kilowatt-hour.
Source: http://guangfu.bjx.com.cn/news/20140313/496645.shtml

(3) Support policies on research and development

These include basic R&D support programmes that cover solar power generation technology in the future, and technical R&D support programmes which support the industrialisation of solar power generation technology.

(4) Industry entry policies

By the end of 2010, the Polysilicon Industry Entry Requirements put forward clear demands for technology, environmental protection, investment, and other aspects as access requirements into the polysilicon industry.

(5) Trade remedy policies

Regarding the dumping behaviours of foreign polysilicon enterprises, China's Ministry of Commerce decided, since November 2012, to determine whether to impose anti-dumping duty on imported solar-grade polycrystalline silicon coming from the US, South Korea, and the EU, or impose countervailing duty on imported solar-grade polycrystalline silicon originating in the US and the EU.

After implementing a series of industrial policies, China’s domestic PV application market has been rapidly expanding and has progressed in solving its overdependence on external demand. Also, in 2013, the Chinese government greatly improved its policy support to the PV industry. In 2014, as the domestic PV application market was seeing signs of increase in growth, some companies began working again, and the operations of a few firms markedly improved.

7. Problems with existing policies

There are some obvious problems with existing policies in promoting the development of photovoltaic industry.

1. More emphasis on the subsidies of subsidising end-product application than the supporting R&D support for the front-end industrial technology.

Subsidising PV industry is necessary at its present stage. However, almost all subsidies are concentrated in end-product applications, which may be conducive to the rapid expansion of the domestic PV market in the short term, but of little importance in reducing PV product costs and application costs. In fact, the biggest obstacles to China's producing PV products and reducing application costs are the key technology gaps, such as purification of silicon materials. Because advanced planning and support for the R&D of industrial technology are lacking, intrinsic and stable cost-reducing mechanism has yet to be formed.

2. More emphasis on subsidising projects' initial investments than electricity regulations after completion of projects

The electricity subsidies for 'settlement after electricity generation' are more reliable. The Solar Roof Plan and the Golden Sun Demonstration Project use initial investment subsidies. However, due to the lack of electricity regulations after completion of projects, some areas take advantage of government subsidies without these funds being utilised in full.

3. More emphasis on the construction of large-scale power plants than distributed local development and utilisation

Although the total solar energy is huge, its energy density is quite low, and thus, its scale development needs a great deal of land resources. From the perspective of construction costs of commercialising PV projects and management efficiency, it is difficult to adopt the ways of 'decentralised grids, local consumption'. Instead, the 'large scale–highly concentrated–long distance–high voltage delivery' pattern is preferred.

Investments in multiplex power transmission and annual utilisation hours are relatively low, leading to low efficiency in power transmission system, line losses, and long distance wheeling costs. It also weakens the economic benefits of PV power generation, which is aimed to replace fossil energy.

4. More emphasis on the cleanliness of every power-generating stage than control of energy consumption and pollution in the production processes

From the perspective of power generation, PV power generations are characterised as 'zero consumption, zero emissions', resource-saving, and environment-friendly. However, from the perspective of a full life cycle, the greenhouse gas emissions of PV power generation are less than the traditional fossil fuels, but larger than the major sources of renewable energy. In other words, the energy consumption during production process of PV products is not low, and in some stages even poses risks of environmental pollution. Based on this, China has not laid enough emphasis on the PV industry.

It is necessary to set up clear long-term development plans and development policies especially addressing the insufficient fiscal funds support, for China's PV industry, so as to create a favourable condition and build up a super platform for domestic PV firms to be internationally competitive.

5. Financing Situation

(1) The Main Financing Modes of Photovoltaic Industry in China and Scale of Financing

The capital-intensive and technology-intensive photovoltaic industry demands huge funds. The present financing modes for new energy industries in China include bank loans, stocks, corporate bonds, venture capital, etc.

1) Bank Loans. As a policy bank, the National Development Bank is the main force supporting the development of the PV industry in China. Sixty percent of bank loans for PV power plants and distributed PV power generation projects come from this bank. By the end of August 2013, the total loan to PV industry was CNY41.05 billion.

Although credit funds of state-owned commercial banks have taken shape, various market changes have forced commercial banks, since 2009, to impose tight and strict credit policies on PV firms and wind-power equipment manufacturers.

2) Capital Markets (mainly based on stock and bond markets). China's stock market is subject to high listing threshold, complex listing process, long approval procedure of financing proposals, and other policy barriers. Compared with equity financing, China's bond market has lagged behind, restricting bond financing scale of some firms to some extent.

3) Venture Capital. As most international venture capitalists keep a wait-and-see attitude, their investments in China's renewable energy projects are still at the trial stage, i.e. very limited. The main reasons are technical barriers, historical failures, undeveloped capital markets, and rough exit mechanism.

(2) The Main Financing Problems of the PV Industry in China

1) Due to high industrial, technology, and market risks, the PV industry’s financing scales are negatively restricted as it is considered a high investment risk.

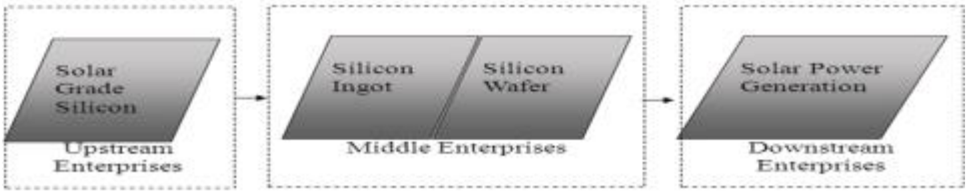
2) Financing channels are simple and credit scales of traditional banks are limited. Direct financing accounts for a relatively low 10% of total industrial funds.

3) Low degree of specialisation in venture investment.

8. Conduction Mechanism of China's Photovoltaic Upstream and Downstream Industry Policies

The solar PV industry is an industry chain that develops and utilises silicon materials. This chain generally includes upstream firms that mainly produce solar-grade silicon, middle firms that mainly produce solar battery components such as silicon ingot, silicon wafer, etc., and downstream firms that mainly conduct grid-connected and off-grid solar power generation (Figure 8.8).

Figure 8.8: Solar Energy Photovoltaic Industry Chain



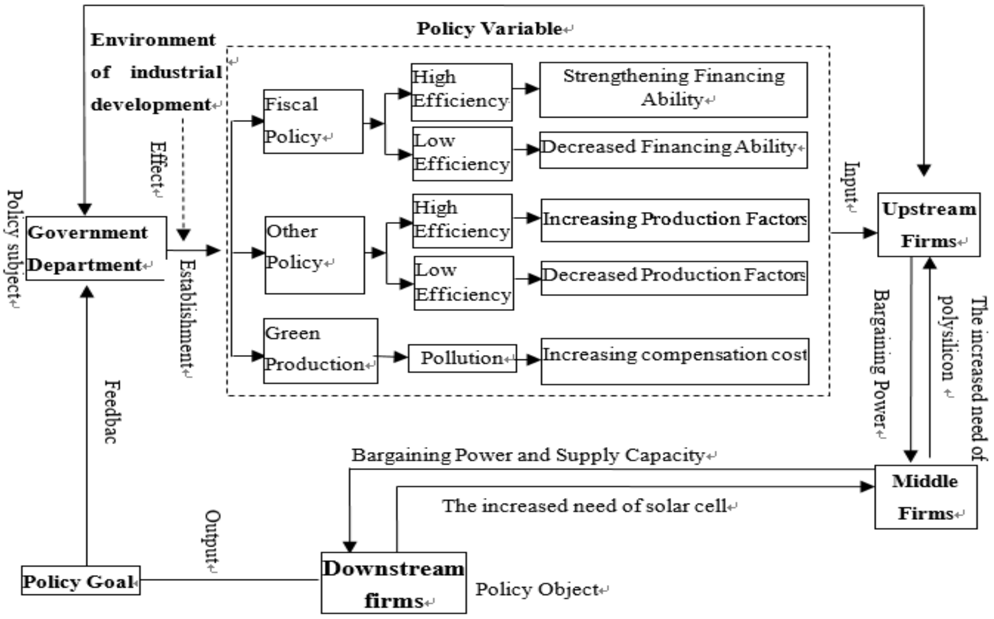
Source: Compiled by the authors.

To meet the requirements of low-carbon economy, developing its solar PV industry—referred to as an important industry providing clean energy in the future—is of great practical and strategic significance to China's energy security. The central government and local governments have issued a series of solar PV industry policies in recent years to promote the development of the solar PV industry. Continuous good policies have become one of the main driving forces of the development of China's solar PV industry, covering upstream firms, middle firms, and downstream firms. How would these policies promote the development of the PV industry, or how would the policies for upstream firms affect the development of downstream firms and vice versa? The following aspects will be considered in a study.

8.1. Conduction mechanism of China's photovoltaic industry policies: from upstream to downstream

The main objects involved in policy-conducting path from upstream firms to downstream firms in the solar PV industry are government, policy variables, upstream firms, middle firms, and downstream firms (Figure 8.9).

Figure 8.9: Conduction Mechanism of China's Photovoltaic Industry Policies: From Upstream Firms to Middle Firms to Downstream Firms



Source: Compiled by the authors.

According to Figure 8.9, the main policy subject of China's solar PV upstream enterprises is the government, which sets fiscal policies, tax policies, and other policies (technical research and development, input and pollution compensation, etc.) based on the developing environment and trends. These policies take effect on the upstream firms, then through the middle firms and to the downstream firms. This policy-conducting process is not only influenced by the macro environment of the PV industry and by the development of the middle enterprises, whose feedback influences the development of the downstream enterprises. In the end, the task of realising the whole policy goal goes back to the government, which continues to modify and formulate corresponding policies to realise the industry goal. During the policy conduction process, the government and the enterprises act as subjects and objects, respectively, in a game. The goal of the government is to promote the development of the PV industry and guarantee the future supply of clean energy. The goal of the enterprises is to maximise their interests. Clearly, the government must ensure energy security while, at the same time, playing a game with the enterprises.

During this process, the government issues a series of industrial policies favouring the development of upstream firms according to the external macro environment of the industry (if the upstream firms can produce high-quality polysilicon products or the efficiency of polysilicon is quite high). For fiscal policies, the government first helps related upstream firms smooth financing channels by implementing more proactive fiscal policies and increasing their subsidies. Secondly, for the other policies, the government further intensifies efforts of developing and upgrading the polysilicon technology, optimising the investment environment, and implementing trade remedy policies, which eventually help the upstream polysilicon plants gain good advantages in international competitiveness. These policies further enlarge the production scale of upstream firms, and stimulate increase in production; enable the upstream firms to provide cheaper and high-quality supply of goods to the middle firms that assemble solar panels, thus promoting the development of middle business and improving product quality. In return, the development of middle firms and improvement of product quality provide a solid foundation and reliable supply for the development of the downstream firms.

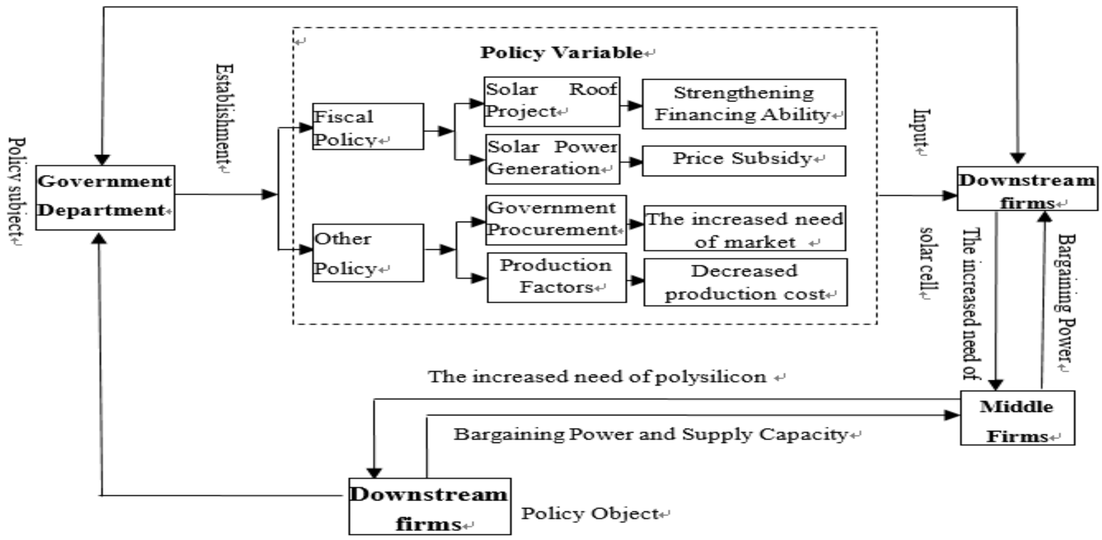
Conversely, if the government reduces its financial inputs to the upstream solar PV firms, cancels tax subsidies, and decreases R&D investments, etc., the production costs of the upstream firms will greatly increase and their advantages in the international market may be gradually lost. Then the middle firms that assemble solar panels will be faced with high-priced supplies with relatively low quality. As a result, the middle firms would not be able to provide sufficient resources for the downstream firms.

8.2. Conduction mechanism of China's photovoltaic industry policies: from downstream to upstream

The policies for the downstream firms that take a large proportion of the total policies of the solar PV industry affect the whole PV industry the most. For example, the Solar Rooftop Program, jointly implemented by the Ministry of Finance and the Ministry of Housing and Urban-rural Development in 2009 with CNY1.27 billion central budget, contributed to a nine-month continuous growth of price for polysilicon from CNY338.475 to CNY609.255 in 2010.

Policies for the downstream firms greatly promote the development of the upstream firms (Figure 8.10).

Figure 8.10: Conduction Mechanism of China's Photovoltaic Industry Policies: from Downstream Firms to Middle Firms and Upstream Firms

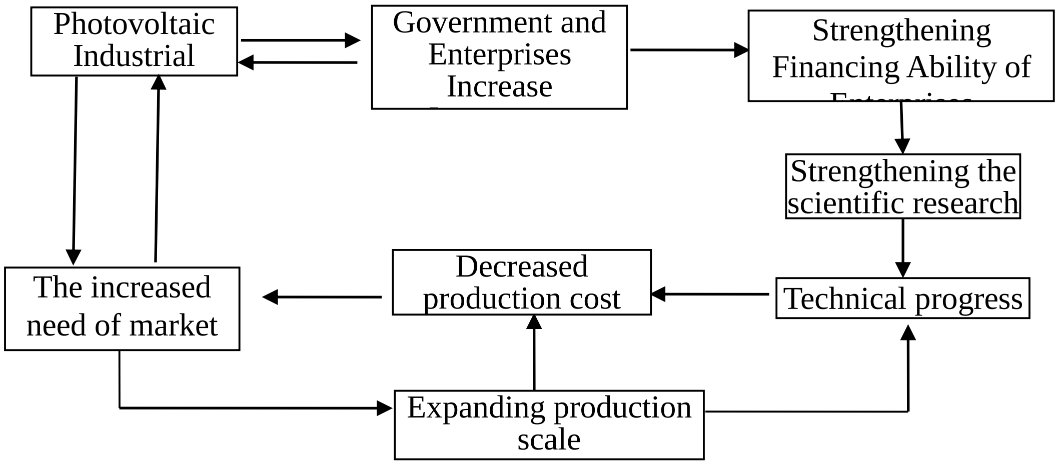


Source: Prepared by the authors.

According to Figure 8.10, the main body of the policy-conducting process from the downstream firms to the upstream firms is still the government. To begin with, the government effectively expands the market demand of downstream firms by implementing the Solar Rooftop Program, the Golden Sun Demonstration Project, and the government purchases. The downstream firms benefit from government subsidies that promote their development to some extent. Secondly, the feed-in tariff on solar power reduces the enterprises' production costs. These policies can greatly promote the development of the solar PV downstream firms, which, as a result, will further effectively increase the product needs of upstream-middle firms by expanding product market and reducing prices.

In conclusion， there are three main paths to promote the development of PV enterprises based on the impacts of the policies for upstream firms on the downstream firms and vice versa (Figure 8.11). Firstly, improve the investment environment of PV firms and enhance their financing ability; secondly, increase the openness of the PV market and raise the R&D and innovation level of PV firms; thirdly, expand the market demand for PV products, provide price subsidies, and reduce the enterprise's production and operating costs.

Figure 8.11: Conduction Mechanism of China's Photovoltaic Industry Policies



Source: Prepared by the authors.

9. Conduction effects of China's photovoltaic upstream and downstream industry policies

9.1. The introduction to the policy-conducting structure of solar photovoltaic industry chain

The solar energy industry chain covers upstream firms that mainly produce solar-grade silicon, middle firms that mainly produce solar energy battery components such as silicon ingot, silicon wafer, etc., and downstream firms that mainly conduct grid-connected or off-grid solar power generation. There are factors that influence the development of the solar PV industry chain. This paper only selects five indicators: price of polysilicon, government subsidies on polysilicon plants, price of solar cell, price of solar power, and the government's price subsidies on solar power.

9.2. Data

To reflect the relationships among these five indicators, data from China's PV industry, China environment, websites, and databases of renewable energy from January 2005 to December 2014 were processed. The selected data were used as sample data and processed separately. Given the non-stationary characteristics of most time series, statistical analysis was conducted on the data of price of polysilicon, government subsidies on polysilicon plants, the price of solar cell, the price of solar power, and the government's price subsidies on solar power. Eviews7.0 was used to analyse the correlation between variables.

Table 8.6 shows that the correlation coefficient between the price of polysilicon and government subsidies on polysilicon plants is 0.92896, between the price of polysilicon and the price of solar cell is 0.81236, between the price of polysilicon and the price of solar power is 0.52466, between the price of solar cell and solar power price is 0.82365, between the price of solar power and government subsidies on solar power is 0.96358. The data above reflect the high correlation between the price of polysilicon and government subsidies on polysilicon manufactures, that is, changes in government subsidies on polysilicon plants will lead to changes in the price of polysilicon, and this effect is relatively significant. Similarly, the impacts of government subsidies for solar power on the price of solar power are also significant. The correlation coefficient between polysilicon prices and government subsidies on solar power is 0.01235; between government subsidies on polysilicon plants and the government's price subsidies on solar power is 0.00235. It indicates some correlation between the price of polysilicon and government subsidies on solar power, as well as government subsidies on polysilicon plants and on solar power, but it is weak. The correlation coefficients between them are small.

Table 8.6: Correlation Coefficient Between Variables

	Price of Polysilicon	**Government Subsidies on Polysilicon Plants**	**Price of Solar Cells**	**Price of Solar Power**	**Government Price Subsidies on Solar Power**
Price of Polysilicon	1				
Government Subsidies on Polysilicon Plants	0.92896	1			
Price of Solar Cells	0.81236	0.02356	1		
Price of Solar Power	0.52466	0.61356	0.82365	1	
Government Price Subsidies on Solar Power	0.01235	0.00235	0.56951	0.96358	1

Source: Prepared by the authors.

9.3. Methodology

The unit root test, Johansen co-integration analysis, Granger causal test, and the more recently developed technique of directed acyclic graphs (DAG) were used in this study. Most scholars have applied DAG to conduct various effective analyses. The data of the five indicators (the price of polysilicon, government subsidies on polysilicon plants, the price of solar cell, the price of solar power and the government's price subsidies on solar power) of the solar PV industry chain are all time series. If the linear combination of them is stable, their long-term equilibrium relationship can be reflected by their linear combination. If the five indicators are co-integrated, there are unbiased estimators between them; however, it cannot indicate where the strongest correlation exists and which one plays the leading role in their causal relationship. Therefore, a Granger causal test is needed among the five indicators of the solar PV industry chain. Granger causality is based on the short-run causal relationships between variables and is used here to study whether there is a causal relationship between the five indicators of the solar PV industry chain, that is, a relationship of 'cause and effect' between them. Granger causal test proves to be relatively accurate in testing the causal relationship of prices and has been widely used as a result.

Based on the research ideas above, Granger clearly defined the causal relationship in 1969, which not $x_{t\text{-n}}$ only can be accurately tested, but also can be used to quantitatively analyse x_t the causal relationship y_t between variables. Granger causality test is a technique for determining whether one time series is useful in forecasting another. For two time serious x_t and y_t, if y_t can be explained by its past of y_{t-1}; and if the lagged value is added at the same time and significantly improves the explanatory power, the x_t is the Granger reason of y_t . This part will give a brief introduction to the Ganger causality test.

(1). Unit Root Test

An important prerequisite to Granger causality is all the time series must be stationary, and this testing process is called unit root test. There are several unit root test techniques and Aggregation-Diffusion-Fractal is the most common. The ADF unit root test is based on the following three regression forms:

1）: $$\Delta y_t = \beta y_{t-1} + \sum_{i=1}^{p} y_i * \Delta y_{t-i} + \varepsilon_t$$

2）: $$\Delta y_t = c + \beta y_{t-1} + \sum_{i=1}^{p} y_i * \Delta y_{t-i} + \varepsilon_t$$

3）: $$\Delta y_t = c + \alpha t + \beta y_{t-1} + \sum_{i=1}^{p} y_i * \Delta y_{t-i} + \varepsilon_t$$

The null hypothesis, for all of them, is: Ho: β =0, that is, the unit root exists. The difference between model 1) and the other regressions is whether the drift and time trend are included. The constant c makes no impact on the asymptotic distribution of β in regression 3), but the trend α affects it indeed. So it should be considered whether the time trend is needed when model 3) accepts the null hypothesis (β =0) according to the ADF critical value, namely, considering whether α =0 while testing β =0. If the testing result shows that the null hypothesis α = β =0 can be accepted, the model 2) should be tested. In the same way, the constant c of the model 2) impacts the asymptotic distribution of β . So it should be tested whether c=0 when β =0. If null hypothesis c= β =0 can be accepted, the model 1) should be tested. The three models will be tested one by one, starting from model 3) to model 1). The test doesn't stop until the null hypothesis is rejected, namely the unit root doesn't exist and the series is stationary.

(2). Granger Causal Test

After the unit root test, Granger causal test can be conducted if the x_t and y_t are both stationary series. Granger causal test can be expressed as the following regressions:

1）: $$y_t = \sum_{i=1}^{m} \alpha_i x_{t-i} + \sum_{j=1}^{m} \beta_j y_{t-j} + u_t$$

2）: $$x_t = \sum_{i=1}^{m} \lambda_i x_{t-i} + \sum_{j=1}^{m} \delta_j y_{t-j} + v_t$$

Where the error terms u_t and v_t are assumed to be uncorrelated the null hypothesis of Granger causality is "X does not Granger-causes Y" or "Y does not Granger-causes X". The testing process can be discussed as follows:

1） If the coefficients of lagged x in model 1) are significantly different from zero （$\sum \alpha_i \neq 0$）, and coefficients of lagged y in model 2) are not significantly different from zero （$\sum \delta_i = 0$）, there is a unidirectional causality from x to y, namely x→y.

2）If the coefficients of lagged x in model 1) are not significantly different from zero （$\sum \alpha_i = 0$）, and coefficients of lagged y in model 2) are significantly different from zero （$\sum \delta_i \neq 0$）, there is a unidirectional causality from y to x, namely y→x.

3）If both the coefficients of lagged x in model 1) and the coefficients of lagged y in model 2) are significantly different from zero （$\sum \alpha_i \neq 0$ & $\sum \delta_i \neq 0$）, there is a causal relationship between x and y, namely $y \leftrightarrow x$.

4）If both the coefficients of lagged x in model 1) and the coefficients of lagged y in model 2) are not significantly different from zero, there is no causal relationship between x and y, namely x and y are independent on each other.

(3). Directed Acyclic Graph

The Directed Acyclic Graph (DAG) is at present a widely-used analytic method. It mainly uses graphics to explore causal relationship that has nothing to do with the time sequences between variables. This method determines the causal relationship between variables mainly through calculating the conditional correlation coefficient and correlation coefficient, and mainly makes use of statistics to test the significance of the causal relationship between variables. The following three hypotheses are used to prove and determine whether the causal relationship exists between variables: sufficiency of causal relationship, confidence of causal relationship, and Markov Conditions. Sufficiency of causal relationship: All of the influencing factors of causal relationships can be found based on the premise that there is no missing data and the variables are complete, so the results of DAG by PC algorithm are accurate. Regarding confidence of causal relationship (with the relationship between correlation coefficient and the variables of directed edge and undirected edge), if both the conditional correlation coefficient and the correlation coefficient are zero, there is no undirected and directed link between these two variables. Markov Conditions: Change the probability distribution of variables in DAG into only probability distribution of the parent node and variables analysed. The PC algorithm mainly uses the Fisher's Z-statistics, mainly to test whether the partial correlation coefficient is significantly different from zero. The formula is as follows:

$$\mathrm{z}[\mathrm{p}(\mathrm{i},\mathrm{j}|\mathrm{k})\mathrm{n}]=1/2\,(n-|k|-3)^{1/2}\times\ln[\frac{|1+\mathrm{p}(\mathrm{i},\mathrm{j}|\mathrm{k})|}{|1-\mathrm{p}(\mathrm{i},\mathrm{j}|\mathrm{k})|}]$$

Where n is the number of observation samples used to estimate the correlation coefficients , $\mathrm{p}(\mathrm{i},\mathrm{j}|\mathrm{k})$ is the $\mathrm{z}[\mathrm{p}(\mathrm{i},\mathrm{j}|\mathrm{k})\mathrm{n}]\_\mathrm{z}[\mathrm{p}(\mathrm{i},\mathrm{j}|\mathrm{k})\mathrm{n}]$ partial correlation coefficient of variables of i and j with k conditional variable ; $|k|$ is the number of conditional variables. If $\mathrm{r}(\mathrm{i},\mathrm{j}|\mathrm{k})$ is the partial correlation coefficient of observation samples and if variables i, j and k are distributed normally, the bears a standard normal distribution.

(4). State Space Model

The linearised state-space model is conducted in this research, mainly including two equations: the state equation and the signal equation. The state equation can be expressed as:

$$\mathrm{P_t} = \alpha_t X_t + R_t I + \chi L + \varepsilon T + \mathrm{B}_t$$

where, P is the product price of China's PV firms; L is the government's supporting policy for the PV labours and expressed as the total employment of PV firms; T is the government's R&D supporting policy for the PV enterprise and expressed as the government's R&D investments in the PV enterprise; I is the price subsidy of country or enterprises on their products and expressed as the total price subsidies of ten representative firms in PV chains; X is industrial policy and acts as a virtual variable, which is 0 before implementing the industrial policies and is 1 after the implementation. The signal equation is:

$$X_t = T_1 \mathrm{X_{t\text{-}1}} + \Phi_t \mathrm{V_t}$$

Where, I, L and T are exogenous variable matrices, and B and V are white noise matrices. Suppose that X and P have joint normal distribution, and $\mathrm{X}|\mathrm{P}$ is conditional probability distribution, so the state equation and the signal equation are interrelated. Pt is constructed by the state vector X_t, exogenous variables It, Lt, Tt and residual item BT; State vector X_t is by its lag form X_t - 1 and residual Vt.

According to the theoretical analysis in this paper, the policies for the upstream (downstream) PV industry can greatly influence the development of the downstream (upstream) enterprises. These influences are not fixed; on the contrary, they will continually change with the changes of domestic and international economic environments as well as the characters of the PV industry itself. In order to accurately describe the dynamic relationship that how the policies for the upstream (downstream) PV industry impact the development of the downstream (upstream) enterprise, the time-varying parameter model of the state space model will be conducted in this paper, which can be expressed as:

$$@\,signal\ c1\,1 = c(1) + sv\,1 * jy + sv2 * j\,s + sv3 * zc + sv4 * cz + \left[var = exp\left(c(2)\right)\right]$$
$$@\,state\ sv1 = c(3) + sv1(-1)$$
$$@\,state\ sv2 = c(4) + sv2(-1)$$
$$@\,state\ sv3 = c(5) + sv3(-1)$$
$$@\,state\ sv4 = sv4(-1)$$

9.4. Empirical results and discussion

The conducting direction and conduction pathway should be clearly specified when analysing the policy conduction process of the solar PV industry chain, that is, analyse what relationship exists between these two influencing factors of the industrial chain. Generally, there is a co-integration relationship between some time series, which can be divided into two cases: one-way relationship and two-way relationship. But there are some special cases where they influence each other but there is no co-integration relationship between them.

According to the Eviews7.0, all the variables are stationary after second differencing at 5% significance level (Table 8.7) and meet the necessary conditions of building co-integration equation.

Table 8.7: Unit Root Test

Variable	**Silicon**	**S-subsidy**	**Solar**	**Power**	**P-power**
Testing Form	(c,t,1)	(c,t,1)	(c,0,0)	(c,0,1)	(c,t,1)
t-ADF	-3.14	-1.26	--2.36	-0.42	-0.56
Critical Value	-3.56**	-3.56**	-2.96**	-2.94**	-3.56**
Conclusion	Non- stationary	Non- stationary	Non- stationary	Non- stationary	Non- stationary
Variable	Δsilicon	Δs-subsidy	Δsolar	Δpower	Δp-power
Testing Form	(c,0,1)	(c,t,1)	(c,t,0)	(c,t,1)	(0,0,2)
t-ADF	-3.12	-4.53	-6.13	-4.25	-1.89
Critical Value	-2.96**	-4.36**	-4.36**	-3.62**	-1.52*
Conclusion	Stationary	Stationary	Stationary	Stationary	Stationary

ADF = Aggregation-Diffusion-Fractal.
Notes: Testing form (c,t,k) means the constant, time trend and lag length included in the unit root test.**and* implies stationary at 5% level and 10% level.
Source: Prepared by the authors.

Table 8.7 provides the unit root test results. The T-ADF of five variables are all larger than the critical values at 5% significance level, implying these five variables are non-stationary; but they are stationary after first differencing, suggesting these five indicators are I(1) series. There is a long-run and stable co-integration relationship between solar PV industry chains.

The results above reveal the price system of the solar PV industry chain bears a long-term equilibrium relationship with each other; but the causal relationship between prices of the solar PV industry has not been determined, which need further testing by Granger causality test. As shown in Table 8.8, the prices of polycrystalline silicon, solar cell, and solar power Granger cause each other. Government subsidies on polysilicon plants is the Granger cause of the price of polysilicon, and government subsidies on solar power generation is the Granger cause of the price of solar power; but the price of polycrystalline is not the Granger cause of government subsidies on polysilicon plants, and the price of solar power is not the Granger cause of government subsidies on the solar power. There is a co-integration relationship between solar PV industry chains. The influences of government subsidies for polysilicon plants on the price of polysilicon, and government subsidies for solar power on the price of solar power are relatively significant.

Table 8.8: Granger Causality Test

Null Hypothesis	F-Statistic	P-Statistic	Accept/ Reject the Null Hypothesis
The price of polysilicon does not Granger cause government subsidies on polysilicon plants	1.04532	0.4126	Accept
Government subsidies on polysilicon plants does not Granger cause the price of polysilicon	5.62381	1.E-26	Refuse
The price of polysilicon does not Granger cause the prices of solar cell	2.31256	0.02589	Refuse
The prices of solar cellos does not Granger cause the price of polysilicon	4.58963	0.12356	Refuse
The price of polysilicon does not Granger cause the prices of solar power	2.38965	0.09632	Refuse
The price of solar power does not Granger cause the price of polysilicon	3.34569	0.19865	Refuse
The price of polysilicon does not Granger cause the government's price subsidies on solar power	0.79968	0.58694	Accept
The government's price subsidies on solar power does not Granger cause the price of polysilicon	2.36986	0.08965	Refuse
The prices of solar power do not Granger cause the prices of solar cell	3.18653	0.13256	Refuse
The prices of solar cell do not Granger cause the prices of solar power	2.89564	0.46531	Refuse
The prices of solar power do not Granger cause the government's price subsidies on solar power	1.56897	0.09865	Accept
The government's price subsidies on solar power do not Granger cause the prices of solar power	3.65891	1.56234	Refuse

Source: Prepared by the authors.

The Vector Error Correction (VEC) model can be considered according to the results above. The VEC model is often used for non-stationary time series and the variables in it should be co-integrated. The vector auto regression can be expressed as:

$$\Delta Y_t = \alpha\beta Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i Y_{t-i} + \varepsilon_t$$

The error term of each equation is stationary. But the co-integration can be expressed in many forms. In Error Correction Model, it can be expressed as:

$$\Delta Y_t = \alpha \text{vecm}_{t-1} + \sum_{i=1}^{p-1} \Gamma_i Y_{t-i} + \varepsilon_t$$

Each equation is an Error Correction Model. $\text{vecm}_{t-1} = \beta Y_{t-1}$ is an error correction that implies the long-term equilibrium relationship between variables, α indicates the speed of adjusting the variables to the equilibrium.

By accurately estimating parameters of ECM, a Correlation Matrix of these five indicators (the price of polysilicon, government subsidies on polysilicon plants, the price of solar cell, the price of solar power and the government subsidies on solar power) is worked out (Figure 8.12).

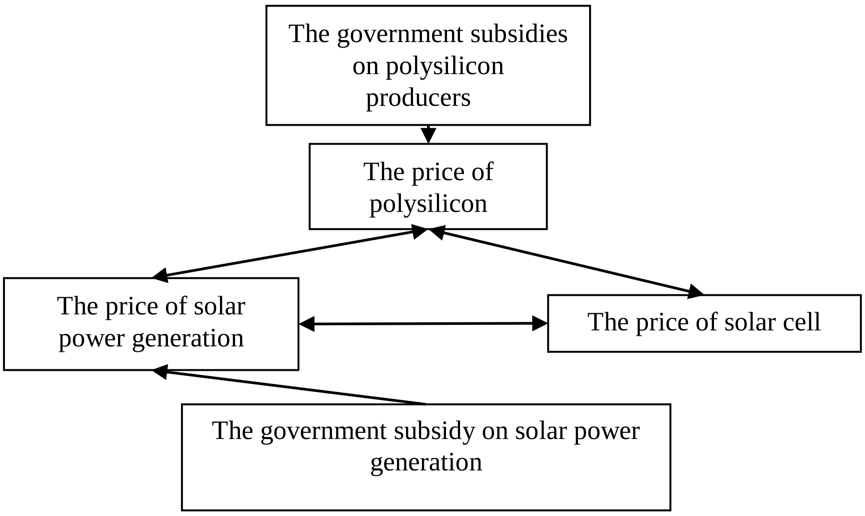
Figure 8.12: Correlation Matrix of Variables

$$\begin{bmatrix} 1 & & & & \\ 0.568956332 & 1 & & & \\ 0.163569732 & 0.045689324 & 1 & & \\ 0.412356871 & 0.423568793 & 0.235686369 & 1 & \\ 0.562368742 & 0.259657364 & 0.162368027 & 0.089563242 & 1 \end{bmatrix}$$

Source: Prepared by the authors.

Based on this Correlation Matrix of these five indicators, a study of their contemporaneous causal relationship is conducted by Directed Acyclic Graph (Figure 8.13). According to the results, the price of polysilicon, the price of solar cell, and the price of solar power affect each other; the changes of the prices of solar cells can also cause the changes of polysilicon's price, so do the price of solar power and the price of solar cell. It should be noted that government subsidies on polysilicon plants can cause the changes of polysilicon's prices, and then affect the price of solar power through middle enterprise's products. Similarly, government subsidies on solar power can affect the polysilicon's price fluctuations in the same way.

Figure 8.13: Contemporaneous Granger Causality Analysis Between Variables



Source: Prepared by the authors.

9.5. Empirical Results and Discussion

This part constructs the state space model so as to empirically analyse the policy-conducting effects at China's PV industry level (taking impact on price as example). The empirical results are also deeply studied.

(1) Unit Root Test. The variables of state model should be stationary. According to the principles of unit root test, two groups of variables are selected at first. One group is the products' price in the downstream PV industry P1, the government's supporting policy for the upstream PV labours L1, the government's R&D supporting policy for the upstream PV enterprise T1, the price subsidy on upstream PV enterprises I1. The other group is the products' price in the upstream PV industry P2, the government's supporting policy for the downstream PV labours L2, the government's R&D supporting policy for the downstream PV enterprise T2, the price subsidy on downstream PV enterprises I2. Next, ADF text is conducted for these two groups of variables. According to the testing results, the T-ADF is larger than the critical value at 10% significance level, implying these two groups of variables are stationary.

(2) The impact of upstream industry policy on the prices of downstream products. Considering the impacts of upstream PV industry policy on downstream products, this study covers 10-year data from 2005 to 2014 and uses the fixed average method for the regression analysis (Table 8.9 and Table 8.10).

Table 8.9: Impacts of Explanation Variables on the Prices of Downstream Photovoltaic Products

	Coefficient	Std.Error	z-Statistic	Prob.
C(1)	3.2098	0.00439	616.6895	0
C(2)	-3.9886	1.99E-09	-152.3657	0
C(3)	0.2015	0.00058	1223.006	0
C(4)	0.1985	1.23E-02	15612.58	0
C(5)	0.1135	4.65E-02	254.8596	0
	Final State	Root MSE	z-Statistic	Prob.
SV1	-0.1686	0.0248	-4685.009	0
SV2	26.6896	0.0475	5639.326	0
SV3	0.2986	3.39E-04	9189.26	0
SV4	0.0161	0.0456	28956.89	0
Log likelihood	-2.58E+06	Akaike info criterion		49869597
Parameters	4	Schwarz criterion		49869598
Diffuse priors	3	Hann an-Quinn criter		49869597

Source: Prepared by the authors.

Table 8.10: Dynamic Impacts of Explanation Variables on the Prices of Downstream Photovoltaic Products

Obs	SV1F	SV2F	SV3F	SV4F
2005	0.000	0.000	0.000	0.000
2006	0.1983	0.2894	0.5984	0.000
2007	0.3865	4.5896	-0.108	0.000
2008	-19.233	4.3981	0.098	0.000
2009	96.325	1.798	0.019	0.000
2010	-97.026	1.986	0.156	-368.887
2011	-152.364	5.986	-0.102	309.653
2012	-568.056	-10.365	-0.268	54.562
2013	-319.356	32.892	0.385	1496.356
2014	-509.365	41.236	0.568	2008.369

Source: Prepared by the authors.

As shown in Table 8.9 and Table 8.10, the coefficients of variables are all significant at 1% significance level. In general, (1) For the impacts of upstream PV industrial policies on the downstream products, the policy-conducting effects are not obvious, that is, one unit of price drop due to the subsidy for the upstream PV enterprises leads to 0.016-unit price drop of downstream products, which is mainly due to the nature of the PV industry in China. First, the impacts of polysilicon imports ： Generally, China's polysilicon production technology is poor and, as a result, the costs are higher than the costs abroad and competitive advantages are lost. Relevant data show that the spot prices of polysilicon imports are generally CNY0.5–10,000/tonne lower than the domestic products at the same grade. The domestic polysilicon firms are definitely shocked by these low prices and have to reduce their prices to compete with polysilicon imports for the limited market share. For example, due to the government policies, subsidies, and many other factors, the spot price of domestic polysilicon dropped from CNY165,000/tonne to CNY125,000/tonne, decreasing by 24.24%, from April 2014 to April 2015. The electricity-generating price of downstream PV industry only dropped from CNY1.2/kwh in 2014 to CNY1.15/kWh, only by 4.17%, which was small.

Second, the large impacts of demand for downstream products. For the same kinds of polysilicon products abroad, China is not competitive and has less export demands. On the contrary, the polysilicon imports greatly influence China’s polysilicon enterprises. According to the silicon industry branches, China’s polysilicon enterprises had about 8500 tonnes of internal inventory by the end of April 2015, which means most domestic firms suffered more than one month of inventory, which was much more than the normal range of one-week inventory and caused considerable pressure on firms’ sale and capital operation. Faced with the double pressure of dumped imports and weak demand, domestic polysilicon’s price had to continuously decrease, from CNY166,000/tonne in early April 2014 to CNY120,000/tonne at the end of April 2015. So, the impact of policy and subsidy for the upstream enterprises on the product price of downstream enterprises are weak. (2) For the analysis of the dynamic coefficients, the upstream industry policy had great influence on the downstream products in 2006, 2013, and 2014. In 2006, polysilicon firms were at the early stage of development, and the government introduced the Measures for The Control of Renewable Energy Fund, both of which made the price changes of upstream products produce large influence on the prices of downstream products. In 2013 and 2014, Chin’s solar cells saw sustainable production growth. For example, China produced 26.2 million kW solar cells in 2013, with year-on-year growth of more than 20% and accounting for 65% of global production, which greatly promoted the development of the polysilicon enterprises and further increased the influences of the polysilicon price on that of downstream products. (3) The impact of downstream industry policy on upstream product prices. The method is the same as (2), using 10-year data from 2005 to 2014 and conducting regression analysis by fixed average method. See Table 8.11 and Table 8.12 for results.

Table 8.11: Impacts of Explanation Variables on the Prices of Downstream Photovoltaic Products

	Coefficient	**Std.Error**	**z-Statistic**	**Prob.**
C(1)	2.1986	0.00256	589.3651	0
C(2)	-2.6589	0.98E-12	-123.3645	0
C(3)	0.1956	0.0127	563.986	0
C(4)	0.2032	0.98E-19	9883.23	0
C(5)	0.1025	3.96E-09	243.368	0
	Final State	Root MSE	z-Statistic	Prob.
SV1	0.2358	0.0566	-456.156	0
SV2	9.3651	0.0759	2356.234	0
SV3	0.2866	2.99E-08	8563.45	0
SV4	2.3564	0.0563	12368.58	0
Log likelihood	-1.49E+06	A kai ke info criterion		38978447
Parameters	4	Schwarz criterion		38978448
Diffuse priors	3	Hann an-Quinn criter		38978447

Source: Prepared by the authors.

Table 8.12: Dynamic Impacts of Explanation Variables on the Prices of Upstream Photovoltaic Products

Obs	**SV1F**	**SV2F**	**SV3F**	**SV4F**
2005	0.000	0.000	0.000	0.000
2006	0.4563	0.5637	0.1235	0.000
2007	0.5632	5.4563	-0.068	0.000
2008	18.3642	6.4521	0.098	0.000
2009	56.325	0.5621	0.063	0.000
2010	32.376	5.7531	0.638	-125.456
2011	12.452	6.4573	-0.174	234.653
2012	45.237	9.457	-0.453	65.123
2013	23.54	13.653	1.478	2356.568
2014	63.365	23.647	1.037	2145.368

Source: Prepared by the authors.

According to Table 8.11 and Table 8.12, the coefficients of variables are all significant at 1% significance level. In general, (1) for the impacts of downstream PV industrial policies on the upstream products, the policy-conducting effects are relatively obvious, that is, one unit of price drop due to the subsidy for the downstream PV enterprises led to 2.356-unit price rise of upstream products, which is mainly because the demand of upstream products are greatly influenced by the downstream product demand. As mentioned before, China's polysilicon suffers from poor production technology, high costs, and weak competitiveness. As a result, little changes take place in polysilicon exports but are greatly affected by the domestic demand. For example, the National Development and Reform Commission issued National Development and Reform Commission's Notice of Promoting Healthy

Development of the Photovoltaic Industry by Price Leverage Function in 2013, which set whole power subsidy for the distributed PV power and the feed-in tariff was CNY0.42/kWh. In the same year, the polysilicon price rose from CNY122,500/tonne to CNY132,800/tonne, increasing by 8.4%. Obviously, the upstream product demand can be greatly influenced by the downstream product markets. (2) For the analysis of the dynamic coefficients, the downstream industry policies had relatively large influence on the upstream products from 2007 to 2012. During this period, China's polysilicon industry at rising stage gradually went into the product-accumulating stage. In addition, the decreasing demand for downstream products and poor subsidy policy led to downstream inventory backlog, which seriously affected the upstream product sales and decreased the prices. According to the silicon industry association, China produced 23,700 tonnes of polysilicon in the first two months of 2015, 11,900 tonnes in January, and 11,800 tonnes in February. However, the domestic demand is far less than the production. At the same time, the US and South Korea exported a large number of polysilicon to China by processing trade last year, which also caused downstream inventory backlog, especially the inventory of last year.

The above analysis implies that the policy-conducting effect from upstream PV enterprises to the downstream products is smaller than that from the downstream PV enterprises to the upstream products.

10. Conclusion and policy implications

The solar PV industry in China has faced many challenges as we have discussed in the previous sessions. Therefore, the government needs to carefully design its policies to encourage healthy growth of the industry. Based on the economic analysis we have conducted above, we would like to recommend the following policy implications:

First, the government should focus on the coordinative implementation of the policy plan and promote the healthy and coordinated development of the solar PV industry. The central government should coordinate with local governments to provide macroeconomic guidance. For example, the central government should set the solar PV generation plan and annual guidance. Local governments should optimise their annual power generation plans and enforcement projects subject to local resource, electric grid construction, and national quota control. Solar PV generation plants should be built with planned and unplanned investments, as well as generation restrictions led by such unplanned investments should be discouraged. Meanwhile, local governments should improve market transparency and avoid local protection.

Second, the government should increase technology standards for market entry. Some standards should be raised to international levels. Moreover relevant technology regulations should be implemented to enhance technology requirements to ensure that firms with more advanced technology will have better growth potential. More complete and strict standards and authorisation systems should be built up. After sale service standards should also be improved and products that could not reach the standards or overdue projects that could not be restructured should be eliminated from the market. Market should play more important role. Mergers and acquisitions should be encouraged and social resources should be allocated to the firms that meet regulation standards, which indirectly lead underdeveloped firms to exit the market.

Third, the government needs to support indigenous innovations and help solar PV firms enhance their competitiveness. There are many problems in technology economy issues, solar PV grid-connection, storage equipment manufacture and system integration, and electric system adaptation, among others. China should increase research funding to achieve technology breakthrough from materials to system industrial chain integration and local manufacture of high-end equipment. Through construction of research centres or technology upgrade, policymakers should support indigenous innovations and leading firms that have indigenous technologies. With these, the industry will benefit from increased competitiveness and accelerated commercialisation of research outputs.

Fourth, policymakers should improve electricity pricing and cost allocation policies to offer a stable market growth expectations. As there are several lessons to be learned from government subsidies to solar PV power generation projects, policymakers should make further complete policies to provide growth expectations to investment parties. Such a way will make it possible for higher capacity solar PV power generation.

Multilevel solar PV generation markets should be established. On-grid generation and off-grid applications should be integrated. Centralised development and localised application should be coordinated. Policymakers should release the enforcement rules for solar PV grid-connection and cost allocation in electricity pricing. More research should be carried out to find the mechanism to decrease solar PV on-grid prices. Government subsidies should be coordinated with market competition to encourage firms to cut costs and increase technology innovations.

Fifth, fiscal support and tax incentive policies should be applied to eliminate market obstacles. Tax incentives should be provided to solar PV firms and more complete subsidy policies should be established. If resources allow, multi-level subsidies would be the optimal policy choice, i.e. different fiscal subsidies will be given to companies with different technologies and products on different development stages. For firms with less developed technologies, subsidies should focus on technology R&D and demonstration projects. For those with more developed technologies, subsidies should focus on PV generation products. For those with mature technologies, subsidies should be added to electricity consumption, i.e., to end consumers. Market mechanism should lead the development of the PV industry.

Sixth, financial systems should be improved and social capital investments should be encouraged. Policy financing institutions should provide credit support to commercialisation of technology innovation and acquisition of foreign firms with industry-leading technology. The government should also lead various commercial finance institutions on innovative loan products to support indigenous innovations and commercialisation of the PV industry. PV firms that passed the requirements could issue enterprise bonds, corporate bonds, short-term financing bills, and mid-term notes, etc.

Seventh, policymakers should implement strategies that integrate technology, market, and policy. Experience in developed countries has proved that strategies that integrate technology, market, and policy are necessary conditions to secure commercial competition of the PV industry. In China, technology, market, and policy are disconnected from each other, which lacks scale-up effect. The government should give relevant guidance to encourage industry mergers and acquisitions and restructure. It should support those firms with essential technology and strong indigenous innovation potentials. By this way, those PV firms could extend industrial chain, grow large and strong, and then increase risk resistance ability.

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Chapter 9

Retail Electricity Tariff and Mechanism Design to Incentivise Distributed Generation[34]

Ramteen Sioshansi

Abstract

*This chapter examines the question of how to incentivise the adoption and use of renewable energy resources, with particular attention given to distributed renewable energy. Prior experience suggests that price and quantity-based programmes such as feed-in tariffs provide more efficient renewable adoption and use and lower costs than programmes that set quantity targets only. Some cost-allocation issues raised by the use of distributed renewable energy systems and fixed time-invariant retail pricing are also examined. This combination can result in customers with distributed renewable energy systems paying a disproportionately small portion of system capacity costs. This chapter suggests two retail-pricing schemes – i.e., real-time pricing and a two-part t*ariff with demand charges – to address these issues.

Keywords: Distributed generation, retail electricity pricing, incentive mechanisms

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All the opinions expressed here are solely those of the author and do not necessarily represent those of any other individual or organisation, including ERIA.

1. Introduction

The recent years have seen more installation and use of distributed renewable energy (DRE), especially photovoltaic (PV) solar, in many parts of the world. This has been spurred, in part, by subsidies and favourable regulations.

According to Sawin et al. (2014), at least 144 countries had some type of renewable energy target or incentive programme in place as of early 2014. These incentive mechanisms aim to reduce the privately incurred cost and risk of installing these technologies, spurring greater use in the short run. In the long run, the greater the use of these technologies, the lower the expected costs because of economies of scale in manufacturing and installation and `learning-by-doing' effects. These technologies thus become more competitive compared with alternatives. If taken to fruition, the incentive programmes can drive DRE technologies to a point of maturity such that they will be able to compete with alternatives even without any incentive mechanisms at all.

Different jurisdictions have used various combinations of incentive mechanisms to spur DRE adoption. These mechanisms can be in terms of either (a) direct financial subsidy for DRE adoption or use or (b) provision of a guaranteed market for DRE energy. Experience to date has shown that these mechanisms have different levels of success in encouraging DRE adoption.

Moreover, there are key implementation nuances that can help or hinder the performance of incentive mechanisms. Some incentive mechanisms have created unintended negative cost-allocation issues. These cost-allocation issues are mostly related to the fact that retail electricity pricing lumps the variable cost of energy generation with the fixed cost of investing in generation, transmission, and distribution capacity. These two types of costs are remunerated using a volumetric charge on energy consumption to retail customers. Some price-based incentive mechanisms for DRE result in capacity-related costs being increasingly borne by customers who do not have access to DRE, creating undesirable cross-subsidies. As such, some jurisdictions have, *ex post*, limited or rescinded incentive programmes to mitigate these issues.

This chapter studies the problems in incentive and retail tariff programmes that are designed to efficiently encourage DRE adoption and use. It also identifies lessons from previous attempts and failures. It presents its recommendations on how to mitigate the unintended cost-allocation consequences of DRE-related incentive schemes through better tariff design.

The remainder of this chapter is organised as follows: Section 2 summarises the types of incentive programmes used to date. It also provides a comparative assessment of how well different programmes faired and discusses the philosophical reasons certain mechanisms are sometimes favoured over others. Section 3 introduces the negative cost-allocation consequences of these programmes. Section 4 discusses a proposal for retail tariff design that can address some of the cost-allocation issues discussed in Section 3. Section 5 presents the conclusions.

2. Distributed renewable generation incentive policies

This section provides an overview of the different types of incentive mechanisms commonly used in different jurisdictions to encourage the adoption and use of DRE.[35] Distributed renewable energy historically has two competitive disadvantages relative to other alternatives. The first is that DRE can be seen as a risky investment compared to better-understood conventional alternatives. *Ceteris paribus*, investors may prefer conventional alternatives to DRE, thus increasing the financing costs of DRE technologies. Second, DRE technologies may have higher upfront costs due to their relative immaturity compared to conventional alternatives, further complicating financing.

Incentive mechanisms aim to reduce the privately incurred cost and risk of adopting and using DRE technologies. The incentive mechanisms that have been historically used can be differentiated by how they drive this cost and risk reduction. The four major incentive mechanisms commonly used are the (a) feed-in tariff (FIT), (b) quota-obligation, (c) tendering, and (d) net-metering systems. This study also discusses other financial subsidy systems that have been used and important technical considerations when integrating DRE into electric power systems.

2.1. Feed-In tariffs

Feed-in Tariffs (FITs) are currently the most widely used DRE-related incentive

[35] The incentive mechanisms discussed here have typically been applied to all sources of renewable energy, including DRE and utility-scale systems.

mechanism. Umamaheswaran and Seth (2015) defined the fundamental features of FITs as a guaranteed price for and guaranteed purchase of energy produced by a DRE system. That is to say, a FIT programme provides a guaranteed payment for each kWh of energy produced by a qualifying DRE installation. Most FIT programmes also require the local utility or system operator to accept any DRE provided by the end customer, except when this is infeasible for technical reasons. These design features reduce the risk associated with a DRE investment by providing a guaranteed market for energy produced.

The primary advantage of a FIT programme is that it manages the revenue risk in a DRE system by guaranteeing the quantity of energy sold and the price at which it is sold. This lowered risk tends to effectively ease project financing. According to Lipp (2007), these price and quantity guarantees are often provided for 8 to 15 years, but sometimes for as long as 30 years. Fouquet and Johansson (2008) and Umamaheswaran and Seth (2015) noted that the reduced risk allows DRE developers to more effectively leverage debt and to bring down financing costs.

Lipp (2007) also highlighted that a FIT programme can be tailored to different DRE technologies. For instance, the guaranteed price per kWh provided by a distributed solar plant can be set differently from that for a distributed wind plant. This allows the FIT programme to accommodate the relative maturity of different technologies. Van der Linden et al. (2005) and Lipp (2007) observed that the price guarantees in a FIT programme can also decline over time.

Van der Linden et al. (2005) noted that the main criticism of the FIT system is that its efficiency depends on how accurate the price guarantee has been set. If the price is too high, the system could result in excessive windfall profits to generators at the expense of consumers or taxpayers. If it is set too low, the programme may be ineffective in spurring any DRE development.

The information needed to correctly set FIT price guarantees largely comes from DRE owners or developers, although these may not have any incentive to reveal their true costs. In fact, these agents may have strong incentives to overstate their costs.

The FIT design is even more complex than this information asymmetry suggests. The mix of generation technologies that is ultimately deployed depends on the relative price guarantees set for them. This becomes an even more formidable task for a regulator, as it must know the costs of technologies and what an `optimal' technology mix is, taking into account relative technology maturity and performance. Another criticism of FITs, according to Lipp (2007), is that the guaranteed prices for different DRE technologies do not encourage competition between technologies. As such, the mix of DRE technologies deployed may not be the least cost.

Feed-in tariffs have been implemented in a number of jurisdictions successfully; that is, in the sense that they have spurred DRE adoption. One of the first examples, the Public Utility Regulatory Policy Act (PURPA) of 1978 in the United States, guaranteed payments for qualifying energy-producing facilities. Payments were based on assumed future fossil fuel costs, which were estimated at $100 per barrel of oil by 1998. However, the high price guarantees of PURPA did not prevail and the programmes were ended as a result of falling fossil fuel prices and the introduction of restructured wholesale electricity markets in the late 1990s and early 2000s.

The second wave of FITs was implemented in Germany and Denmark in the 1990s. Programmes required utilities to purchase energy from qualifying renewable energy installations at prices that were established by the government. The price premia aimed to compensate renewable energy facilities for the unpriced environmental benefits of their renewable energy generation. Denmark introduced its FIT programme in 1993 with a fixed price paid to qualifying facilities. This was modified towards a more market-based design in 2001. Under the new design, qualifying facilities are paid the price established by NordPool[36] plus an environmental premium. According to Mitchell et al. (2006), this created a price risk for a DRE deployment, because part of the guaranteed payment is tied to a volatile wholesale electricity market price. However, a portion of the price guarantee (i.e., the environmental premium) is fixed through legislation.

Germany began DRE-related incentive programmes in the 1970s. As with PURPA, these programmes were spurred by high fossil fuel prices. The first German programme had a similar design as PURPA, but provided much lower price guarantees. Thus, it had very limited success in spurring technology deployment. A FIT bill, which required utilities to connect DRE generators to the grid and purchase their produced electricity at a price that is 65% to 90% of the average tariff for retail customers, was later passed in 1990 (Mitchell et al., 2006). This bill helped spur close to 1 GW of renewable energy capacity in the system

[36] NordPool is the wholesale electricity market operator in the Scandinavian countries.

within five years.

The FIT law was revised in the 2000s in several important ways (Mitchell et al., 2006). One was to move away from fixing the price supports based on retail prices. Instead, the price supports were set based on technology and location within the country. According to Lipp (2007), and Fouquet and Johansson (2008), this action acknowledged the differences in technology maturity and renewable resource availability in different parts of the country.

The method of allocating FIT costs across ratepayers within Germany was also modified to better distribute costs. Under the original FIT law, costs were borne by customers of each local utility. The new programme, on the other hand, spreads these costs nationwide. This way, it avoids the scenario where costs are being borne disproportionately by customers residing in areas of the country with relatively good renewable resources (which is where qualifying facilities are more likely to cluster). The new FIT law fixed payments to qualifying facilities for 20 years but also included explicit provisions to reduce rates paid to new deployments over time to reflect the maturing of technologies.

Parts of the FIT concept here have been employed in other parts of the world as well. As an example, Liu and Kokko (2010) discussed the `Opinion on Wind Power Farm Construction and Management' of the Chinese Ministry of Power in 1994. This policy statement required power grids to purchase all electricity generated by wind plants and made sure that the price paid was set high enough to cover costs. It provided the guaranteed purchase requirement of a FIT and suggested a remuneration scheme for cost recovery. This was followed up by a policy outlining the `Approach of Grid Enterprises Purchasing Renewable Energy Electricity' in 2007. The policy states that renewable facilities have priority access to the electric power grid and that grid enterprises are required to purchase renewable energy at a regionally defined benchmark price.

2.2. Quota-obligation system

Compared to the FIT, the quota-obligation system takes a fundamentally different approach to incentivising DRE. Under this system, there is a legal obligation to procure a certain amount of energy from qualifying resources. Most quota-obligation systems take the form of a renewable portfolio standard (RPS). The RPS, widely used in the United States and in other countries, typically covers all renewable energy sources, including DRE, in its mandate.

Renewable portfolio standards can vary considerably in their implementation details. One question on the design of RPS is: To whom should the obligation be placed? Often, the obligation is placed on the retail energy supplier. However, it could presumably be placed on generators or end customers. In the latter's case, the retail energy supplier would procure qualifying energy resources on behalf of most customers. This is tantamount to the RPS placing the obligation on the retail supplier. However, placing the obligation on the customer may give large commercial and industrial customers added flexibility to procure qualifying energy resources on their own through competitive tenders. Quota-obligation systems typically provide strong financial penalties for unmet obligations.

Another design question is whether the RPS should specify either the amount of renewable energy or the renewable capacity that must be procured. Of the two, the former is more typically used as it provides a strong incentive to build plants in locations that have available renewable resource and to drive plants to operate efficiently. These outcomes, in contrast, cannot be attained if generating facilities' obligation is capacity-based.

Energy-based RPS programmes typically create a new set of tradable instruments known as renewable energy certificates (RECs) whenever a qualifying renewable facility produces energy. These can be traded or sold to entities that then use them to meet their RPS obligations. Renewable energy certificates do not typically have to be sold to the buyer of the energy from the renewable facility. In fact, the separation of the REC from the underlying energy can help to facilitate renewable delivery. For instance, a small retail supplier with an RPS obligation may have difficulty balancing variable generation from a renewable generator, and its customers' demands and its other energy supply sources. In such a case, the retail supplier can purchase RECs from a qualifying renewable facility to meet its RPS. It can then use dispatchable generation to serve its customers' demands.

The renewable facility can sell its energy in an organised wholesale market or through bilateral contracts with a third party that does not purchase the associated RECs. Quota obligation systems also vary in terms of how much RECs can be exchanged intertemporally – i.e., whether excess RECs can be `banked' for future use or to satisfy previous unmet obligations.

The primary benefit of a quota-obligation system is that it theoretically achieves the target DRE level at minimal cost (van der Linden et al., 2005). This is because the design explicitly incentivises parties to met their obligations using the lowest-cost technology available. Relatedly, the design provides strong incentives to reduce technology costs. Mitchell et al. (2006) and Lipp (2007) saw a philosophical advantage to quota-obligation systems, in that the technology choice and prices are not set by legislative or regulatory fiat. Instead, by setting an obligation and allowing entities to use any combination of qualifying technologies to meet it, the quota-obligation systems allow the market to determine what combination of technologies to use. Mitchell et al. (2006) further noted that because the quota-obligation system does not set specific prices for different technologies, the government is not in a position to pick 'winners' and 'losers.'

However, these features of the quota-obligation system can be weaknesses as well. If a goal of DRE incentive programmes is to drive down costs in the long run, a quota-obligation system may only achieve this for mature technologies (van der Linden et al., 2005; Lipp, 2007). The less mature technologies that are costlier will not be deployed until the marginal cost of the mature technology is equalised with the less mature one.

This 'myopic' design of a quota-obligation system can retard the development of a nascent technology that shows some promise from a long-run perspective. To overcome this problem, one can set technology-specific obligations or technology-specific `REC production rates'. For example, one can design a programme wherein wind generators produce one REC per megawatt hour (MWh) whereas tidal generators produce three RECs per MWh. This way, a distinction is set among technologies at different maturity levels. The United Kingdom implemented such a technology-specific conversion rate in its quota-obligation system (Fouquet and Johansson, 2008).

However, the same issues related to setting the proper price in a FIT will now be faced if this conversion rate approach is used in a quota-obligation system.

Another major weakness of the quota-obligation system is that it can introduce more price uncertainty than the FIT. This is largely because the REC price is set in the market, and market dynamics can vary over the life of a DRE or other renewables deployment. Moreover, economic theory holds that RECs in a quota-obligation system only have value if the obligation is not met. Otherwise, there would be excess RECs, and the price should presumably fall to a level that drives excess renewable projects (and their RECs) out of the market. In some cases, these design features have led to the obligation being persistently unmet. The underlying goal of the programme is therefore not achieved, unless the quota-obligations are intentionally set at higher-than-desired levels.

In other instances, the price risk and uncertainty have made financing DRE and renewable projects more difficult. A way to deal with this price risk and the associated financing difficulties is for retail suppliers to develop their own renewable projects and self-supply their obligations. By integrating, these firms now become larger and thus have greater access to the capital and financing they need. Moreover, each retail supplier has a guaranteed 'market' for its RECs, reducing the volume risk that an independent renewable generator faces. Thus, quota-obligation systems as a mechanism are less likely to incentivise DRE projects. That is, while DRE projects tend to be owned and operated by small producers, quota-obligation systems are often observed to favour large producers instead (Mitchell et al., 2006; Lipp, 2007). The self-supply of obligations by large retail suppliers also reduces the liquidity of the REC market, which can hinder price formation.

The quota-obligation system implemented in the United Kingdom has an additional provision that further exacerbated RECs' price uncertainty. In the United Kingdom's programme, penalties that are assessed for non-compliance with the mandate are 'recycled' back to compliant entities. These recycled payments are made in proportion to the number of RECs that an entity submits. Thus, these recycled payments, which can be difficult to predict from year to year, effectively increase the value of each REC (Mitchell et al., 2006).

Another weakness of the quota-obligation system is that its cost is difficult to predict *a priori*. The market price of RECs is determined by how aggressively the obligation is set, the level of the penalty for non-compliance and other factors. It is also important to stress that if values are set too aggressively, this can result in excessively high REC prices and windfall profits to qualifying renewable and DRE suppliers.

The first application of quota-obligation systems, which was in the form of RPSs, appeared in the United States (van der Linden et al., 2005). Through the years, the US experience has been quite mixed. On one hand, Texas has had a very successful programme that seems to have overcome many of the volume and price risks that a quota-obligation system can carry. Langniss and Wiser (2003) noted that under the RPS in Texas, electricity suppliers have been willing to sign 10- to 25-year contracts with renewable suppliers for RECs and the associated energy. These long-term contracts provide the type of revenue guarantee that a FIT does, allowing for lower-cost financing of a renewable project.

On the other hand, van der Linden et al. (2005) cited the case of utilities in the state of Nevada. Here, the utilities had signed contracts with renewable developers that failed to bring their projects on-line, resulting in substantial under-compliance with the state's quota-obligation. The state regulator further declined to penalise the utilities for this lack of compliance. This regulatory uncertainty and apparent willingness by the regulator to rescind penalties can significantly undermine future attempts at implementing an RPS in the state.

Similarly, Sweden implemented a quota-obligation system beginning in 2003 that has seen disappointing results (van der Linden et al., 2005). In the first year of the programme, the compliance level was about 77.1% of the quota, despite an excess of about 2 million RECs being banked for future use. The outcome was due to market participants' expectation that the price of RECs will rise in subsequent years.

There too was the issue with regulatory uncertainty in the Swedish system. The programme was initially slated to run from 2003 to 2010 – a total of 7 years – without any clear indication of whether it would continue past that point. Thus, a potential renewable/DRE project could only rely on a seven-year REC market. This design feature significantly limited the extent to which the programme provided revenue certainty to a potential DRE or renewable developer. Moreover, the programme underwent several modifications during this 7-year period and beyond. This included changes to the future quota level and potential harmonisation of the programme with Norway. All these uncertainties increased financing challenges on potential renewable energy projects.

One major lesson from the experience with quota-obligation systems – which applies just as well to any other type of incentive programme – is that there must be clear political commitment to the programme. Any risk (or even a perceived risk) that a programme will be substantively modified or abandoned could significantly halt a project's development.

Some DRE and renewable incentive programmes include explicit provisions for the government to conduct subsequent studies of the effectiveness of the programme. One such example is the quota-obligation system implemented in the United Kingdom (van der Linden et al., 2005). These types of provisions can be interpreted by the market as an indication that political support for an incentive programme may waver in the future, even if the government insists that the reviews are limited in scope.

These and other issues have kept some quota-obligation systems from delivering their theoretical promise of meeting renewables targets at minimum cost. Fouquet and Johansson (2008) estimated that in 2003 wind generation in the United Kingdom, which operates a quota-obligation system, cost €0.096/ kilowatt hour (kWh) as opposed to the FIT cost of between €0.066/kWh and €0.088/kWh in Germany. This is despite wind speeds being much more favourable to wind energy development in the United Kingdom than in Germany.

Lipp (2007) found similar disappointing cost results for the quota-obligation system in the United Kingdom. That is, the incentive scheme in the United Kingdom delivers wind energy at an average cost of €110/MWh as opposed to the average costs of €80/MWh and €57/MWh in Germany and Denmark, respectively. According to Lipp, the excellent performance of the Danish FIT system has motivated its producers to reduce wind turbine costs, as this allows them to sell more turbines within the country.

Meanwhile, India uses state-level RPS-type mandates that are supplemented with tariffs and other provisions to subsidise renewable costs (Umamaheswaran and Seth, 2015). The national-level legislation further mandates that the state-level programmes introduce technology tiers – for instance, specifying targets for solar. An issue that has hampered the success of these efforts is that states have been focused on minimising policy costs. For instance, the tariff supports provided by many states for wind have been too low to encourage more investment and development.

2.3. Tendering system

Tendering systems are very similar to quota-obligations in their approach to incentivising renewable and DRE development. Like a quota-obligation, a tendering system is a purely quantity-based approach, without any guaranteed price levels. The main difference between the two types of programmes is that a tendering system relies on a centralised auction-like mechanism, which is often administered by the government, to award renewable energy power purchase agreements (PPAs). As with a quota-obligation system, a tendering scheme may set different targets for different renewable and DRE technologies.

Most tendering systems, however, do not differentiate between technologies. This design choice is made for the same reason as with a quota-obligation system. By fixing the total quantity of renewable resources desired, the market determines the least-cost combination of technologies to deploy.

In theory, tendering systems are functionally equivalent to quota-obligations and should give the same results. This includes developing a least-cost combination of renewable technologies. Moreover, a secured PPA should provide a potential renewables developer with price and quantity stability. A price guarantee in the PPA should provide greater risk reduction than a quota-obligation system. In practice, however, most tendering schemes have not worked as well as FIT or quota-obligation programmes.

The tendering system implemented in China provides valuable lessons for other countries. Liu and Kokko (2010) noted that China's aim to get the most minimal cost for its tendering system resulted in bids that were too low such that it was unlikely for the winning bidder to recover its costs. This resulted in several of the contracted projects being severely delayed or never built. Similar results were seen in tendering systems used in England, Wales, and California (Langniss and Wiser, 2003; van der Linden et al., 2005; Lipp, 2007; Fouquet and Johansson, 2008; Umamaheswaran and Seth, 2015). These programmes have since been replaced with quota-obligation systems.

2.4. Net-metering system

Unlike the three other types of incentive systems discussed thus far, net-metering schemes are specifically geared towards incentivising investment in DRE. A net-metering system requires a local utility to purchase energy produced by its customer from the latter's onsite facility at the same retail price charged to the customer for energy consumption. If the customer's onsite renewable energy facility produces less than his/her energy consumption, this DRE production offsets the amount of energy drawn from the utility's system. Thus, the utility sells less energy to the customer.

On the other hand, if the customer's onsite renewable energy facility produces more than his or her energy consumption, the excess energy is fed back into the local utility system. In this case, the customer's meter runs backwards to reflect the energy being sold to the local utility. In other words, the utility only charges the customer for *net* energy sales.

A net-metering system is similar to a FIT in many ways. This is because its whole DRE system has a guaranteed 'market' for energy sales, insomuch as the utility company is required to accept excess energy produced by the system. Moreover, the DRE system also has a guaranteed price, which is the retail price of electricity. Indeed, many FIT programmes are applied to both utility-scale renewable plants and DRE systems. In such a case, the FIT is functionally similar to a net-metering scheme, except that the price paid to the DRE system may be higher than in a pure net-metering scheme. This depends on whether the DRE earns the guaranteed payments specified in the FIT programme (in addition to offsetting consumption when computing customer retail supply charges).

Net-metering schemes can also be combined with quantity-based schemes such as a quota-obligation system. For instance, many RPS programmes in the United States allow a utility to use RECs created by DRE resources in its service territory to meet its quota.

Net-metering schemes have been fairly successful in areas where conditions are appropriate. In the United States, the schemes have been very successful in the southwestern states, especially in California. This region has excellent solar resource, and rooftop PV solar is the most practical DRE technology available today. Moreover, retail electricity rates in California have historically been high, making the economics of such installations cost-effective. Kavalec et al. (2013) reported that so-called self-generated solar PV in the state of California in 2012 (which would have been eligible for net metering) contributed 668.2 MW during peak demand.

2.5. Other financial subsidies

In addition to the four programmes already discussed, some jurisdictions have pursued more direct financial subsidies. One approach, which addresses the high capital cost of many DRE and renewable technologies, is direct capital subsidies.

Direct capital subsidies can take the form of project-specific grants. In the United States, these are in the form of investment tax credits, which provide tax relief based on the capital cost of a project. However, capital cost-based subsidies are typically seen as suboptimal, because the incentives are not performance-based (van der Linden et al., 2005). Thus, a DRE or renewable developer may not operate or maintain the facility efficiently. Similarly, the incentive to locate a project where renewable resources are ideal is muted and a developer may instead opt for a location that minimises investment cost.

For these reasons, production- or performance-based subsidies are strongly preferred. The four mechanisms discussed earlier all have this feature (Note that in the case of a tendering or quota-obligation system, it has this feature if the obligation is energy-based as opposed to capacity-based.).

Tax-based incentives (either production- or investment cost-based) are often preferred over more direct financial subsidies or grants. This is because the cost of a tax-based incentive is typically more opaque, thus reducing potential political opposition to a programme.

2.6. Renewables Integration

Integrating renewables and DRE resources into an electric power system can entail ancillary costs, in addition to the capital cost of the plant itself. One is the cost of transmission and distribution infrastructure that can interconnect a plant with the DRE system. Transmission infrastructure would apply more to utility-scale renewables whereas distribution infrastructure is to DREs. Texas and China present two interesting case studies on how to address these additional investment costs.

In the case of Texas, the state has proactively made transmission investments in anticipation of where it expects future renewable resources will be deployed (Langniss and Wiser, 2003). These costs are then socialised to customers on a pro-rata basis. In the case of China, Liu and Kokko (2010) noted that the State Grid (one of the two transmission system operators in the country) invested in a wind power project. The investment provided the State Grid with a strong incentive to make transmission investments. By doing so, it was able to maximise the value of its wind plant investment. It should be noted, however, that the State Grid's investment in the wind plant contradicts China's policy decision to separate power generation from transmission operation.

These two cases suggest policy steps that may be taken to incentivise transmission and distribution investments. Proactively making transmission and distribution investments in anticipation of renewable and DRE installations reduces risks associated with plants' inability to deliver their product to the market. Although cost socialisation is typically suboptimal, it is an easy means of allocating costs.

Vertically integrating transmission and generation runs counter to most electricity market restructuring efforts. For this reason, this paper does not necessarily recommend the Chinese approach of transmission investment. However, this type of an arrangement could be implemented for distribution infrastructure investments needed for DRE integration. One approach is to have distribution utilities directly contract with DRE owners to purchase their energy and, if operating with a quota-obligation system, RECs. Doing so would provide the utility with proper incentives to ensure that there is sufficient capacity to distribute available DRE resources.

3. Cost-allocation issues with distributed renewable energy

Distributed renewable energy programmes and others that incentivise renewable energy adoption and use have some unique retail pricing challenges that have not been encountered in the past. This is because electricity service involves the provision of capacity and energy. Sufficient generation, transmission, and distribution capacity must be built and maintained to serve the anticipated system peak. At the same time, these assets are operated to provide energy to end customers.

Historically, the cost of providing energy and capacity services has been recovered from customers through volumetric charges on energy consumption. This type of volumetric pricing is especially applied for residential customers. Some large commercial and industrial customers may, conversely, be subjected to more exotic pricing mechanisms. The use of energy-based volumetric pricing emanates from the assumption that the costs of providing customers' capacity and energy needs are roughly proportional to their energy use. In other words, a customer with twice as much energy consumption as another would impose roughly double the capacity-related costs on the system.

The cost of implementing volumetric pricing is low. Volumetric pricing requires a simple electromechanical induction meter to be read periodically to determine aggregate electricity consumption. More exotic retail pricing schemes may require an advance metering infrastructure that has historically been relatively expensive.

Distributed renewable energy (and indeed, all forms of distributed energy) threatens the viability of this historic cost recovery mechanism. This is because DRE can affect a customer’s energy needs disproportionately to their capacity needs. To understand this effect more concretely, the concept of capacity value is used (Garver, 1966). A resource's capacity value measures its contribution to system reliability, which is the likelihood that the system will be able to serve customer demands in the face of supply and demand uncertainties. Supply uncertainties can include mechanical, maintenance, or fuel-related outages of conventional generators or the inherent variability of renewables. As a commonly used capacity value metric, the effective load carrying capability (ELCC) assesses how much system loads can increase when a given resource is added to the system without changing the system's overall reliability.

To understand how DRE affects electricity system cost recovery, consider the case of a residential customer in the Los Angeles area. According to Kavalec et al. (2013), the average residential customer in the Los Angeles area consumed 6625 kWh of energy in 2013 and had a peak coincident demand of 1.6 kW. This means that the average customer imposes variable costs associated with the 6625 kWh consumed and fixed costs associated with the 1.6 kW of generation, transmission, and distribution capacity that must be built and maintained for the customer.

Now, consider a rooftop PV panel installed on the residential customer's home. Madaeni et al. (2013) simulated PV generation in the Los Angeles area and estimated that a 1 kW panel produces an average of 1726 kWh annually. They also estimate the ELCC of such a solar panel to be 0.52 kW. Thus, installing a PV panel reduces the customer's energy consumption and associated variable cost incurred by the system by 26% (compared to the 6625 kWh of average annual consumption) per kW of PV.

Moreover, the customer's utility can reduce the amount of generation, transmission, and distribution capacity built and maintained for the customer (thereby avoiding the associated fixed cost) by 0.52 kW per kW of PV installed. This is because the utility can rely on the PV panel to contribute to serving the customer's demand and to reduce the amount of capacity built and maintained for the customer by 32% (relative to the 1.6 kW peak customer demand).

If the residential customer pays a volumetric tariff that depends solely on energy consumption, the customer's annual retail costs are reduced by 26% for each kW of PV capacity installed if a net-metering or similar system is in place. This creates an inefficiency, because the customer is undercompensated for the capacity value of the PV installation. Other incentive mechanisms (for instance, an FIT) will exacerbate this inefficiency, because most of these programmes provide incentive payments based on energy generated by a DRE without consideration of its effect on capacity needs and cost.

Volumetric charges based on energy consumption only can result in `arbitrary' cost allocation to a customer with DRE because the capacity value of DRE resources is highly system-specific. Madaeni et al. (2013) estimated ELCCs for 1 kW PV panels in the western United States and found that they can range between 0.52 kW and 0.70 kW. It is also important to stress that the ELCC estimates from Madaeni et al. (2013) are for marginal PV capacity being added to a system. As the penetration of PV increases, the ELCC of additional PV panels will be lower. This is because the hours of the year during which the system has the greatest probability of experiencing a load shortage will shift from sunny afternoons to other hours that may have less solar resource available. This is supported by the survey done by Mills and Wiser (2012) on a variety of systems at different PV penetration levels: They found that capacity value estimates of solar PV drop quite rapidly as the penetration of PV increases.

This diminishing capacity value of PV has its implication. That is, as the penetration of PV increases, customers who install PV bear less of the cost of the capacity that must be installed to serve them. As an extreme example, consider a customer who installs enough PV to consume zero net energy from the electric grid. If such a customer pays a volumetric charge, the payment to the utility would be zero. However, generation, transmission, and distribution capacity would have to be installed and maintained to reliably serve such a customer. In this extreme example, all of the costs of this capacity would be borne by other customers! Moreover, if the system's overall PV penetration is sufficiently high, the PV installed by the customer in this example has almost no benefit in reducing capacity needs and costs.

Overall, volumetric charges result in inefficient cost allocation in DRE. It should be stressed that this issue is not limited to PV, as it can apply just as well to other DRE resources (e.g., distributed wind). Moreover, this cost allocation problem is not limited to high penetrations of DRE. However, a high penetration of DRE exacerbates the issue, because the capacity value of most DRE resources tends to decrease as the penetration rises.

In many parts of the world, the combination of DRE and volumetric energy-based tariffs can also create undesirable cross-subsidies. This cross-subsidy is because DRE tends to be installed by customers that are socio-economically better off than average. As these customers install more DRE, they pay a disproportionately smaller portion of capacity costs. These capacity costs are instead borne by customers without DRE and who tend to be socio-economically worse off than those with DRE.

4. Proposed tariff design

In this section, two retail pricing structures are proposed – i.e., real-time pricing (RTP) and a two-part tariff with demand charges – to address the cost-allocation issue raised in Section 3. The stylised screening model introduced by Stoft (2002) is used here to justify the proposed pricing schemes.

This section first introduces the simplified capacity investment model. Then, it presents the two cost recovery theorems that explain what wholesale pricing structures could be used to recover fixed capacity investment and variable operating costs. Finally, results of the two cost recovery theorems are used to justify the proposed retail pricing schemes. This paper then discusses the relative trade-offs between the two. Some practical implementation details are also discussed.

4.1. Capacity investment model

The capacity investment model here assumes that a power system entails capacity investment and generator operation. Capacity planning includes investments in generation, transmission, and distribution. The system is assumed to have N different generation technologies available. Let F_n denote the per-MW fixed cost of installing and maintaining generation technology n. The model is indifferent as to whether F_n represents the total fixed cost of the generation asset over its lifetime or an amortised cost (e.g., the sum of an annualised capital cost and annual fixed maintenance cost). For ease of exposition, assume that F_n is an annualised fixed cost. Also, F_n includes the cost of generation capacity in addition to the incremental transmission and distribution capacity required to deliver energy to end customers during the coincident peak-load period of the planning horizon. Let C_n denote the per-MWh cost of operating generation technology n to serve customer demands.

Assume that when capacity investments are made, the system can plan on load curtailment. Load curtailment is denoted as the `zeroth' technology. Here, $F_0 = 0$, because there is no fixed investment cost associated with planning on load curtailment. Let C_0 denote the value of lost load (VOLL), which is the 'operating cost' of load curtailment.

Without loss of generality, assume that the technologies are rank-ordered so that:

$$F_0 < F_1 < F_2 < \ldots < F_N,$$

and:

$$C_0 > C_1 > C_2 > \ldots > C_N.$$

If this assumption does not hold, then at least one technology is dominated by another (i.e., it has higher fixed and variable costs). Such a dominated technology would not be built or operated in an optimal technology mix and can be excluded from consideration. Also assume, without loss of generality, that VOLL is greater than the operating costs of all of the generating technologies. If this is not the case, then it would be suboptimal for the technology that has a higher operating cost than VOLL to be built or operated. Because it has the lowest fixed and highest variable cost, technology *1* is hereafter refer to as the `peaking' generation technology.

An optimal generation mix has three important properties:

Property 1. Once the generation mix is determined, the installed generators are operated based solely on the merit order of their variable costs. That is to say, generation decisions are determined solely based on the values of C_n and the capacity of each technology installed.

An important assumption underlying Property 1 is that technical restrictions are not considered (e.g., ramp-constrained unit commitments) in generator operations. Hereafter, generating technology with the highest variable cost operating in a given hour is referred to here as the `marginal' generating technology.

Property 2. Each technology should be marginal for the hours of the year during which it is the lowest total cost (inclusive of fixed and variable costs) alternative.

Property 3. Total system capacity should be built to equate the marginal cost of curtailing an incremental MW of load with the marginal cost of reducing an incremental MW of load curtailment with an additional increment of peaking capacity.

Property 3 can be expressed mathematically by defining T_0 as the number of hours of the year during which load is curtailed. The marginal cost of an incremental MW load curtailment is defined as:

$$C_0 \cdot T_0,$$

or as the product of VOLL and the number of hours that load is curtailed. The marginal cost of reducing an incremental MW of load curtailment is:

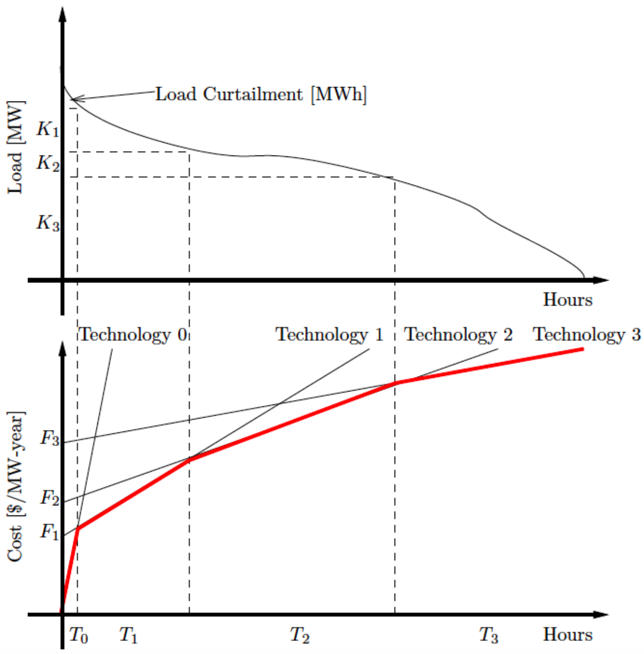
$$F_1 + C_1 \cdot T_0,$$

or as the sum of the cost of building an additional increment of peaking capacity (i.e., F_1) and the cost of operating the incremental peaking technology T_0 hours (i.e., $C_1 \cdot T_0$). Thus, Property 3 requires that:

$$C_0 \cdot T_0 = F_1 + C_1 \cdot T_0$$

Figure 9.1 illustrates Properties 1 to 3 and how they can be used with a load-duration curve (LDC) to determine an optimal generation mix for a three-technology example. Cases with greater or fewer technologies are analysed analogously. The bottom pane of Figure 9.1 shows the total cost per MW-year of installing and operating each of the three generation technologies available, as well as Technology *0* (i.e., load curtailment). The vertical intercepts of the cost curves are the fixed per-MW costs – i.e., the F_n's – and the slopes are the variable per-MWh costs, the C_n's.

Figure 9.1: Determination of an Optimal Generation Mix By Combining Load-duration and Cost Curves



Source: Prepared by the author.

The three properties of an optimal generation mix imply that the system should be built in such a way that it is operated along the lower envelope of the technology cost curves. This lower envelope is indicated by the bold red piecewise-linear curve in the lower pane of Figure 9.1. The kink points of the piecewise linear curve are used to determine the number of hours that each of the three technologies and load curtailment are marginal. Meanwhile, T_0 represents the number of hours that load is curtailed and T_1 through T_3 are the number of hours that each of technologies one through three is marginal. An optimal generation mix is found by projecting the kink points of the piecewise linear curve up onto the LDC, which is in the upper pane of Figure 9.1, and then projecting the intersection point with the LDC onto the vertical axis.

Then, K_1 through K_3 indicate how many MW of each of the three technologies should be optimally built. The difference between the vertical intercept of the LDC and the sum of K_1 through K_3 indicates the maximum amount of load that is curtailed given this optimal generation mix. Moreover, the triangle at the top of the LDC indicates how many MWh of load is curtailed with the optimal generation mix.

4.2. Cost recovery theorems

This section presents the two cost recovery theorems, which are then used to justify this study's proposed retail pricing mechanisms.

Theorem 1. If the generation capacity mix is optimal (i.e., it satisfies Properties 2 and 3) and generators are dispatched in merit order based solely on C_n (i.e., Property 1 is satisfied), then the following remuneration scheme ensures full fixed- and variable-cost recovery:

1. whenever load is curtailed, the system marginal cost is set equal to VOLL (i.e., C_0); and

2. each MWh produced is paid the system marginal cost.

Proof. This result is proven by referring to Figure 9.2. Consider the increment of capacity of technology n that operates:

$$\sum_{i=0}^{n-1} T_i + \hat{T}_n,$$

hours. The total fixed and variable per-MW cost of this capacity increment is given by:

$$F_n + C_n \cdot (\sum_{i=0}^{n-1} T_i + \widehat{T}_n)$$

which is indicated by the dot in Figure 9.2.

Now, consider the per-MW revenue earned by this capacity increment through the remuneration scheme proposed. During the T_0 hours of the year that load is curtailed it is paid C_0 per MWh. During the T_1 hours of the year that Technology *1* is marginal, it is paid C_1 per MWh. By repeating this argument, its total revenue is given by:

$$\sum_{i=0}^{n-1} C_i \cdot T_i + C_n \cdot \widehat{T}_n$$

Adding each of the revenue terms (corresponding to the hours of the year during which the different technologies are marginal) in the above equation traces the lower envelope of the cost curves and gives the same dot in Figure 9.2 corresponding to the per-MW cost of the capacity increment.

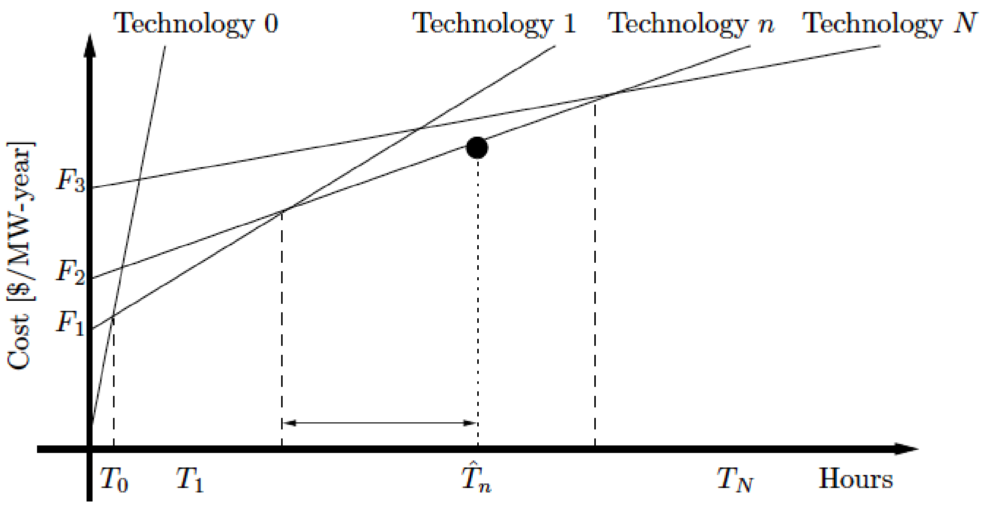
Thus,

$$F_n + C_n \cdot \left(\sum_{i=0}^{n-1} T_i + \widehat{T}_n \right) = \sum_{i=0}^{n-1} C_i \cdot T_i + C_n \cdot \widehat{T}_n$$

meaning that this capacity increment exactly recovers all of its fixed and variable costs through the proposed remuneration scheme.

■

Figure 9.2: Illustration of Proof of Theorem 1



Source: Prepared by the author.

Theorem 2: If the assumptions of Theorem 1 hold then the following remuneration scheme ensures full fixed- and variable-cost recovery:

1. whenever load is curtailed, the system marginal cost is set equal to the variable cost of the peaking technology (i.e., C_1);

2. each MWh produced is paid the system marginal cost; and

3. every generator is given a capacity payment equal to the capacity cost of the peaking technology (i.e., F_1).

Proof. This result follows easily from Theorem 1. Under the remuneration scheme proposed here, the increment of generation capacity shown in Figure 9.2 earns:

$$C_1 \cdot T_0,$$

in per-MW revenues whenever load is curtailed. It also receives a per-MW capacity payment of F_1. Thus, its total per-MW revenue is defined as:

$$\mathrm{F_1 + C_1 \cdot T_0 + \sum_{i=1}^{n-1} C_i \cdot T_i + C_n \cdot \widehat{T}_n}$$

However, Property 3 requires that:

$$\mathrm{C_0 + T_0 = F_1 + C_1 \cdot T_0}$$

Thus, under the remuneration scheme proposed here, the capacity increment shown in Figure 9.2 earns:

$$\mathrm{F_1 + C_1 \cdot T_0 + \sum_{i=1}^{n-1} C_i \cdot T_i + C_n \cdot \widehat{T}_n = C_0 + T_0 + \sum_{i=1}^{n-1} C_i \cdot T_i + C_n \cdot \widehat{T}_n = \sum_{i=0}^{n-1} C_i \cdot T_i + C_n \cdot \widehat{T}_n}$$

in per-MW revenues, which is exactly equal to the per-MW revenue earned under the remuneration scheme proposed in Theorem 1.

■

4.3. Retail pricing proposals

Following the two cost recovery theorems, two retail pricing structures that can alleviate the cost recovery and potential cross-subsidy issue raised in Section 3 are now proposed. The first is the retail-level RTP with a net-metering system. The second is a two-part tariff that includes a demand charge.

4.3.1. Real-time pricing

The motivation for RTP comes directly from Theorem 1. Theorem 1 shows that marginal pricing at the wholesale level ensures that the variable and fixed costs of all generation, transmission, and distribution assets are fully recovered. This is because infra-marginal rents between the marginal price at any given time and a particular asset's variable cost contribute to recovering its fixed cost. Under this proposal, the time-variant wholesale marginal price is directly transferred to customers through time-variant, real-time prices.

The primary advantage of RTP is that it efficiently prices the energy and capacity values of DRE resources. The ability of a DRE installation to reduce variable generation costs is captured by the time-varying retail price. If DRE produces energy when the retail price is high (meaning, during times that the system is relying on high variable cost generation), the DRE is reducing this variable cost. The customer is given a direct financial incentive for providing this high-value energy, by having to purchase less energy from the system and relying on self-generated energy instead exactly when the retail price is high.

Under RTP, the retail price is at its highest when system capacity is limited and the load is either being served with high variable cost generation or curtailed. When a DRE resource provides energy when real-time prices are high, it is providing energy when system capacity is scarce. However, such a DRE resource is reducing the need for capacity to be built and maintained. Thus, the real-time prices properly value DRE in reducing system capacity needs.

Real-time pricing also provides for efficient allocation of capacity cost among customers. Customers with DRE that reduces capacity needs will purchase less energy from the system during periods of scarcity and contribute less inframarginal rent towards fixed cost recovery.

Borenstein (2005) noted other advantages of RTP, which are independent of DRE, in providing for more efficient short-run consumption decisions and long-run investment than the alternative, i.e., the time-invariant retail pricing. Borenstein (2002) also noted some benefits that RTP could provide in reducing the exercise of market power in liberalised wholesale electricity markets. Real-time pricing also has the potential to provide benefits in integrating large amounts of distributed and grid-scale renewable energy into power systems. These benefits include improved technical operations (Sioshansi and Short, 2009; Madaeni and Sioshansi, 2013a), long-term investment (De Jonghe et al., 2012), and short-run operations (Klobasa, 2010; Sioshansi, 2010; Dietrich et al., 2012; Madaeni and Sioshansi, 2013b).

The benefits of RTP in renewables integration stem from having customer demands follow the real-time availability of renewable energy. This is because real-time marginal prices reflect this availability. When the system has excess renewable energy available, real-time prices drop. On the other hand, prices rise when the system is short on renewable supply. Having consumption patterns reshaped based on such price patterns mitigates the negative effects of renewables' variability and uncertainty.

These RTP benefits would apply just as well to integrating DRE as they do to utility-scale renewable plants. Thus, RTP has an added benefit (beyond cost recovery) of easing technical challenges raised by integrating large amounts of DRE.

The primary disadvantage of RTP is that it can introduce price and cost uncertainty to end customers. One way to overcome this is to use a hedging-type mechanism, such as that suggested by Borenstein (2007). Under such a scheme, customers receive a certain allowance of energy at a locked-in, time-invariant price. They then pay or are paid the real-time price for any deviation between the contracted quantity and their actual consumption. This type of arrangement reduces bill volatility while still exposing customers to real-time prices for their `marginal' energy consumption.

Another possibility is to introduce blocked time-of-use (TOU) or a similar pricing scheme. If such a pricing scheme is designed properly (e.g., reflects the average wholesale price of energy during different blocks of time), it should provide some of the DRE-related efficiency and cost-allocation benefits of RTP. Moreover, Borenstein and Holland (2005) showed that such a retail pricing scheme can provide some of RTP's general economic efficiency benefits. However, the renewables integration benefits listed above would not be provided as these rely on customer demands responding to real-time renewables' availability. Static blocked pricing such as a the TOU scheme could not provide such demand response.

Moreover, for such a TOU-type scheme to address the DRE cost-allocation issue, the price blocks would need to be updated as new renewable capacity is installed in the system. This is to ensure that the time blocks and the associated retail prices charged during each, reflect capacity scarcity given the current capacity mix. This price update is, in essence, meant to correct for the declining capacity value of DRE resources as their penetration rises.

4.3.2. Demand charges

The use of demand charges as an alternative stems from Theorem 2, which suggests the use of a capacity payment to supplement energy revenues for cost recovery. In theory, demand charges could be implemented with time-variant retail prices. Indeed, implementing such mimics the remuneration scheme in Theorem 2. However, if time-variant pricing is to be used, RTP (in line with the first recommendation) would be preferred for the reasons discussed earlier. The alternative proposal here is to price retail energy using a two-part tariff. The first part is a time-invariant energy charge, which is based on the average per-MWh variable cost of operating the system. The second is a capacity charge, which is based on the fixed cost of the peaking capacity in addition to capital and maintenance costs for transmission and distribution (i.e., F_1).

As with the RTP proposal, this proposal is to base the energy charge on the energy consumption of end consumers net of energy produced by any DRE installation. The demand charge would be based on the peak net (of DRE production) customer demand. Setting the demand charge based on net peak demand ensures that the capacity value of DRE is properly remunerated. When a DRE resource contributes to the capacity value, it reduces the amount of capacity that must be built and maintained to serve the customer. Thus, the DRE resource should reduce the demand charge, which is intended to pay for capacity costs.

This proposal is indifferent as to whether the demand charge is determined based on an annual or sub-annual peak. That is, a customer's monthly or seasonal peak may be used. A more important implementation issue is whether the demand charge is based on each customer's individual peak consumption or on consumption during the coincident-peak period.

Setting the demand charge based on the coincident peak provides the correct economic signal. A customer's consumption during the coincident-peak period determines how much capacity must be built and maintained to serve that customer. However, such a pricing scheme would introduce some uncertainty, as the customer would have to anticipate when the coincident-peak period is. On the other hand, such uncertainty may also come with an advantage in that it may incentivise conservation during periods that the customer believes to be the peak-coincident period.

The easier pricing option is to set the demand charge based on each customer's individual peak consumption. It may be simpler and carries less uncertainty to the end customer. However, it also undervalues the capacity value of DRE resources. That is, a DRE resource may not reduce an individual customer's peak demand but may produce energy during the system's peak demand (thereby reducing capacity needs).

The primary disadvantage in using demand charges is that it does not carry all the ancillary benefits that RTP has. As noted earlier, an added benefit of RTP is that it can help mitigate the negative impacts of uncertainty and variability in real-time DRE's availability. On the other hand, demand charges would have no benefit in this area. Demand changes allow less-efficient energy consumption decisions and loss of renewable integration benefits.

5. Discussion and conclusions

This chapter examined how the adoption and use of renewable energy resources, with particular attention on DRE, is incentivised. Incentive mechanisms have historically been used to reduce the privately incurred cost and risk of investing in renewable energy. In the short run, these mechanisms reduce project-financing costs and increase the deployment of renewables. In the long run, increased deployment of renewables reduces technology costs through economies of scale and learning by doing.

The tendering system has been the least successful of those mechanisms implemented in the past. If well designed, a quota-obligation system can effectively encourage renewable adoption. However, even in the case of Texas, where an RPS has been largely successful, it is not clear if an FIT would not have delivered the same levels of renewable investment at lower cost (given the cost results observed in the United Kingdom).

A comparison of the experiences of the United Kingdom, Germany, and Denmark suggests that FITs can deliver renewables at lower total cost than quantity only-based mechanisms. This study's survey of systems used thus suggests that FiTs tend to work better than quantity-based systems.

The particular case of a DRE net-metering system---either on its own or in conjunction with a FIT or quantity-based incentive programme---can effectively spur renewable investment. As seen in the southwestern United States' case, the programme's success largely depends on the quality of the renewable resource and the level of retail prices.

High penetrations of DRE come with some major cost-allocation issues between customers with DRE systems and those without DRE systems. Distributed renewable energy with time-invariant volumetric charges see an increasing share of capacity costs being borne by customers without DRE. This can create a vicious 'death spiral', where more and more customers adopt DRE systems due to rising retail prices. Eventually, capacity costs may be borne almost entirely by the socio-economically disadvantaged who do not have the means to invest in DRE systems.

To date, regulatory bodies in regions that have acutely suffered from cost-allocation issues have reacted by limiting, rescinding, or eliminating incentive programmes for DRE. In other instances, explicit limits on how much DRE can be deployed have been enacted. These types of reactions adversely affect DRE investment and risk by threatening the financing-cost reductions that the incentive programmes are meant to bring about.

Finally, this study proposes two alternative retail-pricing schemes – RTP and two-part tariffs with demand charges – to alleviate these cost-allocation and cross-subsidy issues. Real-time pricing has some general economic efficiency and techno-economic renewable integration benefits. For one, it can mitigate the negative impacts of real-time DRE availability variability and uncertainty. Demand charges, on the other hand, do not provide these ancillary benefits.

It is important to stress that these retail price structures are directly amenable to and built off the concept of a net-metering system. Moreover, other incentive programmes, such as FITs and quantity-based schemes, can be directly used along with these retail-pricing schemes.

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Chapter 10

Financing Solar PV Projects: Energy Production Risk Reduction and Debt Capacity Improvement

Romeo Pacudan[37]

Abstract

Various risks influence the decision in obtaining financing and determining the cost of financing for utility-scale solar photovoltaic (PV) projects in many developing countries. One of the risk areas is in the estimation of solar PV energy production, which is significantly derived from the uncertainty in solar resource data and measurement. Due to the lack of ground-measured data sets, the solar PV industry mainly relies on satellite-derived irradiation data to estimate on-site solar energy resource, but modelled data often lacked the accuracy to mitigate energy production risks. The use of multiple data sources has been increasingly employed and emerging to be the best practice in the solar industry. One of the methodologies that combine various sources of data is the measure-correlate-predict (MCP) approach, which correlates short-term measured data with long-term reference data sets. The study, using the proposed 27 megawatt peak (MWp) solar PV project in Brunei Darussalam, evaluates the impact of using correlated irradiation data sets on energy production and capital structuring of utility-scale solar PV projects. The study results confirm the outcome of other studies—that correlated solar irradiation data sets generate superior, high-confidence energy estimates (probability of exceedance at P90 and P99 levels) than those using satellite-derived data sets. With assumed financial parameters, the high-confidence energy estimates from MCP-derived data comfortably satisfy the debt-service coverage ratios (DSCRs) set by lending institutions and credit rating agencies, as well as generate lower levelised production cost of electricity. Also, the study shows that to achieve the minimum target DSCR of 1.3x and 1.2x for P90 and P99 energy production levels, the share of debt on the overall project capital structure could be further increased by around 7% for both cases from a reference debt share of 70%. The use of high-quality data sets therefore reduce project risks, increase project financial leverage, and enhance financial competitiveness. The government's support measures that address the issue on resource data uncertainty and establishing best practice in data measurement and use in project analysis would be crucial in developing solar PV industry in developing countries.

Keywords: Solar irradiation data sets, measure-correlate-predict, probability of exceedance, capital structuring

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1. Introduction

Solar photovoltaic (PV) power generation started to emerge recently in the national energy mix of a number of Association of Southeast Asian Nations (ASEAN) countries. This development is due to the improvement of solar PV cost competitiveness at the international market and the introduction of policies and regulatory frameworks that promote the deployment of renewable energy technologies in these countries. This is particularly evident in countries that have introduced reforms allowing private sector participation in the generation segment of the power industry. Also, due to increasing sizes of solar PV projects being planned and implemented in some of these countries, project financing or non-recourse financing has been increasingly used as one of the main mechanisms to finance utility-scale solar PV projects.

There exist, however, a number of project risks inherent to solar PV project planning, construction, and operation that inhibit the full development of solar energy resource potential in these countries. These can be broadly categorised into regulatory, market and operational, and technological risks (Lowder et al., 2013; Cleijne and Ruijrok, 2004). These risks, as perceived by lenders and investors, could influence in obtaining and determining the cost of financing.

One of the main risk areas is in the estimation of the expected annual production of electricity from solar PV power plant at the pre-construction stage of the project (Vignola et al., 2013; Schnitzer et al., 2012)—the stage where mobilisation of financial resources is crucial. There is a risk that the expected annual production would be overestimated and that failure to achieve the target production compromises the project's ability to meet its debt obligations. This risk emanates from the uncertainty in solar resource data, which is the focus of this study, and in the models to forecast solar project performance used in the feasibility studies.

Banks and investors providing financing to solar PV projects, on the other hand, require higher production probability (higher level of confidence on actual energy production) to determine the associated risk with a project's ability to service its debt obligations and other operating costs.

Due to lack of available ground measurement data near identified project sites in many developing countries, project developers often rely on satellite-derived solar irradiation data in their feasibility studies. High-resolution satellite data have, however, high uncertainty due to difficulties in integrating key atmospheric parameters in the radiative transfer models (McMahan et al., 2013; Vignola et al., 2013; Stoffel et al., 2010).

To ensure accuracy in solar irradiation estimation and obtain high-confidence estimate of solar energy resource, there is an increasing recognition in the solar energy industry to analyse and use multiple data sources, instead of relying solely on modelled data. One of the measures used that take advantage of using various sources of solar data is the measure-correlate-predict (MCP) approach, which correlates short-term data measurements with long-term reference data sets (Vignola et al., 2013; Schnitzer et al., 2012). This methodology has been widely utilised in the wind industry to increase the confidence level and minimise uncertainty in long-term wind energy resource assessments (Rogers et al., 2005; Carta et al., 2013).

Thuman et al. (2012) have demonstrated that in the case of several sites in the United States (US), the MCP technique could generate data sets with lower uncertainty levels compared with satellite-derived irradiation data sets. Schnitzer et al. (2012), on the other hand, have shown that high-confidence energy estimates from MCP-derived data sets are higher than those from satellite-derived irradiation data.

This study further extends the analysis by looking into the implications of using MCP-derived data sets on the financial structuring of projects. Using the proposed expansion of 27 megawatt peak (MWp) solar PV project in Brunei Darussalam, the study combines the measured irradiation data on-site with satellite data through the MCP methodology, estimate the expected production of the proposed project for cases using satellite-derived data and correlated data sets, and compare the high-level confidence energy estimates of these cases. From these, the study further investigates capital structuring of the project by simulating combinations of project debt-to-equity ratio to satisfy the debt-service coverage ratio (DSCR) targets set by lenders and credit rating agencies for high-confidence energy estimates.

The study results could strengthen the case for policymakers to introduce—in addition to policy and regulatory frameworks such as feed-in tariff, net metering, renewable portfolio standards, and tradable certificates that promote renewable energy deployment in general—other support mechanisms that address the lack of information and awareness related to energy resource data.

2. Methodology and data

In quantifying the impact of using a bankable solar radiation data set on solar PV project's financial leverage, the study carried out the following methodological approach: (i) establishment of solar irradiation data sets, with on-site measured data as the base and satellite-based data as reference data sets in deriving a forecast data derived from MCP methodology, as well as quantification of their associated resource measurement uncertainties; (ii) estimation of the energy yield of the solar PV project case studies with these two data sets; (iii) estimation of energy production at higher confidence levels based on the overall project uncertainty levels; (iv) estimation of the potential improvement of the project's debt capacity based on a target DSCR for the two data sets using a simple cash flow model. These are further explained in the following subsections.

2.1. Project case study

The above methodological approach is applied to the 27 MWp expansion study of the Tenaga Suria Brunei (TSB) project. The TSB s a 1.2 MWp solar PV power generation demonstration project, which is jointly implemented by the Government of Brunei Darussalam and Mitsubishi Corporation. The project is situated in Seria, Belait District with global coordinates of 4.61°N, 114.34°E, and an altitude of 4.6 metres above mean sea level.

One of the core objectives of the TSB project is to identify the most suitable and high-performance PV technologies that are suited for local meteorological conditions (Mitsubishi Corporation, undated). This project was interconnected to the grid and commenced operation in May 2010. The demonstration phase was performed in May 2010 and October 2013 in which the Mitsubishi Corporation and the Department of Electrical Services jointly carried out the operation and maintenance services, data collection, and analysis (Pacudan, 2015a). At present, the project is being operated by the Department of Electrical Services with continued technical support from the Mitsubishi Corporation.

The Brunei National Energy Research Institute carried out a study to assess the potential expansion of the TSB project. The study identified a total land area of more than 24 hectares in three plots adjacent and within close proximity to the sites that are suitable and available for solar PV development. Using polycrystalline solar PV modules, a minimum of 27 MWp capacity could be potentially developed and added to the existing TSB project

(Pacudan, 2015b).

2.2. Solar irradiation data sets

The radiant power from the sun is known as the total solar irradiance, which is estimated at the mean earth–sun distance to be 1,366 ± 7 W/m^2 with the variation attributed to the 11-year sunspot cycle, while on the other hand, due to the earth's elliptical orbit, the solar radiation reaching at the top of the atmosphere also varies annually between 1,415 W/m^2 to 1321 W/m^2 (Stoffel et al., 2010; Paulescu et al., 2013). The solar irradiance that is available at the top of the earth's atmosphere is known as the extraterrestrial solar radiation. When the solar radiation passes through the earth's atmosphere, its spectral distribution is modified by absorption and scattering processes, and separated into different components (Stoffel et al., 2010). The direct normal irradiance is the part of the solar radiation that directly reaches the earth's surface and normal to the sun's position; the diffuse horizontal irradiance is the part of the radiation scattered in the atmosphere as measured on a horizontal surface. The sum of the direct and diffuse irradiation is known as the global horizontal irradiance (GHI). Energy production from solar PV power facilities are estimated using engineering simulation tools and GHI data sets (Coimbra et al., 2013; Stoffel et al., 2010).

At present, there are various sources of GHI data used by project developers in solar PV project preparation stage, and these are (i) modelled data, (ii) reference station data, and (iii) on-site data. Modelled data consist of a combination of satellite-modelled, numerically modelled, and back-filled data sets; reference station data are data sets collected from international, national, regional, and state level surface-based measurements; while on-site data are those collected through on-site solar measurement and monitoring campaigns (Schnitzer et al., 2012; McMahan et al., 2013).

On-site measurements are the most accurate data set for project analysis because they provide site-specific data with known technical details and management scheme, and the level of measurement uncertainty is relatively low (Stoffel et al., 2010; Vignola et al., 2013). Most on-site measurements, however, have shorter record period and do not capture the long-term historical climate trend. Surface reference stations have also higher accuracy and may have longer period of data record. These stations are sparsely distributed and, in most cases, they are not located within close proximity to project sites. In addition, some reference stations have also poor maintenance practices. Modelled data have the highest measurement uncertainty. To establish bankable data sets, the objective is to combine different data sources to create a reliable, long-term record of irradiances at the project site (Vignola et al., 2013).

2.2.1. On-site measured data

Meteorological parameters were monitored and analysed during the demonstration phase of the TSB project. Two first class pyranometers were installed together on-site with other sensors to measure other meteorological variables. On-site data were collected by the Department of Electrical Services and analysed by the Mitsubishi Corporation for the period 2010-2014. An independent review and analysis were carried out by Pacudan (2015a). The data is collected during a short period of time and do not encapsulate long-term trends.

The measured global solar irradiation in terms of daily average for each month is shown in Figure 10.1. The global solar irradiation pattern reflects the trend of the weather pattern of Brunei Darussalam, which is affected by two monsoon seasons—the northeast monsoon, which starts in December; and the southwest monsoon, which begins in June. The solar irradiation is lowest during the monsoon seasons and highest during the dry seasons.

The daily solar irradiation has the highest peak of 5.7 kWh/m^2 (kilowatt-hour/square meters) in March, then it goes down to around 5 kWh/m^2 in June, before it goes to another peak of 5.3 kWh/m^2 in August. From August, the irradiation starts to fluctuate downward until reaching the lowest level in January. The average daily irradiation for the period is 5.1 kWh/m^2 with an average annual sum of 1,857.4 kWh/m^2.

2.2.2. Reference irradiation data

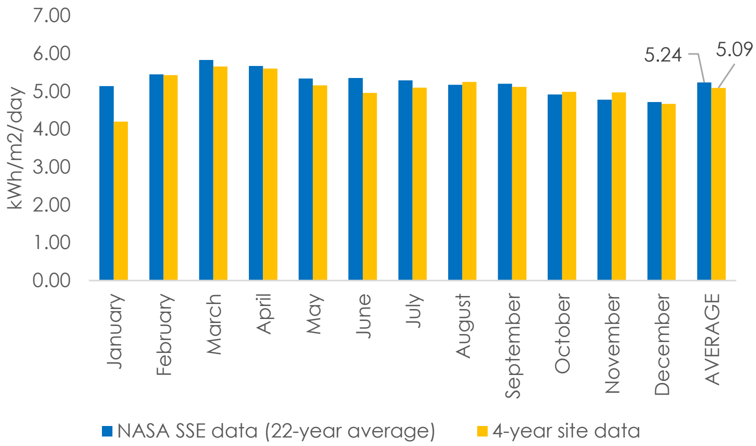
In most developing countries, including Brunei Darussalam, potential project sites are often not situated within close proximity to high-quality meteorological stations. Zelenka et al. (1999) have shown that satellite-derived solar radiation data provide a better estimate of the hourly solar resource than those extrapolated data from high-quality ground station if the site of interest is situated more than 25 kilometres from the measurement station. Project developers in developing countries therefore rely on modelled data for their solar project analysis.

Modelled data that are available and widely used in developing countries include the National Aeronautics and Space Administration (NASA) Surface Meteorology and Solar Energy (SSE) data and information, Meteonorm, Photovoltaic Geographical Information System (PVGIS), and others (Stoffel et al., 2010; Vignola et al., 2013; Yates and Hibberd, 2010). The NASA SSE data is publicly available and free of charge while other data sets are offered for a fee. This study uses the 22-year NASA SSE data set for the TSB site as the baseline data for the analysis.

The SSE data set is based on 1°×1° longitude latitude grid and provides estimates of global horizontal, direct normal, and diffuse horizontal mean monthly daily total irradiances and other meteorological parameters (Myers, 2009). While the 1° grid is relatively large for site analysis, project sites in the United States within the grid tend to follow the variations in solar resource and track closely with those from the National Solar Radiation Database of the National Renewable Energy Laboratory (Vignola et al., 2013). The NASA SSE used a physical model in estimating the solar irradiance, which is fairly accurate particularly when various atmospheric parameters are known (Vignola et al., 2013).

The site-specific solar irradiation data (4.61°N, 114.34°E) from NASA SSE were downloaded from the NASA website (https://eosweb.larc.nasa.gov/). NASA SSE's data sets tend to underestimate the solar irradiation during fall months while overestimate during the other seasons. The seasonal pattern is, however, similar to that of on-site data. This is shown in Figure 10.1. The average daily irradiation is 5.24 kWh/m^2, which is around 3% higher than the measured irradiation from TSB. The main implication is that using NASA SSE data for project planning would tend to overestimate the energy yield of a project.

Figure 10.1: Average Daily Global Horizontal Irradiation



kWh = kilowatt hour; NASA SSE = National Aeronautics and Space Administration Surface Meteorology and Solar Energy.
Source: Prepared by the author.

2.2.3. Correlated irradiation data

To increase accuracy, confidence, and reduce uncertainty, short-term ground-measured data are often validated using reference data sets, which in this case is the NASA SSE data. The method used in the study is the MCP technique. The MCP approach and its variants have been widely applied in the wind (Bass et al., 2000; Rogers et al., 2005; Carta et al., 2013) and solar industries (Meyer et al., 2008; Hidalgo and Mau, 2012; Thuman et al., 2012; Vignola et al., 2013; Gueymard and Wilcox, 2009). The MCP technique correlates short-term data with site-specific seasonal and diurnal characteristics with data set having a long period of record and consistent long-term annual trend so that a relationship between them is established.

Various MCP methods are used in wind and solar energy analysis. The most basic is the linear regression method, which is employed in this paper. Under this approach the predictor equation is given by the following:

$$\hat{I} = \beta_0 + \beta_1 I$$

Where; I is the reference GHI in kWh/m^2, $\hat{I}$ is predicted GHI also in kWh/m^2 at the target site, and β_0 and β_1 are the estimated intercept and slope of the linear relationship.

The linear regression used in the analysis is a model with a single independent variable x that has a relationship with a response variable y, which is a straight line. The simple linear regression model is given by

$$\hat{y} = \beta_0 + \beta_1 x + \varepsilon$$

Where the intercept β_0 and the slope β_1 are unknown constants and ε is a random error. The errors are assumed to have zero mean and unknown variance σ^2. The equation is also known as the least square regression equation since the criterion used to select the best-fitting line is the least sum of the squares of the residuals. The correlation coefficient evaluates the goodness of the fitting of data considered. This value can vary in the range of -1 and +1 for the strong correlation between the 2 variables x and y. The coefficient of determination, R^2, indicates the goodness of fit of the model. This is also called as the proportion of variation explained by the regressor x. R^2 value varies between 0 and 1.

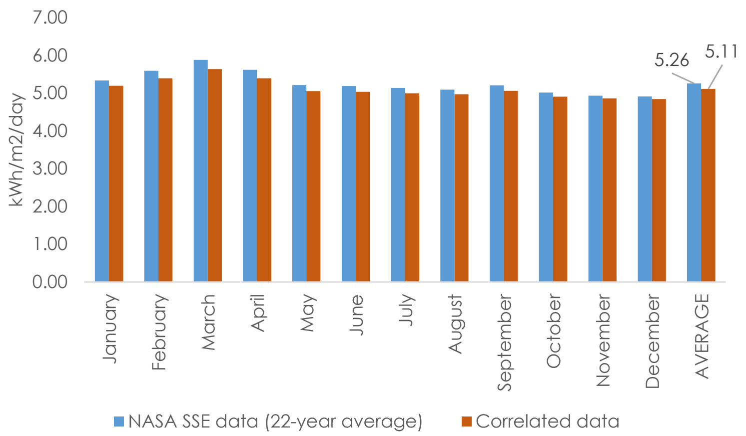
The values of β_0 and β_1 were determined from the simple linear regression of the short-term target site measurements (TSB site) against the reference data (NASA SSE). The derived coefficients are the following: β_0 = 0.7259 and β_1 = 0.8336.

The reference data are then used in the regression equation to predict the historical climate at the TSB site. Both strengths of the two data sets are being captured and that the uncertainty of the long-term irradiation estimate is being reduced.

Results of the analysis also confirm the findings of Rogers et al. (2005) that when using linear regression, the predicted mean irradiation at the target site will be close to the value of the measured mean. In this case, the predicted mean of correlated data and measured data have the same value at 5.1 kWh/m^2.

Figure 10.2 shows both the NASA SSE and predicted solar irradiation data. The data shown are for the incident global radiation on the collector plane with a tilt angle of 5° since solar PV modules at TSB site are inclined at an angle corresponding to the site's latitude. The satellite data is 2.8% higher than the correlated data.

Figure 10.2: Average Daily Incident Global Irradiation at 5° Inclined Plane



kWh= kilowatt hour; NASA SSE = National Aeronautics and Space Administration Surface Meteorology and Solar Energy.
Source: Prepared by the author.

2.3. Solar resource uncertainty and measurement uncertainty

Solar resource uncertainty comprises the following four main components (with uncertainty value ranges shown in the parenthesis): (i) spatial variability (0%–1%), (ii) representativeness of monitoring (0.5%–2%), (iii) inter-annual variability (2%–5%), and iv) measurement uncertainty (2%–15%) (Schnitzer et al., 2012). The focus of this study is the measurement uncertainty which represents the highest source of solar resource uncertainty. Modelled data have measurement uncertainties ranging from 8%–15% while on-site measurement have uncertainty range between 2% and 7% (Schnitzer et al., 2012; Vignola et al., 2013; Myers, 2009; Remund and Mueller, 2012).

On-site data have lower measurement uncertainty since they depend mainly on the quality and the frequency of on-site maintenance, while for modelled data, the uncertainty stems from the limitations of the computer-intensive radiative transfer models particularly during cloudy or partially cloudy periods (Schnitzer et al., 2012; Vignola et al., 2013).

Based on Myers (2009), the NASA SSE data has a measurement uncertainty of ±15% in global horizontal irradiation and ±20% in direct beam data. As mentioned earlier, the uncertainty for ground measurements is influenced by the quality and calibration of the pyranometer as well as the frequency of the field maintenance. The application of best practices in on-site measurement would help in reducing uncertainty in the measurements. Following Vignola et al. (2013) and Thuman et al. (2012), the measurement uncertainty for the validated GHI data used in this study is ±5%.

Table 10.1: Solar Resource Uncertainty

Uncertainty	NASA SSE	Correlated Data
Spatial variability*	0.50	0.50
Representativeness of monitoring period*	1.25	1.25
Inter-annual variability*	3.50	3.50
Measurement uncertainty**	15.00	5.00
TOTAL	15.46	6.25

NASA SSE = National Aeronautics and Space Administration Surface Meteorology and Solar Energy.
Notes: * Taken as mean value from Schnitzer et al. (2012).
Sources: Myers (2009) for NASA SSE data and Vignola et al. (2012).

To determine the impact of using a highly accurate data set, only the measurement uncertainties were changed in the two cases analysed in this study. The average values of the three other sources of uncertainties were used in the analysis and that these values were unchanged in both cases. The solar resource uncertainty for each case is taken as the sum of individual uncertainty components. The total estimated solar resource uncertainty for satellite-based irradiation data is 15.5% while that of correlated data is 6.3% (Table 10.1).

To calculate the total uncertainty, all single uncertainties were considered to be stochastically independent. The approach to estimate the joint uncertainty of independent (un-correlated) uncertainties is to calculate the root-mean-square value. Single uncertainties of the energy level are merged by the root-mean-square function (Abel et al., 2000).

2.4. Estimating energy production

2.4.1. Energy production modelling tools

The energy production of the 27 MWp TSB solar PV expansion plant was estimated for both two cases discussed above using a solar PV production modelling tool. Based on the review and assessment by Yates and Hibberd (2010), Cameron et al. (2008) and Klise and Stein (2009), solar PV production modelling tools available in the market could be broadly characterised to comprise two main algorithms: the first determines the amount of sunlight that falls on the array, and the second estimates the amount of electricity that could be produced with that given sunlight.

The first algorithm consist of modules that contain site-specific meteorological data, translate the radiation into inclined surfaces (radiation models), take into account the shading effect of distant objects, obstructions, and the system itself, and factor in the decrease of the amount of sunlight due to soiling. The second algorithm includes modules that predict the power output of different PV technologies (PV performance models), discount the losses in direct current (DC) production and in the conversion of DC power into alternating current (AC), and take into account the performance of inverters. Solar PV production software packages used by industry stakeholders vary in model system complexity. Some models have simplified assumptions related to system components and ratings while complex models consider manufacturer parameters, derived parameters, and empirically derived data (Klise and Stein, 2009; Yates and Hibberd, 2010; Cameron et al., 2008).

Yates and Hibberd (2010), in their comparative performance assessment of the main models currently used by researchers, integrators, and project developers in North America, conclude that the radiation model components of the evaluated tools perform consistently and predicting similar plane-of-array irradiance from the same weather data. In terms of overall energy production, the difference between the estimates of the most aggressive and the most conservative modelling tool is 9%. The software packages evaluated were PV Watts, Solar Advisor Model, PV-Design Pro, PV*SOL, and PVsyst.

The study used the PVsyst software in simulating the energy production of the two cases of data sets. The software is one of the most powerful and accurate tools in PV or solar cell production. The model allows a very detailed definition of the PV plant, including special geometries, as near shading objects or tracking systems and permits monthly variations of soiling, which accurately reflect real world conditions (Yates and Hibberd, 2010; www.pvsyst.com). The software package also contains a huge database of technical and electrical properties of the most common PV components (modules and inverters) available in the market.

In estimating the solar PV power plant energy production, the study used a typical polycrystalline solar PV modules and inverter models available in the market. Key model input parameters are shown in Table A1 of the appendix. In the model, DC electricity is generated from PV modules and converted into AC electricity through central inverters.

In the simulation process, PV arrays are fixed to face south and inclined at 5°, which corresponds to the project location’s latitude (NREL, 1990). Several methodologies exist in translating the horizontal radiation into plane-of-array irradiance. Among these models, the Perez et al. (1990) model was considered to be the most complex and most accurate

(Cameron et al., 2008; Yates and Hibberd, 2010; McMahan et al., 2013). The PVsyst model employs the methodology of Perez et al. in its solar irradiation module.

The PVsyst simulation model endogenously estimates the technical losses of the system based on the technical parameters specified in the case study. In addition to this, the study exogenously estimated the loss in production due to PV module degradation and plant availability. Annual degradation of 1% was used in the study following IRENA (2012) and DBRS (2014) and an average of 98% availability based mainly on average inverter manufacturers' guarantees.

2.4.2. Uncertainty in energy production

Electricity production estimate using satellite-derived irradiation data set has higher uncertainty than that of using ground-correlated data set. As discussed in the previous section, this is due to higher solar data uncertainty of the former compared with the latter. In addition to solar resource uncertainty, there exist other sources of uncertainty in the calculation of energy production, and these include the following (with the uncertainty value range shown in the parenthesis): (i) energy simulation and plant losses (3%–5%), (ii) transposition to plane of array (0.5%–2%), and (iii) annual degradation (0.5%–1%) (Schnitzer et al., 2012).

Table 10.2: Solar PV Energy Production Uncertainty

Uncertainty	NASA SSE	Correlated Data
Annual degradation*	0.75	0.75
Transposition to plane of array*	1.25	1.25
Energy simulation, plant losses*	4.00	4.00
Solar resource uncertainty**	15.46	6.25
TOTAL	16.04	7.56

NASA SSE = National Aeronautics and Space Administration Surface Meteorology and Solar Energy; PV = photovoltaic.
Notes: * Taken as mean value from Schnitzer et al. (2012).
Sources: ** Derived from Table 10.1.

In estimating the total energy production uncertainty, the study used the mean values of each of the above uncertainties. Also, since the focus of the study is on solar resource uncertainty (specifically measurement uncertainty), the same uncertainty values were used for both production estimates using satellite- and ground-correlated data sets. These were combined with the solar resource uncertainty estimated earlier for both sets of irradiation data. The total uncertainty of the electricity production using satellite-derived solar irradiation data set is 16% while that of ground- correlated data set is 7.6% (Table 10.2).

2.5. Debt structuring

2.5.1. Project risks and probability of exceedance

The uncertainty in energy production estimates translates to energy risk for the 27 MWp TSB expansion project. There is the risk that the expected production, hence project revenues, will not be achieved in actual condition. Project financial stakeholders rely on the probability of exceedance analysis to characterise and quantify risks related to energy production and, ultimately, revenues of solar PV projects (McMahan et al., 2013; Dobos et al., 2012). The exceedance probability is the likelihood of attaining or exceeding an energy production value.

Project lenders and credit rating agencies often require project developers to estimate the P50, P90, and even P99 of annual electricity generation of a given project. If a P50 annual generation value of a solar power plant is 10 megawatt-hours (MWh), this means that there is a 50% likelihood that the generation would be greater than 10 MWh. Similarly, a P90 value of 10 MWh would mean that the power plant would generate more than 10 MWh 90% of the time.

In estimating the probability of exceedance, the uncertainties related to solar resource measurement and other uncertainties related to energy production (uncertainties described in previous sections) characterise the source of statistical variations. Following Dobos et al. (2012) and McMahan et al. (2013), the normal distribution (Gaussian distribution) and the cumulative distribution function were constructed based on the mean annual yield and standard deviation (uncertainty values). The P90 or P99 values were calculated from the distribution's cumulative distribution function.[38]

[38] Following function (Dobos et al., 2012), cumulative distribution function is defined by the following function:

$$\Phi\left(\frac{x-\mu}{\sigma}\right) = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{x-\mu}{\sigma}\frac{1}{\sqrt{2}}\right)\right]$$

The value of P90 occurs when $\Phi\left(\left(\frac{x-\mu}{\sigma}\right)\right) = 0.1$. Setting $\gamma = \left(\frac{x-\mu}{\sigma}\right)$, the following equation can be solved numerically.

$$\Phi(\gamma) = 0.1 \rightarrow \gamma = 1.282 = \frac{x-\mu}{\sigma}$$

Rearranging, this gives an expression for P90 value given the mean (μ) and standard deviation (σ) of the data set that is assumed to fit a normal distribution.

$$x = \mu - 1.282$$

2.5.2. Debt sizing

Lenders, particularly those involved in project finance or non-recourse financing, are conservative and would only provide an amount of debt that they are confident can be repaid from revenues generated by the project. To determine if borrowers can fulfil their financial obligations, banks rely on the DSCR measure (McMahan et al., 2013; Cleijne and Ruijgrok, 2004). DSCR is defined as the ratio of project cash flow (after all operating expenses are paid) to debt repayment during a given period. If the DSCR value is around 1, this means that the borrower would be able to meet its financial obligations. Banks, however, could require a higher DSCR if their perception of the project risk is high.

Credit rating agencies also employ similar risk analysis method to major debt lenders to characterise credit risk (McMahan et al., 2013; Schnitzer et al., 2012). Fitch ratings and DBRS, for example, require a DSCR of 1.3x for P90 performance level and 1.2x for P99 (DBRS, 2014; Joassin, 2012). In sizing project debt, the DSCR targets specified by credit ratings were adopted in the study.

To estimate the project DSCR, the study established a simple cash flow model for each of the case studies. The financial parameters used in the analysis are shown in the Table A2 of the Appendix.

2.5.3. Levelised cost of electricity

One of the indicators used in the comparative analysis is the levelised cost of electricity (LCOE). LCOE is defined as the net present value of the unit cost of electricity over the lifetime of a generating asset. The levelised cost is that value for which an equal-valued fixed revenue delivered over the life of the asset's generating profile would cause the project to break even. This can be roughly calculated as the net present value of all costs over the lifetime of the asset divided by the total electricity output of the asset (IEA/NEA, 2010; Short et al., 1995).[39] The weighted average cost of capital (WACC)[40] is

[39]Following IEA/NEA (2010), LCOE was estimated using the following equation:

$$LCOE = \frac{\sum_{n=0}^{N} \frac{C_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}}$$

Where: C_n stands for total costs, in the year n; Q_n stands for energy generation, in the year n; n stands for year; N stands for the project life; and d stands for the discount rate.

[40]WACC was calculated using the following relationship:

used as the discount rate in estimating the LCOE.

3. Results and discussions

3.1. Energy production

The two data sets described in Section 2.2 were used in the energy production analysis. Energy production from solar PV power plant is a function of solar irradiation. As expected, the NASA SSE data result had a higher energy production compared with that from ground-correlated data set. Given the same power plant configuration, the energy yield on the first year from the case with satellite data is 3.5 % higher than that using the ground-validated data set.

Associated with this higher energy yield are better performance indicators. As shown in Table 10.3, the case of NASA SSE has higher yield factor and performance ratios, for both first year of operation and for the 20-year average, compared with the correlated data set case. For both cases, the performance indicators for the 20-year average are lower since an annual module production degradation of 1% was considered in the analysis.

Table 10.3: Comparative Performance Results of the 27 MWp Solar PV Project

Output	Unit	NASA SSE Data	Correlated Data
Peak power	kW_p	27,000	27,000
Irradiation on horizontal plane	kWh/m^2	1,911	1,859
Irradiation on inclined plane	kWh/m^2	1,918	1,864
Plant availability	%	98	98
First Year Performance			
Energy yield (after inverter)	kWh/year	41,928	40,457
Overall yield factor	$kWh/kW_p/year$	1,553	1,498
Overall performance ratio	%	81.0	80.4
Average Performance (20 years)			
Energy yield per year (average for 20 years)	kWh/year	38,174	36,835
Total yield for 20 years	kWh	763,483	736,700
Overall yield factor	$kWh/kW_p/year$	1,414	1,364
Overall performance ratio	%	73.7	73.2

kWh = kilowatt-hour; kWp = kilowatt peak; m^2 = square meter; NASA SSE = National Aeronautics and Space Administration Surface Meteorology and Solar Energy.

Note: Yield factor (YF) refers to the plant's specific performance in net kWh delivered to the grid per kW of installed nominal PV module power. This is also equivalent to the number of full load hours for the plant. Performance ratio (PR) is defined as the actual amount of PV energy delivered to the grid in a given period,

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$$WACC = \left[\frac{E}{D+E}\right] \times R_e + [\frac{D}{D+E}] \times (1 - corporate\ tax) \times R_d$$

Where: E = equity share; D = debt share; Re = return on equity (after tax); and Rd = debt interest rate.

divided by the theoretical amount according to standard test conditions (STC) data of the modules.
Source: Prepared by the author.

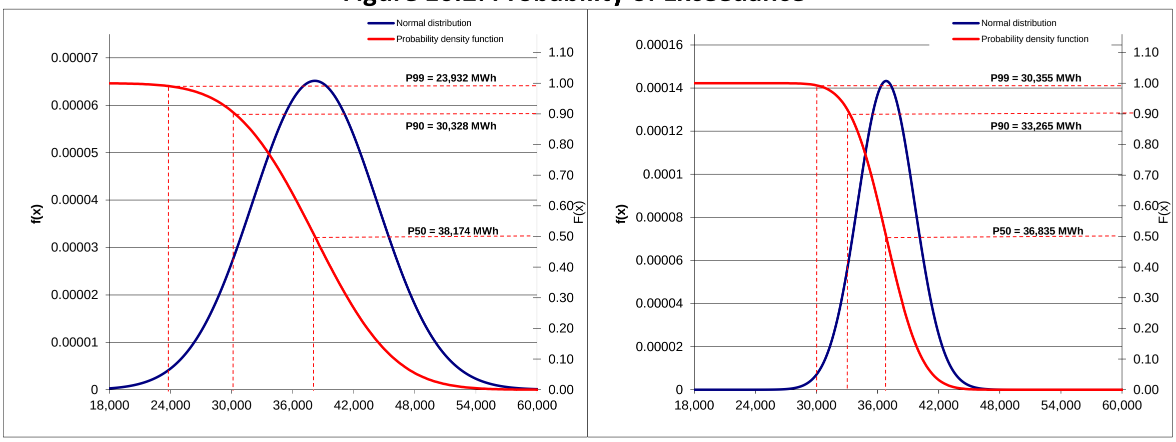
3.2. Uncertainty and project risks

While performance results from the simulation study using NASA SSE data set appear attractive and optimistic, bankers are cautious with these results since the key parameters in estimating the energy yield are fraught with higher uncertainty values. The overall energy production uncertainty for NASA SSE was estimated in the previous section to be 16.04% while that of ground-validated data was only 7.56%. These uncertainties are translated into project operational risks.

The probability of exceedance estimates the energy production values in relation to the given uncertainties. As shown in Figure 10.2, the probability distribution function of the case using ground-correlated data is slimmer compared with the case using NASA SSE data. This is mainly due to its lower value of statistical variation.

The energy production results presented in the previous section represent the expected value (the mean) or the P50 value. As shown in Figure 10.2, the NASA SSE case has higher P50 value than that of correlated data case. The situation appears to reverse when calculating energy production at higher confidence levels that are required by lenders. The ground-correlated case has higher production values for P90 and P99 than the satellite data case. For P90 and P99 values, the energy production with correlated data is 10% and 27% higher than those with NASA SSE data sets.

Figure 10.2: Probability of Exceedance



(A) NASA SSE Data **(B) Correlated Data**

NASA SSE = National Aeronautics and Space Administration Surface Meteorology and Solar Energy.
Source: Prepared by the author.

3.3. Impacts on debt financing

The study quantified the implications of the higher confidence values of energy production to debt financing. The project financial parameters, as mentioned earlier, are shown in Table A2 of the Appendix.

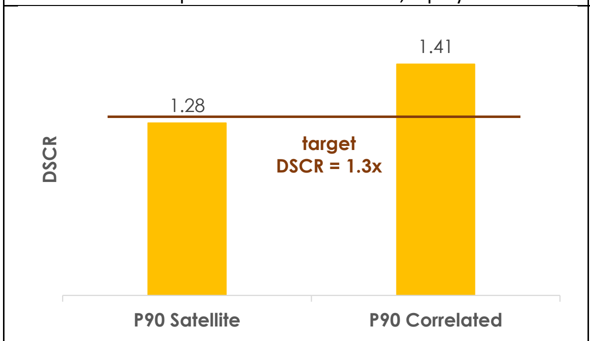
Taking reference from the criteria (target DSCR) used by banks and credit agencies, the DSCRs were estimated using the P90 and P99 energy production values. With constant capital structure of 70% debt and 30% equity, the P90 production value from satellite data results in a DSCR of 1.28x while that of correlated data resulted in a DSCR of 1.41x. The former is slightly below the 1.3x target by most financial institutions while the latter is comfortably higher than the target value. This is shown in (A) in Figure 10.3.

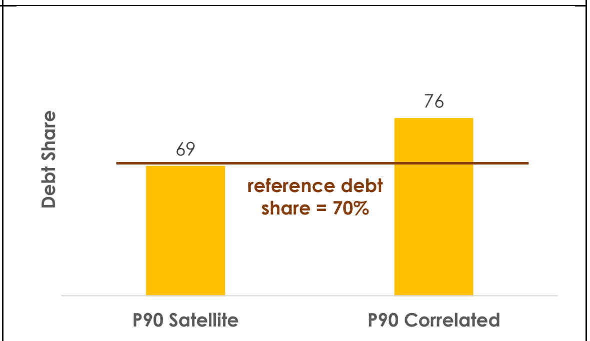
The study also analysed the effect on debt share to keeping the target of 1.3x DSCR constant (B in Figure 10.3). For the satellite data case, the debt share needs to be slightly reduced to meet the target DSCR. On the other hand, for the correlated data case, the debt share could be further improved from the reference share of 70% to 76%.

Improving (reducing) the share of debt also improves (degrades) the project's net present value (NPV), the equity NPV, and levelised cost of electricity. This can be seen by comparing the financial indicators shown in (A) and (B) in Figure 10.3. For the correlated data case, these improvements are attributed to the reduction of the WACC, which is used as the discount rate in the analysis. Similarly, the slight decline in the financial indicators for satellite data case is due to the reduction of debt share and to the corresponding increase of the WACC.

Figure 10.3: P90 Values, Target DSCR, and Debt Capacity Improvement

(A) Constant capital structure: debt=70%, equity=30%	(B) Constant DSCR: 1.3x





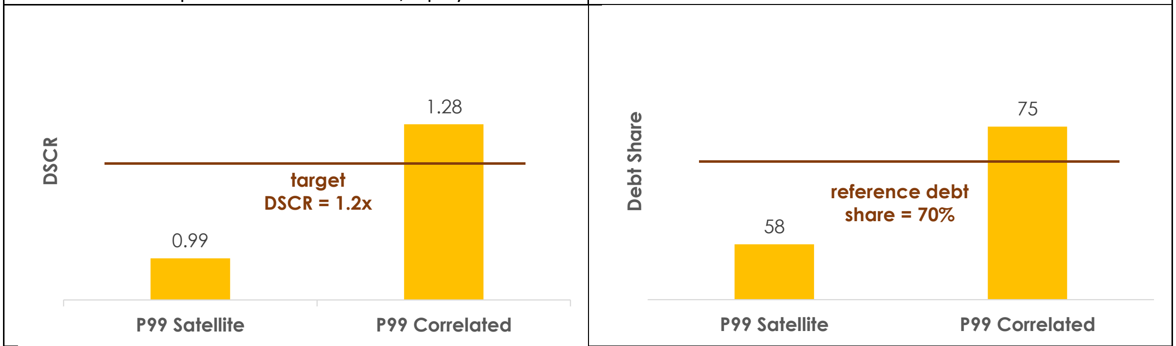
SATELLITE DATA	CORRELATED DATA	SATELLITE DATA	CORRELATED DATA
Project NPV = $7,650 Equity NPV = $657 Levelised cost = $0.2052/kWh	Project NPV = $13,561 Equity NPV = 4,773 Levelised cost = $0.1870/kWh	Project NPV = $7,418 Equity NPV = $557 Levelised cost = $0.2059/kWh	Project NPV = $15,157 Equity NPV = 5,371 Levelised cost = $0.1829/kWh

DSCR = debt-service coverage ratio; kWh = kilowatt-hour; NPV = net present value.
Source: Prepared by the author.

A similar stress test was carried out for P99 values with a target DSCR of 1.2x. The results indicate that the project case with satellite data fails to achieve the target DSCR. In addition, the calculation also shows that the project is not financially viable with key indicators showing negative project NPV and equity NPV. On the other hand, the DSCR value for the project case with correlated data is comfortably above the target limit while its financial indicators are positive. This is shown in (A) of Figure 10.4.

Figure 10.4: P99 Values, Target DSCR, and Debt Capacity Improvement

(A) Constant capital structure: debt=70%, equity=30%		(B) Constant DSCR: 1.2x	



SATELLITE DATA	CORRELATED DATA	SATELLITE DATA	CORRELATED DATA
NPV = ($5,219) Equity NPV = ($8,308) Levelised cost = $0.2600/kWh	NPV = $7,705 Equity NPV = $695 Levelised cost = $0.2050/kWh	NPV = ($7,187) Equity NPV = ($9,504) Levelised cost = $0.2717/kWh	NPV = $8,890 Equity NPV = $1,193 Levelised cost = $0.2012/kWh

DSCR = debt-service coverage ratio; kWh = kilowatt-hour; NPV = net present value.
Source: Prepared by the author.

With DSCR value fixed at 1.2x, the debt share of the project using satellite data needs to be reduced to 58% (from a reference share of 70%) in order to achieve the target. In contrast, the project utilising the correlated data could be further increased to 75% as shown in (B) of Figure 10.4. The satellite data case results in higher WACC while the correlated data case generates a lower WACC value. This explains the slight increase and decrease of the levelised cost of energy for the project case with satellite data and the project case with correlated data. This can be observed by comparing (A) and (B) of Figure 10.4.

4. Conclusion and policy implications

The study has carried out a comparative analysis between a project using satellite-derived irradiation data (NASA SSE) and that using a bankable correlated data set, and their implications related to debt financing. The study results can be summarised as follows:

- Solar resource uncertainty of bankable correlated data set is relatively low and represents around 40% of NASA SSE data set uncertainty.
- The project using NASA SSE data set tends to overestimate energy production at P50 confidence level. On the other hand, energy production at higher confidence levels (P90 and P99) for the project using correlated data set is higher than those using satellite data.
- At constant capital structure, the project with satellite data set has DSCRs below the stress test targets of 1.3x for P90 and 1.2x for P99 production values. Conversely, the project using correlated data set has DSCR values higher than the reference DSCRs.
- To achieve the target minimum DSCR values, the debt share of the project that use correlated data set could be further increased by around 7% for both productions at confidence levels of P90 and P99. This results in a lower WACC, higher project NPV, and lower LCOE.
- The converse could be observed in the project using NASA SSE data set. At P90 confidence level, the debt share needs to be reduced by more than 1% while for P99, the share should be lowered down by 17%. In both production confidence levels, NPV values are negative, and the WACC as well as the LCOE are high.

The study shows that with a bankable solar data set, the overall project risks are reduced, project leverage is increased, and financial competitiveness of the solar PV project is enhanced. The availability of bankable solar irradiation data set reduces financial risks and eventually contributes to the rapid deployment of renewable energy technologies with overall benefits accruing to the society in general.

Governments of developing countries, in addition to introducing policy and regulatory frameworks (such as feed-in tariff, net metering, renewable portfolio standards, and tradable energy certificates) that promote and address economic barriers to renewable energy deployment, must also introduce support mechanisms that address the lack of bankable data and resource information. This could take in the form of (i) incentives or technical support to private sector activities related to resource measurements, or (ii) direct intervention by undertaking renewable energy resource measurements and making the information available to all project stakeholders.

Agencies responsible for renewable energy development could also support financing institutions in the form of awareness-raising activities and capacity building related to resource measurements, type of resource data used in project analysis, and risk analysis to increase their knowledge and understanding of the specific characteristics of renewable energy projects.

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Appendix

Table A1: Solar PV Power Plant Technical Parameters

Module Orientation	
Module inclination	5°
Azimuth	0°
Module-Inverter Configuration	
Installed module capacity	27,000 kW_p
Module type	Polycrystalline silicon
Number of modules	10,800
Nominal capacity of modules	250 W_p
Number of modules per string	18
Number of strings in parallel	6000
Inverter capacity	500 kW AC
Number of inverters	49
Installed inverter capacity	24,500 kW AC

kW_p = kilowatt peak; AC = alternating current.
Source: Prepared by the author.

Table A2: Cost and Financial Parameters

Cost Parameters Capital cost: US$2 million/MW Operating cost: 1% of capital cost	**Fiscal Parameters** Corporate tax rate: 18% Income tax holiday: 10 years Depreciation period: 20 years
Financing Parameters Debt share: 70% Interest rate: 8% Grace period: 2 years Loan term including grace period: 15 years Return on equity: 12%	**Others** Project useful life: 20 years Construction period: 1.5 years Feed-in tariff: $0.23 per kWh

kWh = kilowatt-hour; MW = megawatt.
Source: Prepared by the author.

Chapter 11

Bond Financing for Renewable Energy in Asia[41]

Thiam Hee Ng[42]

Abstract

Energy needs in Asia are huge. Meeting these needs in a sustainable way will require a shift in investment away from fossil fuels towards renewable energy sources. Significant upfront costs and long payback periods of renewable energy projects have often discouraged investors from financing these projects. With government finances already overstretched in many countries, the public sector will find it hard to meet the large financing needs of renewable energy. Improving the financing mechanisms for renewable energy projects is essential to lower the financing cost and make the transition towards renewable energy more affordable for investors, governments, and consumers. The large pool of investable funds available in Asia suggests that the private sector can play a major role in providing financing. With heightened interest in investing in renewable energy, there is a large pool of potential investors. To attract these investors however, the investment will have to be packaged in a form that they are familiar with, which has traditionally been through bonds.

Keywords: Bond financing, renewable energy, Asia

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1. Introduction

Energy needs in Asia are huge. The Asian Development Bank (ADB) (2013a) estimates that Asia's share of world energy consumption will rise from around a third in 2010 to more than half by 2035 if consumption continues on its current growth path. The use of renewable energy (RE) will increase by 50% over this period but will account for only 13% of total energy supply in 2035. To ensure that the growing energy needs of Asia can be met sustainably, energy sources have to diversify from fossil fuels towards RE. Greater use of RE can result in lower cost through improvements in the learning process and reaping benefits from greater economies of scale.

Across the globe, investment in RE is gaining momentum. The Frankfurt School–United Nations Environment Programme Centre (2015) estimates global investment in renewable power reached $270 billion in 2014. This was driven by large installations of solar energy plants in the China and Japan, which totalled $75 billion. While initially, developed countries were the investors in RE, investment in developing countries has grown at a faster pace. In 2014, investment in RE in developing countries was almost on par with that of developed countries. The country with the largest investment in RE was the PRC at $83 billion, which is more than double the $38 billion investment in the United States.

Asian countries have stepped up their investment in RE and we have also seen a substantial increase in the use of RE. India and the PRC have both expanded rapidly their wind power capacity. Data from the Global Wind Energy Council (2014) shows that as of end 2014, the PRC already had the largest installed wind power capacity at 115 gigawatts (GW) or slightly less than a third of the global total. The PRC has also been ramping up its installation of solar power capacity in the face of declining prices for solar panel.

It is clear that RE has many environmental and social benefits. These include very little carbon emission, no air pollution, stable energy costs, and a more resilient energy system. Further, the cost of RE technology has also been falling rapidly. The International Renewable Energy Agency (2015) finds that wind and hydropower are already cost competitive with conventional fossil fuel plants. The fall in solar panel costs also means that solar photovoltaic technology is getting closer to being cost competitive. As technology improves, the cost of RE is expected to fall further. Further advances in energy storage could further encourage the deployment of RE. Heal (2009) highlighted the importance of developing energy storage technology to overcome the intermittent nature of RE. Without sufficient improvement in energy storage, it will be difficult to have a large proportion of energy generation from renewable sources such as wind and solar.

There has been a lot of attention aimed at facilitating greater adoption of RE. Some examples of existing policies include stricter environmental measures, emissions trading systems, and taxes on polluting industries. No doubt these policies have an important role to play in fostering the development of the RE sector. However, at the same time, there is also need to look at the financing aspects of RE projects.

The constraint for adopting RE now lies more in the availability and cost of financing. While the flow of financing for RE has grown, much more investment is needed. Zadek and Zhang (2014) argued that financing for RE has lagged behind what is required and argued for stronger intervention in the financial system. There is still a lack of clear strategy on how to raise the financing needed for RE investment. Most RE projects have a large initial cost and very small operating cost. This means that RE projects will require large and long-term financing. The availability and cost of financing will play an important factor in whether an RE project is viable. Improvements in financing can lower the cost of RE projects. The lack of operating costs means that increasing emphasis is on the financing costs. Improving the efficiency of investments can ensure that RE projects become more affordable and can promote its spread.

This chapter will explore briefly the various financing options available for RE. It will then examine the trends and developments in using bonds to finance RE projects. There has been some success with corporations in Asia with RE operations, particularly in the PRC, which have been able to raise large amounts of funds in the domestic bond market. This chapter will also chart the growing popularity of 'green bonds'.

2. Financing options for renewable energy

The large upfront costs and long payback period of RE projects mean that availability and cost of financing play a critical role. Without the proper financing framework, the necessary investment in RE may not take place. Funds may flow towards conventional sources of energy where risk is lower. Lack of financing can also deter the much-needed investment in the RE sector. Morgenthal et al. (2009) documented that in the aftermath of the global financial crisis, there was a large drop in investment in RE. This underlined the close link between the financing environment and investment in RE.

There are several financing channels that RE projects can avail. These include multilateral development banks, government, and private investors. Financing is crucial to ensure that RE investments are undertaken. Ekholm et al. (2013) warn that lack of financing can constrain the region's ability to meet its RE investment target.

Within Asia, multilateral development banks such as the World Bank and ADB have provided technical assistance and financing for RE projects. These institutions offer market-based financing and concessional financing at below market rates for low-income countries. They have been very active in facilitating RE investments in Asia. Currently, the multilateral development banks have a significant role in financing RE projects in developing countries. In poorer countries, Spratt and Griffith-Jones (2013) argued that support from outside such as that from multilateral banks is needed to help facilitate private sector financing of RE investments.

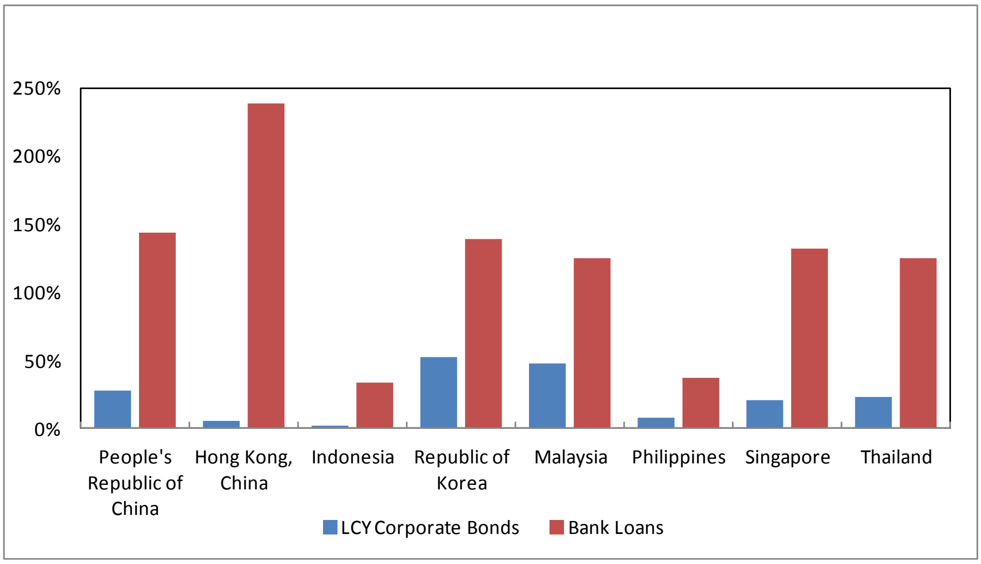
ADB has undertaken strong efforts to combat climate change in Asia. Promoting RE is part of this effort. ADB has been working to increase the amount of RE utilised in the region. It has focused on promoting the use of advanced technologies to increase energy efficiency. At the same time, ADB is also working to raise the share of RE in the energy mix. In 2013, ADB invested $2.3 billion in clean energy. This continues ADB's strong track record in clean energy. Its investment in clean energy has consistently exceeded the $2 billion target since 2011. Most of ADB's clean energy investments go into RE, which reached $1.4 billion in 2013. Most of ADB's support for RE went into solar and wind projects, but it also invests in hydroelectric projects. Further, it has included clean energy in its projects and has helped facilitate financing to help reduce the cost of clean energy projects. ADB launched the Asia Solar Energy Initiative which aimed to produce 3GW of solar-generated electricity in 2010. To achieve that goal, ADB planned to invest $2.25 billion and leverage an additional $6.75 billion in solar power investments. In the wind sector, it launched the Quantum Leap in Wind Initiative to produce 1GW of wind-generated energy.

Governments can also play an important role in supporting the financing of RE by offering subsidies to cover RE projects' higher costs and putting in place a regulation that reduces the risks of RE projects. Public authorities can also provide financing for renewable projects that are cheaper than commercial terms. This can be either soft loans from public financial institutions or loan guarantees. However, given that government finances are already overstretched in many developing countries in Asia, it is unlikely that the government can act as the direct financier. However, governments can put in place the proper policies and regulations that can attract financing from the private sector, both domestically and internationally.

As government finances are already overstretched in many countries in Asia, it is unlikely that the public sector will be able to take on the additional burden to finance the large investment needed for RE. In Africa, Gujba et al. (2012) saw international donors and governments playing a more important role in financing. But the large pool of investable funds available in Asia suggests that the private sector will play a major role. The appeal of investing in developing countries has been increasing. Their growth performances have been outpacing that of developed countries by a considerable margin after the global financial crisis. In addition, some of the Asian countries also have natural advantages in terms of RE potential. Having a relatively less developed conventional energy sector could also be an advantage as it has the potential to leap frog to a more modern technology without having to deal with the sunk cost of previous investments.

In Asia, the banking sector is the main source of financing. Banks dominate the financial sector and are usually larger than the bond market (Figure 11.1). There are several ways that banks could finance RE projects. This could be through loans, project loans, mezzanine loans, and refinancing. A typical corporate loan has no restrictions and could be put to any use. The lending would be based on the overall health of the company. Project finance is also becoming more popular. In this case, the funding is meant for a specific project. This means that the loans are only secured by the project asset and serviced by the revenues from the project. Banks can also provide mezzanine loans which are subordinated loans meant to serve as supplementary financing. This tends to be a riskier lending that lies in between secured debt and equity. As mezzanine loans are riskier, they usually have higher returns.

Figure 11.1: LCY Corporate Bonds and Bank Loans as a Share of GDP*



* GDP = gross domestic product; LCY = local currency.
Note: Data as of end of December 2014.
Sources: International Monetary Fund's International Financial Statistics; Haver Analytics, CEIC; Bloomberg L.P.

While banks are likely to continue to play an important role in financing RE, the new Basel III regulations could make banks more reluctant to lend long term. The new Basel III rules aim to ensure that banks have liquid and high-quality assets so that they can better ride out periods of stress. Hence, Basel III introduces new liquidity requirements for the first time. These liquidity requirements tend to penalise long-term loans for which there is no active secondary market. RE project loans tend to fall under this category and will likely find it harder to access bank financing. It will also likely raise the cost as well. Although banks still have some time to implement the new Basel III regulations, they may have started cutting back already on long-term lending as these loans will still likely be on their books when the Basel III regulations come into force.

Banks in Asia have relatively little experience in financing RE. Renewable technology requires higher level of technical skills to evaluate that banks do not possess. Further, the limited track record for RE projects makes it harder to evaluate. By its nature, RE projects tend to have large upfront costs and long payback period, which may make them less attractive from the perspective of bankers.

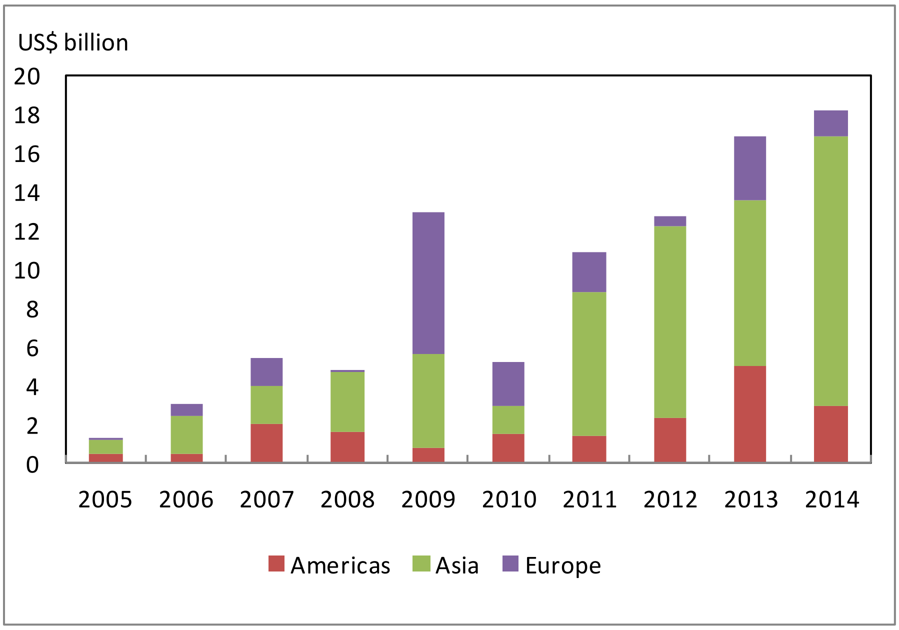
This suggests that the bond market may become the preferred source of financing for RE projects. If banks are becoming less likely to lend to projects, borrowers might turn to the bond markets. There are many similarities between RE project financing and infrastructure project financing. ADB (2013b) highlighted that bonds have large potentials in financing infrastructure projects in Asia.

3. Bond financing for the renewable energy sector

Given heightened interest in investing in RE, there is a large pool for potential investors. However, to attract these investors, the investment will have to be packaged in a form that investors are familiar and comfortable with for them to invest. These large investors such as pension funds and sovereign wealth funds have traditionally allocated a large proportion of their portfolios to bonds. There is a huge pool of investment assets available. Nelson and Pierpont (2013) have estimated the pool of institutional assets globally at around $80 trillion. The development of bond markets for RE is also supported by the general trend towards increased investor interest in environmentally friendly 'green' projects.

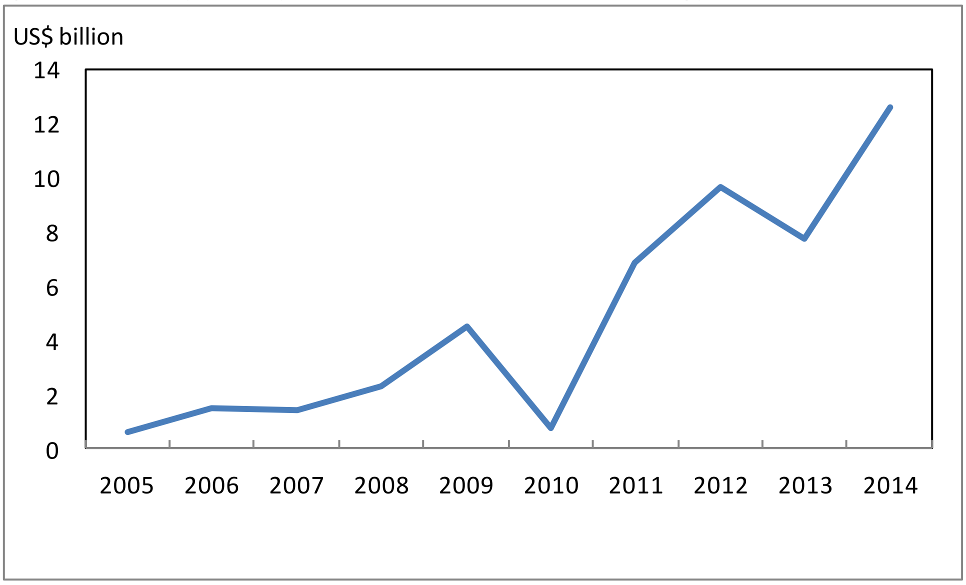
Globally, renewable sector bonds have been increasing rapidly. Since 2010, total bonds issued by RE corporations have increased from $5.2 billion to $18.3 billion (Figure 11.2). Asia has been leading the way in using bonds. However, almost all of the renewable sector bonds in Asia have come from the PRC (Figure 11.3). In 2014, 90% of Asia's renewable sector bonds came from the PRC. This is consistent with the overall trend of increasing investments in the RE sector in developing countries. Zadek and Flynn (2013) found that about half of global RE infrastructure investment in 2012 came from developing countries, with the PRC accounting for the bulk of it. Strong government support and a large financial sector facilitated the rapid expansion of RE in the PRC.

Figure 11.2: Renewable Energy Sector Bonds by Region



Source: Bloomberg L.P.

Figure 11.3: People's Republic of China's Renewable Energy Sector Bond Issuance



Source: Bloomberg L.P.

One reason why Asia has been leading in RE bonds is that Asia has a large pool of funds available for investment. Overall, Asia remains a capital surplus region. In particular, the PRC has a high savings rate and a large current account surplus. At the moment, much of the surplus capital from Asia is invested in low-yielding assets in the developed world. There is great potential to invest some of those funds in the RE sector.

Being more familiar with the region might lead to Asian investors assessing the risks and returns on RE projects in the region differently from investors from advanced economies. As domestic and regional investors have greater knowledge and experience of the situation on the ground, they may be able view risk differently from international investors. Another point in favour is that domestic investors do not face exchange rate risk, which could be an important factor for international investors.

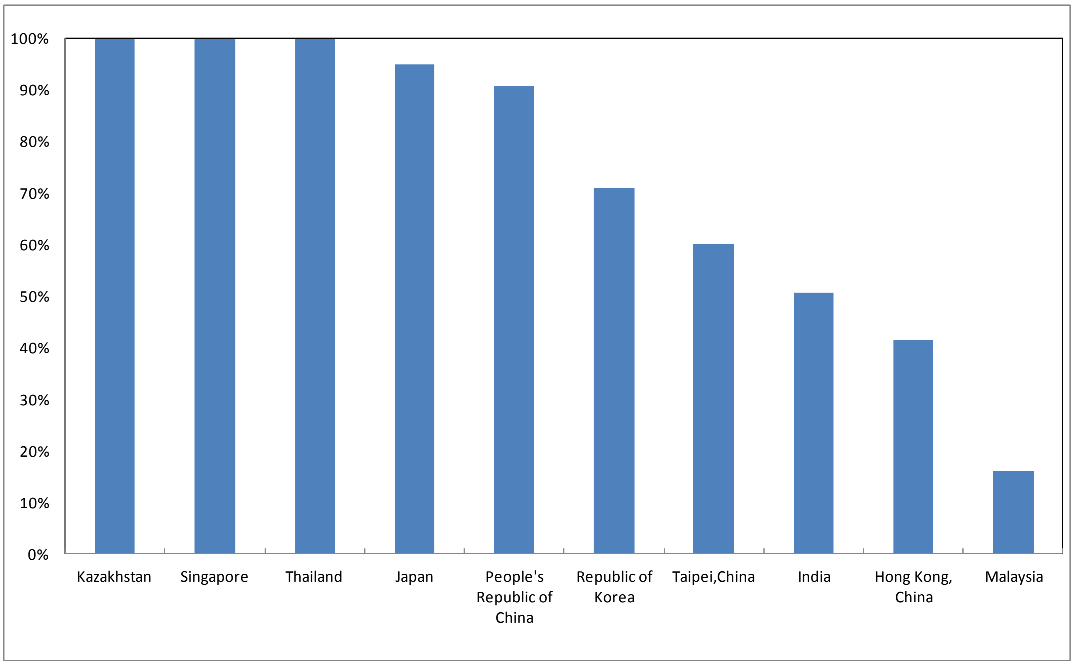
Better knowledge of local conditions may make domestic investors more willing to finance RE projects. Local investors are usually better able to assess the complicated risks of building and delivering RE projects. Better understanding of domestic regulations could also be an advantage to domestic investors. This is especially true in Asia where environmental regulations and incentives for investment in RE are evolving quickly. Being closer to the regulators may also provide domestic investors better opportunity to take advantage of investment opportunities opening up.

In many developing countries in Asia, bringing down the financing cost for RE is important. Having underdeveloped financial markets, the cost of financing tends to be higher in many Asian countries. The higher upfront costs for RE projects also have a greater competitive disadvantage when compared to conventional projects.

Accessing foreign debt could be seen as a way to bypass the inefficiency of local financial markets. But this comes at a price as international debt tends to be priced in foreign currency, usually in US dollars. So, taking on foreign debt would usually mean taking on exchange rate risks as the revenue from the RE projects would be in domestic currency. The foreign exchange rate risk could be hedged but it would then probably offset most of the benefits in terms of lower yields.

The good news is that there are growing local currency bond markets that can help finance large infrastructure projects in Asia. Having a well-functioning and liquid local currency bond market can help these investors finance their activities. In Asia, economies with well-developed bond markets have been able to mobilise large amounts of funds. So far, most of the RE sector bonds in Asia are being issued in local currencies (Figure 11.4).

Figure 11.4: LCY-denominated Renewable Energy Bonds as Share of Total



LCY = local currency.
Note: As of end 2014.
Source: Bloomberg L.P.

One example of a recent RE company issuing bonds is Trina Solar Limited from the PRC. Trina Solar Limited is a large-scale integrated solar power products manufacturer, including crystalline silicon photovoltaic modules and solar system developer. In October 2014, Trina Solar Limited issued a total of $115 million convertible senior notes due in 2019. The proceeds will be used for developing new solar projects.

Another RE company that has tapped the bond market is GS Yuasa Corporation. Its business includes the manufacture and supply of batteries, power supply systems, lighting equipment, and other electrical equipment. In March 2014, GS Yuasa Corporation issued a ¥25 billion zero coupon convertible bond maturing in 2019.

While concerns about climate change are driving policymakers' attention, businesses also have good reason to be interested in RE. There are increasing expectations that carbon will likely be taxed or charged in the future. Partnership for Market Readiness (2015) documents Royal Dutch Shell, Rio Tinto, and Pacific Gas and Electric Company – companies with large carbon intensive operations – to have been preparing for the time that carbon will be taxed. Companies are also under growing scrutiny about their environmental track record. With government fiscal conditions under growing stress, they have been encouraged to cut back on fuel subsidies (ADB, 2013). These policies can strengthen the government's balance sheets while at the same time promote growth in the RE sector.

4. Rising interest in green bonds

While RE companies have been active in issuing bonds, the proceeds from the issuance need not necessarily be used for green projects. A recent innovation is the development of green bonds where there is a commitment by the issuer for the proceeds to be used for projects with environmental benefits. Most green bonds issued so far have been used to finance climate change mitigation or adaptation, including clean energy, energy efficiency, mass transit, and water technology. Green bonds can be either plain vanilla treasury-style retail bonds (with a fixed rate of interest and redeemable in full on maturity), or asset-backed securities comprising several green projects. Most green bonds issued are 'use of proceeds' bonds where the funds raised from the bond issuance are earmarked for green projects. While the proceeds can be used only for green projects, the bond is backed by the entire assets of the company issuing the bonds.

The growing interest in investing in green bonds is due to the growing interest of investors in investing according to environmental, social, and governance (ESG) criteria. The United Nations' Principles for Responsible Investing Initiative lists more than 1,000 investors as signatories, representing about $45 trillion in assets under management. In January 2014, a group of financial institutions launched the Green Bond Principles, which sets out the voluntary process guidelines and clarifies the approach for the issuance of green bonds. Private sector interest was high after seeing strong demand for multilaterals' green bond issuance. Citigroup, Bank of America Merrill Lynch, JP Morgan, and Crédit Agricole were the original backers of the Green Bond Principles. The support has since swelled to 55 underwriters, issuers, and investors as signatories.

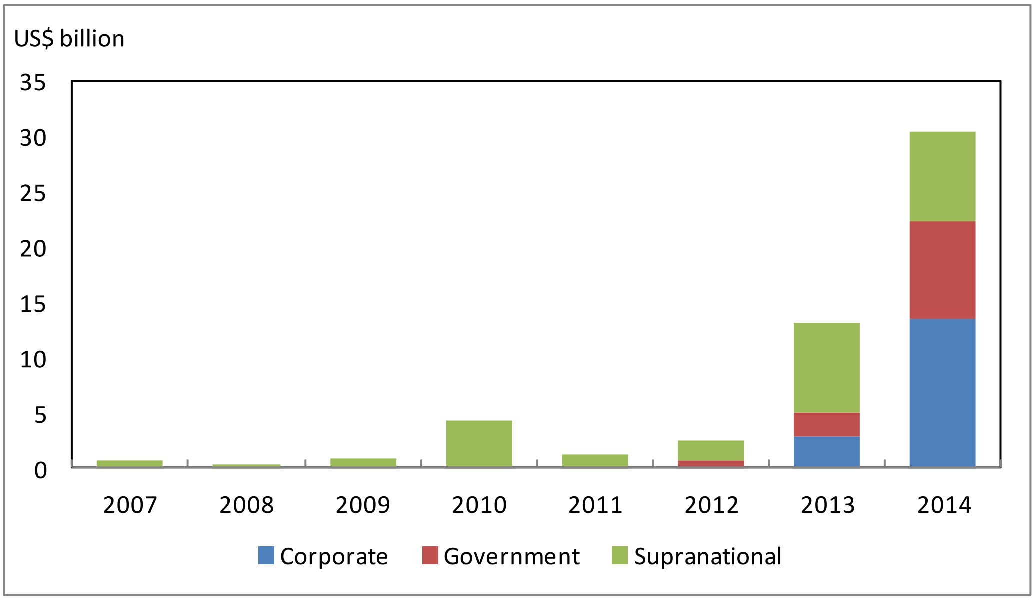
The Global Sustainable Investment Alliance (2014) found that assets invested based on sustainable principles have grown from $13.3 trillion at the beginning of 2012 to $21.4 trillion 2 years later. As a proportion of professionally managed assets, the share of sustainable-related investment has risen to 30.2% in 2014 from 21.5% in 2012. However, while the share of assets managed according to sustainable criteria have increased in all regions, it is important to highlight that the share in Asia is very low at only 0.8%, way below the global average and far behind the almost 60% share in Europe.

While the amount of sustainable investment assets is still low in the region, it has been increasing. Between 2012 and 2014, it has grown by 32% to reach $53 billion. Malaysia; South Korea; and Hong Kong, China are the largest markets for sustainable investment. The leading role of Malaysia is due to the large size of the Islamic fund markets there where investment will have to go through screening based on shariah principles.

As awareness in sustainable investing continues to grow, it is expected that the share of sustainable investment assets will rise substantially. There have been strong moves to urge institutional investors to divest their investments in companies involved in fossil fuels. The Association for Sustainable and Responsible Investing in Asia (2014) documented that several new national policies and regulations are facilitating the process. India and Viet Nam have strengthened their corporate reporting requirements for sustainable business practices. Stock markets in the PRC; Singapore; and Hong Kong, China have introduced guidelines on sustainability reporting. Importantly, some public pension funds have taken steps to integrate sustainability principles into their investment decision-making process. As of August 2014, 160 large institutional investors in Japan, including the giant Government Pension Investment Fund with ¥130 trillion under management, have endorsed the 'Principles for Responsible Institutional Investors'. Given the large pool of assets that these funds manage, this initiative could have a significant impact on facilitating greater investment in RE.

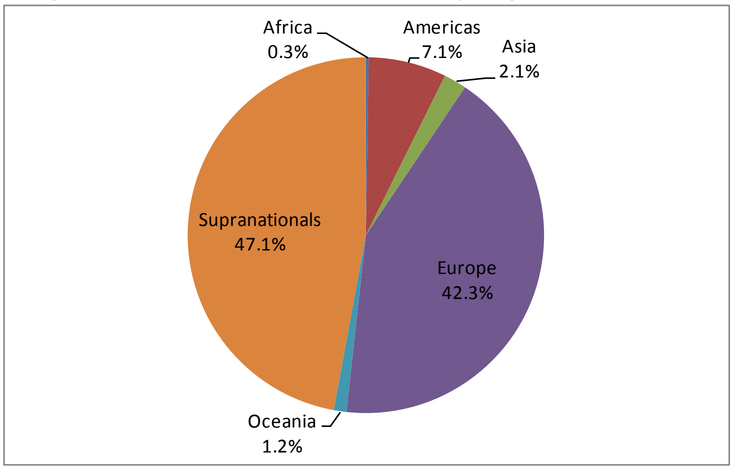
Given the growing demand by investors, it is not surprising that the green bond issuance is surging. In 2014, the total issuance of global green bonds reached US$30.5 billion, more than double the amount in 2013 (Figure 11.5). Most of the green bond issuance has been by 'supranationals', which include the multilateral banks. European government entities and corporations are a close second (Figure 11.6). In Asia, green bonds have been slower to take off. Part of the reason is that there is a smaller pool of assets in Asia that is targeted at sustainable investing. However, it is important to point out that there have been plenty of RE firms that have successfully raised funds in Asia but did not choose to label their bonds as green bonds.

Figure 11.5: Green Bond Issuance by Issuer



Note: As of end 2014.
Source: Bloomberg L.P.

Figure 11.6: Green Bond Issuance by Region, 2007–2014



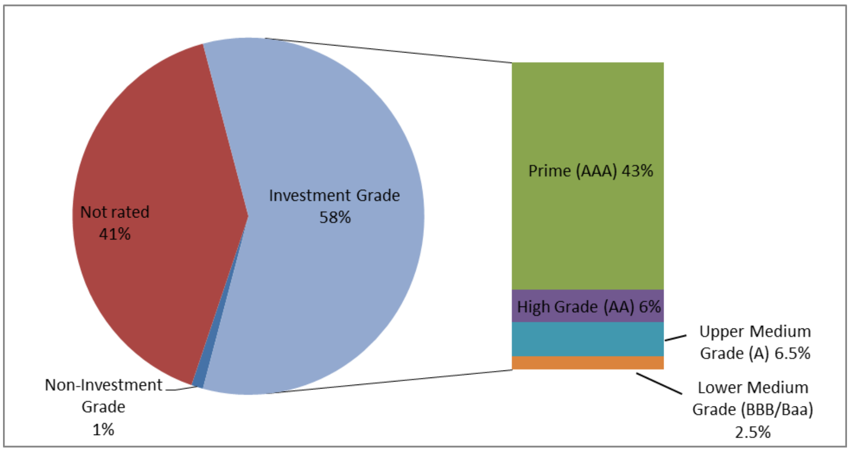
Source: Bloomberg L.P.

Green bonds were first issued by multilateral banks as part of their efforts to combat climate change. They have been well-received and highly rated. The European Investment Bank (EIB) pioneered the first green bond issuance in 2007. To date, EIB is the largest issuer of green bonds with €7.4 billion raised across 10 currencies, of which €4.3 billion were raised in 2014 alone. Most of the funds raised from the issuance of bonds were invested in energy efficiency and RE projects. The World Bank followed soon after, issuing its first green bond in 2008 to support climate change mitigation and adaptation projects. Since then, the World Bank has issued over $7 billion worth of green bonds.

In Asia, ADB sold its first Clean Energy Bonds in September 2010, raising $232 million to support its RE and energy efficiency projects in Asia and the Pacific. This was followed in May 2012 with the second sale of Clean Energy Bonds raising $339 million. More recently, in March 2015, ADB raised $500 million from its inaugural green bond issue, aimed at channelling more investor funds to ADB projects that promote low-carbon and climate-resilient economic growth and development in developing Asia.

The attraction of the multilateral bonds is that they rank equal to the other obligations of the multilateral banks so they have the same AAA credit rating. Institutional investors who are traditional buyers of the multilateral bank bonds are also attracted to them because it gives them the opportunity to invest in environmental projects at little risk. Reflecting the importance of the multilateral issuers, most green bonds have been investment graded, with the bulk rated AAA (Figure 11.7).

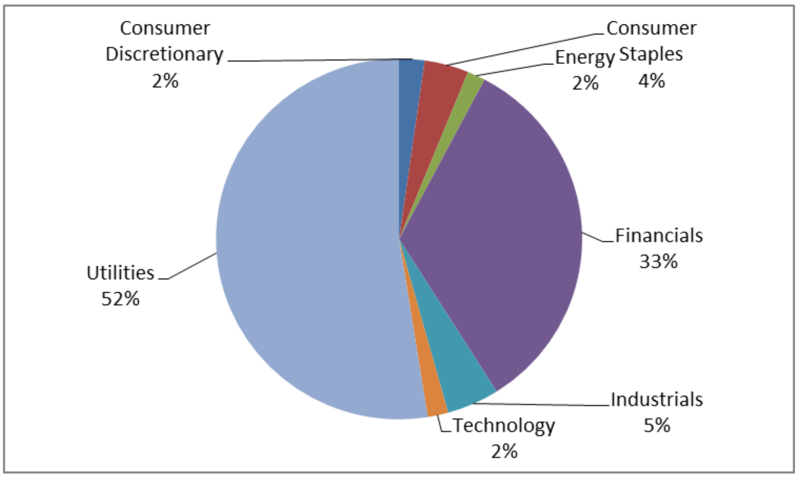
Figure 11.7: Green Bond Ratings, 2007–2014



Note: As of end 2014.
Source: Bloomberg L.P.

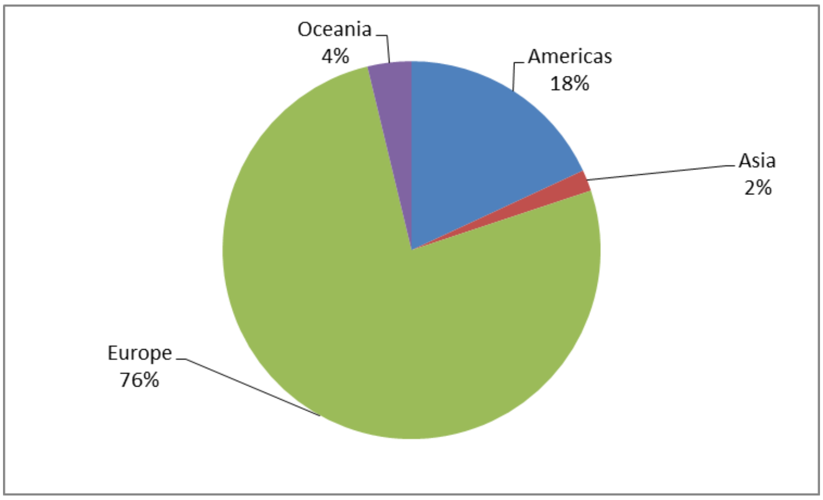
For corporate green bonds, utilities have been raising more than half of the funds in the green bonds market. However, financial firms are also big issuers (Figure 11.8). Financial firms issuing bonds would earmark the funds raised for lending to environmental projects. Corporate issuance of green bonds is concentrated in the European markets (Figure 11.9). At the moment, Asia has only a very small slice of the corporate green bonds market. There has been limited issuance of green bonds in Asia. Part of the reason is that it is still a relatively new trend in Asia. The benefit of labelling bonds as green is the ability to access a broader range of investors. In particular, this would be able to access investors that have environment and sustainable goals as part of their investment criteria. The growing pool of such investors (Environmental and Social Impact Assessment, 2014) suggests that there is potential for lower costs and increased liquidity in the green bonds market.

Figure 11.8: Corporate Green Bond Issuance by Industry, 2007–2014



Note: As of end 2014.
Source: Bloomberg L.P.

Figure 11.9: Corporate Green Bond Issuance by Region, 2007–2014



Note: As of end 2014.
Source: Bloomberg L.P.

However, it should be emphasised that the pool of investors in Asia is still very small. Issuers will therefore have to target investors in developed countries. Another important benefit of issuing labelled green bonds is its benefit to the firm's reputation. It is a visible way to signal firm's commitment to environmental goals. However, Lyon et al. (2013) found that Chinese firms that have been lauded for their environmental achievements had not seen any positive impact on their valuation. This suggests that the halo effect of an environmental firm seems to be limited in the PRC for now.

Against these benefits, there are also additional costs associated with issuing labelled green bonds. For example, there are additional costs for certifying and monitoring the bonds. There is also the risk that investors may seek penalties if the funds are not used for their stated environmental purposes. The lack of a universal standard on what is considered a green bond could make it unclear. And without a proper legal framework, issuers and investors will have to decide among themselves what qualifies as a green bond.

The corporate green bond market is still nascent. So far, there have been only two issuances. The first one was by Advanced Semiconductor Engineering, a provider of semiconductor packaging and testing services based in Taipei,China. In July 2014, it issued a $300 million three-year green bond via its subsidiary, Anstock II Limited. The bond yielded 125 basis points above US Treasuries, which is roughly comparable with that of the company’s bonds. The bond issue was met with strong investor interest, with most of the bonds taken up by Asian investors.

In 2015, Asia’s second corporate bond was issued by YES Bank from India, which is India's fifth largest private sector bank. In February 2015, YES Bank raised 1,000 crores ($156 million) through a 10-year green bond, with the proceeds to be used to finance infrastructure projects in RE. KPMG India will be providing the assurance services annually on the use of proceeds in accordance with the Green Bond Principles.

Green bonds are still a sliver of the overall bond universe at just 0.06% as of end December 2014. But with the right support and policy, there is tremendous potential for green bonds. It is important to ensure that the corporate green bond market develops to ensure that there is a liquid market that can attract new investors to participate. To further facilitate green bond investment, Barclays worked with Morgan Stanley Capital International to introduce a new green bond index that will track the global market for green bonds in 2014. Bank of America Merrill Lynch has also launched a Green Bond Index. These indices will make it easier to track the performance of green bonds in the market. It could also lead to the introduction of passively managed green bond funds that can open up the green bonds market to a larger group of investors.

5. Project bonds for financing renewable energy projects

In addition to 'general use' bonds, there is a growing trend towards using project bonds. With project finance, funds are raised to finance a specific project. The cash flows from that project will be used to cover the servicing cost of the loan. In a project bond, the creditworthiness of the bond is based on the ability of the project to generate the necessary cash flows to cover the servicing cost of the bond and provide a return to the investors. This is contrast to conventional bonds where the issuing firm's entire balance sheet is available for servicing the loan. Therefore, when investing in project finance bonds, investors would have to scrutinise the project's construction costs, operating costs, and revenue to evaluate the payouts.

Project finance can be used to finance large infrastructure projects that might otherwise be too risky or burdensome for a company's balance sheet. With project finance, the lenders provide funding for the project based only the risk and return profile of the project alone. Therefore, the company that develops the project is not liable in case the project fails.

RE investments are similar to long-term infrastructure investments. This means that they would tend to appeal to investors with long investment horizon such as pension funds, which need long-term investment assets to match their liabilities. As in infrastructure projects, most of the risks in RE projects are in the construction phase. Once the project is up and running, the risks are relatively minimal. RE projects have very low operating costs and well-defined stream of revenues if there is a long-term contract or feed-in-tariff.

Tighter prudential regulations for banks brought in after the global financial crisis have made project financing from banks more expensive and difficult to obtain. Long-term loans are riskier and now attract a higher risk weight under the new Basel III regulations. This hurts projects with long-term paybacks such as RE projects. With the payback period from RE projects very similar to that of bonds, it may make sense to package and structure it as a project finance bond. This could be more cost effective than going through a bank.

Another concern that investors may have with RE project bonds is that they may lack liquidity. To get around this problem, we have seen the 'Yield Co' structure gaining popularity in the United States. The Yield Co investment structure is targeted at long-term investors looking for higher yields in the current low-interest rates environment. In the United States where it was first introduced, Yield Co is structured as a public company that puts together a portfolio of RE assets that is already operating and generating revenue to generate a predictable stream of dividends for the investors. It is also typically structured to avoid double taxation. As the Yield Co invests in RE projects that are already up and running, most of the construction and operating risks are eliminated. It also allows the original project developers to recoup their investments, allowing them to invest in other projects. Yield Cos are usually structured by securitising several different RE assets to make them more liquid. A portfolio of assets is also more diversified and less risky. Structures like this could help attract additional investors to the RE market by lowering the risk and increasing the liquidity. Lowering the cost of capital is essential for RE projects given the higher upfront cost. The first 'Yield Co' was NRG Yield, which raised $500 million in 2014 to finance a wind farm. In January 2015, TerraForm Power issued $800 million green bonds to finance its acquisition of a wind farm.

The success of the Yield Co model suggests that there could be great potential for the securitisation model to help improve liquidity and diversify the risk of RE project bonds. Alafita and Pearce (2014) found that securitisation on solar asset backed securities can help reduce project financing costs significantly. However, for the securitisation model to succeed, it is important to ensure that the securitised security is liquid and easily traded. This means there will need to be a well-developed bond market and some standardisation of the assets. It would also involve having a regulatory framework that allows for the securitisation of revenue streams. Greater transparency and availability of data could also make it easier to attract investors.

6. Policy recommendations for promoting greater bond financing

While the case for financing RE is compelling, there are several key challenges that would need to be overcome to ensure that the financing needs for RE can be met. Bond financing can help attract a new class of investors to finance RE projects. Several economies in the region with large developed bond markets have successfully raised funds for large infrastructure projects. Deep capital markets are important to ensure sufficient liquidity to facilitate the issuance of bonds. In addition, it will be important to develop a pool of long-term investors that can invest in these long-term bonds. One way to encourage broader participation in the bond market is to issue retail bonds to target retail investors who usually do not have the large minimum sum needed to invest in regular bonds. Retail bonds are typically issued in smaller volumes, which could be attractive to small- and medium-sized companies. This can enable smaller RE companies to also tap the bond market for financing.

Although the government's financing capacity for RE projects may be limited, they still have an important role to play. Regulatory policies can have a strong influence on the financing environment. Lo (2014) found that in the PRC, the government has taken strong actions to promote the development of RE since 2005. While substantial progress has been made, he argued that more needs to be done such as increasing the rate for solar feed-in-tariff and creating more incentives for local governments to pursue energy conservation.

A stable regulatory regime can also work to reduce the risk of investing in RE. Polzin et al. (2015) find that a long-term supportive policy framework for RE goes a long way towards promoting investment in RE capacity. Given the long-term nature of many RE investments, the stability of the policy framework is very important. Fabrizio (2013) found that the US states that have backtracked in their regulations to promote RE attracted less investments. This suggests that policy uncertainty can deter new investments. Abolhosseini and Heshmati (2014) argued that feed-in-tariff could be useful to reduce the risks to investors for RE projects. Supportive policies that are long-term and do not depend on annual budget allocations tend to be favoured by investors.

While bonds offer a promising avenue for financing RE projects, governments may also need to provide incentives to increase the return on RE investment to attract investors. These can be justified by the positive environmental externalities that RE offers. RE projects tend to be at a disadvantage as they have shorter track records and higher upfront costs than conventional energy projects. Further, RE projects may also face higher transaction costs than conventional energy projects. This is because RE projects tend to be of smaller scale than conventional energy projects.

One way to level the playing field for RE projects is to provide guarantees that can reduce the cost of financing. Traditionally, this guarantee has been provided by governments, but it carries a fiscal risk. Hence, the cost of providing the guarantee has to be carefully weighed. Another way would be to set up a dedicated fund to provide low-cost financing for renewable projects. This can help narrow the cost disadvantage. As more RE projects are completed and running, investors may become more comfortable with investing in them and the need for guarantees or low-cost financing will diminish. Tax incentives or exemptions for RE projects can also help reduce the cost differentials.

At the same time, polluting industries with negative environmental externalities should also bear the burden of their pollution. Traditionally, fossil fuel energy sources have not faced the full costs of the pollution they generate. To level the playing field between fossil fuel and RE sources, fossil fuel energy sources should face higher costs. Higher taxes could be imposed on fossil fuel sources to reflect more accurately the cost of the pollution that they cause. This would reduce the return on investing in fossil fuel, thus making RE more competitive.

There is a perception investing in that RE firms is risky. But generally, RE firms are not necessarily riskier. Donovan and Nunez (2012) found that from the perspective of an international investor, the risks of RE firms in India, Brazil, and the PRC are comparable with that of the overall market. The risks from the perspective of a domestic investor are more varied. Indian RE firms have higher-than-average market risk while Brazilian firms have lower-than-average market risk. Meanwhile, Chinese firms have average market risk. To a certain extent, investors may have been underestimating the risk of conventional energy firms. The threat of tighter environmental regulations in the future could severely affect their profitability.

Therefore, an important priority now is to help narrow the information gap for lenders who are contemplating investing in RE. Making data on RE project costs and performance more transparent will facilitate the participation of institutional investors and reduce the cost of financing. Before investing in infrastructure projects, investors typically would like to examine the track record of similar projects. Without historical data on past financial performance, investors may be reluctant to invest because they lack the information to make the necessary estimate of future returns. Making historical data publicly available would improve transparency in the investment process. Governments can also provide more information about the availability of RE from their assessment and mapping of RE resources. This will help investment into the RE sector.

7. Conclusions

There has been tremendous growth in both the labelled and unlabelled RE bonds. So far, most of the labelled RE bonds have come from AAA rated supranationals. The market has to develop beyond those highly rated issuers to embrace other corporations. A wider variety of issuers offering different risks and return trade-offs will help broaden the market.

The use of project bonds and asset-backed securities is also helping to develop the markets.

Asia, as yet, has lagged behind. The PRC has been a big issuer of unlabelled RE bonds. Its success has been due to corporations tapping into a large pool of liquidity. The rise of RE bonds coincides with the strong government support for RE, which resulted in many state-owned corporations investing in the sector. Investors in the Chinese bond markets are less worried about risk because of the perception that bonds in RE have an implicit guarantee from the government.

Going ahead, we expect more RE companies in Asia to tap the bond markets to finance their investments. So far, only a few investors in the region have ESG investment criteria, but the momentum is growing. Large international investors are also keen to invest here given the low yields in the advanced economies. Innovative public private partnerships can help increase the leverage of public funds and make corporate green bonds more attractive to large investors.

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Chapter 12

Utilising Green Bonds for Financing Renewable Energy Projects in Developing Asian Countries

Jacqueline Yujia Tao[43][44]

Abstract

With the market for green bonds rapidly developing in recent years, interest in this new financial instrument has also been rising. This chapter uses the Strength, Weakness, Opportunities, and Threats (SWOT) analysis to examine the strengths, weaknesses, opportunities, and threats of using green bonds to finance renewable energy projects in Asia. The potential for green bonds to become viable financing instruments for renewable energy projects is great and the market is seen to be gradually moving towards this direction. However, there remain several challenges that can be met with key supportive mechanisms. This chapter proposes a two-tiered national standards system and other supportive policies to support the building of a green bond market in developing Asia.

Keywords: Green bonds, renewable energy, financing, fixed income

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1. Introduction

As public finances become increasingly constrained, it is essential to capitalise on private markets to mobilise the required funding to unlock sufficient and well-targeted investments in renewable energy in developing Asian countries. Despite various policy incentives, renewable energy (RE) projects in Asia still face numerous challenges, particularly at the financing stage, which limit overall RE deployment in the region. While a plethora of risk management instruments are arising to improve RE project economics, a financing gap is still observed. Currently, RE projects in developing Asia are mostly financed by local bank loans (ADB, 2015), which can be poorly suited as a financing source for RE projects. In addition, an over-reliance on bank-intermediated financing subjects the borrower to a variety of potential issues such as maturity mismatch, currency mismatch, higher cost of capital, and risk of credit crunch. Thus, it is critical to source for new sources of private sector finance for RE projects.

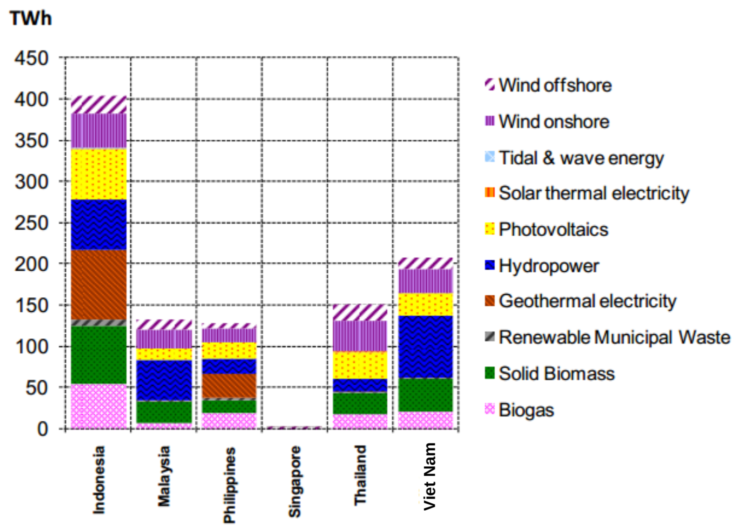
Fixed-income instruments, such as bonds, are suited for large-scale, capital-intensive infrastructure projects such as utility-scale RE projects. Current developments internationally seem to signal an interest, from both the issuers and investors, to utilise green bonds to fuel the growth of RE development.

Despite heightened interest in this new financial instrument, discussions and literature on this topic, particularly in the Asian context, are limited. Thus, this study aims to be a primer for further discussions on this topic around the region. The objectives of this study are three-fold. First, it highlights the current financing challenges faced by RE projects and the need for new financing sources for RE projects in the region. Second, despite recent interest in the rise of green bonds as a viable financing stream for low carbon investments, existing literature on this topic remains limited. As such, this study aims to provide a comprehensive overview on the green bond instrument, thereby serving as a primer for further discussions on this topic. Third, with the increased market interest in green bonds as a growing financing channel for RE, there is interest from policymakers to examine the green bond instrument and assess its viability as a financing channel for RE projects in the region. This study addresses this knowledge gap by providing analysis and facilitating discussion on the subject.

2. Literature review and methodology

Endowed with abundant natural resources, the potential for large-scale RE deployment is high. According to a 2010 International Energy Agency report (Ölz and Beerepoot, 2010), apart from Singapore, which faces serious land constraints, each Association of Southeast Asian Nations (ASEAN)-6[45] member state is capable of generating between 120–400 terawatt hour (TWh) of energy annually from RE sources by 2030.

Figure 12.1: Total Realisable Potentials* for RES-E in ASEAN-6 Countries, by Technology to 2030



ASEAN = Association of Southeast Asian Nations; RES-E = renewable energy sources for electricity; TWh = terawatt hour.
Note: *The study is conducted on ASEAN-6 countries (on all renewable energy technologies) for use in the power, heating, and transport sectors. Thus, total realisable potential in the power sector alone is likely to be less than estimates. However, given the warm climate in ASEAN, the demand for heating is limited to small proportions of industry and domestic uses.
Source: Ölz and Beerepoot (2010).

The maximisation of RE power generation could serve the multiple policy objectives of energy security, economic growth, and climate change in developing Asian states.[46] Given the attractiveness of RE, policymakers in developing Asian states are increasingly adopting policies and measures promoting RE investment and deployment (Ölz and Beerepoot, 2010). Despite such favourable policies, RE deployment has yet to realise its full potential. According to a recent study conducted by the ASEAN Centre for Energy, ASEAN countries generated 169TWh of RE in the power sector from 45.7

[45] The ASEAN-6 countries are Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam.
[46] Please consult seminal papers for a more detailed discussion of the benefits of renewable energy in developing Asian states: for example, Deploying Renewables in Southeast Asia – OECD/IEA 2010.

gigawatts (GW) of installed capacity in 2013. Under a business as usual scenario, ASEAN countries are expected to generate 399TWh of RE electricity with 149GW of installed capacity in 2035. Under an alternative policy scenario, whereby it is assumed that the official targets for RE are successfully implemented, RE installed capacity is estimated to increase to 155GW, of which 548TWh of electricity is expected to be produced in 2035. Even under favourable scenarios, the deployment of RE remains below the realisable potential for the region stipulated by the International Energy Agency report.

A recent Asian Development Bank report cites the financing gap to be a potential contributor to the current deployment shortfall (ADB, 2015). Existing literature seems to frame the financing gap using two different but interrelated aspects of RE project economics — access to finance and the cost of capital (IPCC, 2014). Access to finance refers to the pool of finances available whereas the cost of capital refers to the cost at which financing is raised.

The cost of capital, often a function of the risk and capital structure of the project, directly affects the profitability of a project, which is a key investment criterion for financiers (Eyraud et al., 2011; Sonntag-O'Brien and Usher, 2006). Wiser and Pickle (1998) proved that the reduced cost of capital could improve the RE project returns, thereby improving project attractiveness to investors. Using a discounted cash flow model, Wiser and Pickle (1998) were able to show that financing inputs, such as return on equity, debt interest rates, and debt tenure, have significant impacts on the levelised cost of energy (LCOE) for RE projects. In addition, their study showed that simply increasing the debt tenure from 12 to 20 years will reduce the LCOE for wind and solar photovoltaic power by 12% and 17% respectively (Wiser and Pickle, 1998). Their results were supported by research from the Climate Policy Initiative (Nelson et al., 2012), which stated that unfavourable financing terms, in particular the high cost of debt in India, are expected to increase RE project costs by 24% to 32% in India compared to the United States (US) and Europe. Eyraud et al. (2011) provided further support for this stand and viewed the reduction of the cost of capital of RE projects to be a significant driver for shifting investment into low-carbon projects.

Inferred from the literature, the successful deployment of RE projects would entail raising required amounts of financing at an appropriate cost of capital. For the purpose of this paper, the inability of RE projects to raise the required investment at an appropriate cost is referred to as the financing gap. A variety of studies have viewed the financing gap faced by RE projects to be due to the nature of RE projects and the inability of existing capital market mechanisms to align to such projects. Such capital market imperfections may arise due to imperfect information, risk aversion, or agency problems (Wiser and Pickle, 1998). It has to be understood that RE projects are typically compared against conventional fossil fuel energy based projects (IPCC, 2014), which have longer track records. Compared to the mature fossil fuel energy industry, the relatively nascent RE industry faces issues regarding lack of financier familiarity, which is due to imperfect information in the industry. The lack of familiarity with RE project appraisal translates to higher perceived risks of such projects, thereby increasing the cost of capital, which may affect the project economics (Sovacool, 2009).

In addition, RE projects require a higher proportion of upfront capital costs as compared to future operations and maintenance (O&M) costs. Due to the time value of money, the front-loading of capital costs in RE projects is expected to exert a stronger negative influence on the net present value of the project as compared to large future O&M cash outflows. Therefore, RE projects suffer competitively purely due to cash-flow differences. Brunnschweiler's (2010) research piece lends support to this as his studies show that given similar financing terms, an RE project with a higher proportion of capital cost is appraised as more costly and therefore less commercially attractive to investors as compared to conventional fossil fuel based energy projects in a discounted cash flow model.

Furthermore, RE projects face more financing challenges in developing Asia given that most RE project developers are small and medium-sized enterprises (SMEs). Due to their smaller market capitalisation and possibly poorer track records, they are perceived as less creditworthy than the large conventional power generation companies (Wiser and Pickle, 1998). This limits their capabilities to both raise capital and obtain lower cost financing, which translates difficulty in reaching financial closure. Typically, larger organisations can leverage on the use of corporate finance, which are debt raised based on the balance sheet of the organisation, with the cost of financing attached to the credit worthiness of the organisation. However, smaller organisations, such as RE project developers, typically do not have the market capitalisation and the track record to rely on such financing instruments (Wiser and Pickle, 1998). These smaller organisations would have to rely on project financing, which is debt raised on the credit worthiness of a specific project, backed by project economics alone (Wiser and Pickle, 1998). Given higher associated risks, such debt usually comes at a higher cost. Carlos and Khang's assessment of biomass energy projects in Southeast Asia (Carlos and Khang, 2008) validate such statements. Carlos and Khang (2008) examined the financing structure of typical biomass projects in the region and highlighted three main sources of finance: balance-sheet finance, corporate finance, and project finance. Their study found that while corporate finance is the most commonly used financing channel, projects utilising the higher cost project finance often face difficulties in attaining financial closure. The smaller size of RE industry players also translates to higher transaction costs (Curnow et al., 2010), which may limit both their willingness and ability to raise additional capital from external financing sources.

The relative immaturity of the level of financial development, particularly in developing countries, is said to have a widening effect on the financing gap faced by RE projects (Painuly and Wohlgemuth, 2006). The lack of financial diversification widens the financing gap as there is a lack of financial intermediation to match investments and investors with the appropriate financial instruments, which results in both inadequate access to capital and increased cost of capital (ADB, 2015; Painuly and Wohlgemuth, 2006).

Due to the bank-dominated financial system in developing Asia, local banks are the main sources of project financing in the region (ADB, 2015). As described earlier, RE projects typically require higher upfront costs and longer payback periods. This means that RE project developers typically prefer longer-term tenures of around 15–25 years (IPCC, 2014). However, local banks face various limitations when attempting to extend such long-term loans to local RE developers. For one, local banks face challenges when trying to match the maturities of their long-term assets and their short-term liabilities (Hamilton, 2010). This balance sheet constraint is further aggravated as banks, with the new Basel III regulations requiring banks to hold more liquid assets, may be reluctant to step up long-term lending for RE projects (ADB, 2015). Even prior to Basel III, local banks already faced difficulty in financing RE projects. Regional RE projects tend to carry higher risk characteristics while local banks have lending restrictions on risky assets. The resultant effect would be the outflow of domestic funds into low-risk low-return foreign investments, while financially viable domestic projects suffer a lack of financing and thus have to gain financing at a higher risk premium from international lenders (ADB, 2015). This has led some academics to state the view that RE project structures are not well-suited for the use of bank loans, and thus, RE projects in developing countries are particularly disadvantaged on financing terms (IPCC, 2014).

Most Asian states have bank assets that account for around 80% of their whole financial system (BIS, 2014), leaving little space for the use of capital market instruments. The bank-dominated financial system has restricted the growth and development of Asian financial markets. Therefore, there is limited space for utilising capital market instruments for RE financing. Although it may be argued that this may be a symptom of the relatively small industry players in the region, the lack of market activity surrounding fixed-income markets could also be a contributing factor to the general lack of interest in tapping the capital markets.

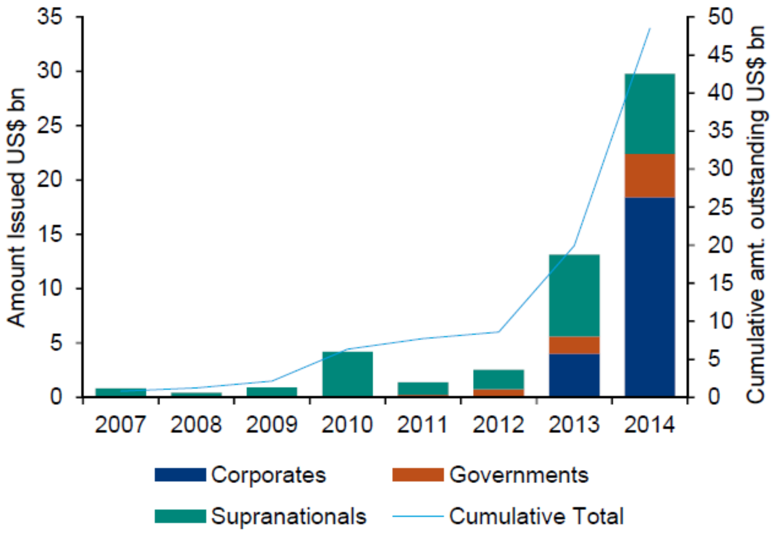
Generally, existing literature aligns with the notion that the characteristics of RE project economics – longer payback periods, high upfront capital costs, smaller-scale projects, and higher real or perceived risks – create an investment profile that does not match the typical size of fund allocations available and the risk-return profile that investors typically require (IPCC, 2014). The financial gap created by such misalignment of RE project dynamics and capital market imperfection is further aggravated given that financiers compare RE projects with conventional power projects. Typically, under the current financing landscape, financiers would reasonably favour conventional energy projects, which have a longer track record, lower upfront costs to maintenance cost ratio, shorter payback periods, and favourable policy incentives, over RE projects (Sonntag-O'Brien and Usher, 2004). Such statements are supported by IPCC (2014), which states that one of the challenges to large-scale RE deployment was the low risk-adjusted rate of return on investment as compared to fossil fuel energy projects. Financing challenges are further aggravated by the bank-dominated financial system, which is poorly suited to finance RE projects in the region. Opening up alternative financing channels would serve to benefit RE financing in the region.

Recently, green bonds have emerged as a potential financing channel for RE financing internationally. Green bonds are debt instruments, of which proceeds are pledged to environmentally friendly projects or uses. In principle, green bonds are considered climate themed-bonds, where proceeds were used for specific environmental causes. By design, there is to be no pricing differential between a green bond and another bond issued by the same organisation since the investors face no additional risk. As such, the critical difference between a green bond and a conventional bond would be that the proceeds raised using a green bond would have to go towards environmentally sustainable investments or projects.

The appeal of green bonds seems to stem from the tremendous investor support, particularly from institutional investors. Most of the green bond issuances were oversubscribed – mostly by pension funds, insurance companies, and asset management companies – signalling strong institutional investor appetite. Tapping into institutional investors is of particular interest given that their investment characteristics seem to align with RE investments. Institutional investors typically hold large volumes of assets, have long-term investment horizon, and, more often than not, align with certain sustainable investment mandates (ADB, 2015; Curnow et al., 2010). These characteristics make institutional investors ideal financiers of renewable infrastructure projects such as utility-scale RE projects.

The Skandinaviska Enskilda Banken AB (SEB) and the World Bank pioneered the idea of a green fixed-income product and, in 2007–2008, they jointly launched the world's first green bond. The first green bond was a product specially tailored to satisfy demand from Scandinavian pension funds looking to invest in environmentally friendly fixed-income products. Since its inception in 2007–2008, the green bond market has grown from being a niche product to a relatively mainstream financial instrument. In 2014 alone, the green bond market raised an estimated $36.6 billion (CBI, 2014a) for low-carbon investments spanning across seven themes – transport, energy, finance, building and industry, agriculture and forestry, waste and pollution control, and water.

Figure 12.2: Size of Green Bond Market According to Issuer Type



Note: Figures as of 26 November 2014.
Source: Bank of America Merrill Lynch.

Developing Asian countries entered the green bond market only in 2013. It could therefore be said that Asia is still at a very early stage of development and that the current market conditions are still relatively immature. As of the writing of this report,[47] there are less than 10 green bond issuances in the region Thus, there is limited scope to draw any concrete conclusions, but a general interest in the instrument could be observed. Table 12.1 lists the existing green bond issuances.

The first Asian bond issuer to tap the green bond market was the Export–Import Bank of Korea, which issued a $500 million bond in February 2013. Following the initial issuance, other supranational, sub-sovereigns, and agencies (SSAs) such as the Export–Import Bank of India, the Development Bank of Japan and ADB began to enter the market with mostly benchmark issuances using international currencies. These green bonds are considered financial green bonds since proceeds are on-lent to eligible green projects, inclusive but not limited to RE projects.

[47] This report was written in June 2015.

Table 12.1: Green Bond Issuances (as of April 2015)

Issuing Organisation	Date of Issuance	Issuance Amount	Issuer Category	Category*
Export–Import Bank of Korea	February 2013	$500 million	SSA	Financial Bond
Toyota	March 2014	Tranches of $	Corporate	Corporate Bond
China's CGN Wind Energy	June 2014	CNY1billion	Corporate	Corporate Bond
Taiwan's Advanced Semiconductor Engineering	July 2014	$300 million	Corporate	Corporate Bond
Development Bank of Japan	October 2014	€250 million	SSA	Financial Bond
YesBank, India	February 2015	₹10 billion	Corporate	Financial Bond
Asian Development Bank	March 2015	$500 million	SSA	Financial Bond
Bangchak Petroleum	March 2015	B3 billion	Corporate	Corporate Bond
Export–Import Bank of India	March 2015	S$500 million	Corporate	Financial Bond

SSA: Supranational, sub-sovereigns, and agencies.

Note: *A financial bond is a bond issued by financial intermediaries, both public and private, whereby the proceeds are on-lent. Corporate bonds are bonds issued by private organisations whereby proceeds are used with the organisation.

Source: Prepared by the author.

The corporate green bond issuance pool is diverse. The first pure RE-based corporate issuance came from the People's Republic of China's (PRC) CGN Wind, which entered the market in 2014. Non-RE based corporate entities have also issued green bonds to support its renewable energy projects. An example would be the Thai oil company Bangchak Petroleum, which issued a B3 billion bond in March 2015. India's Yesbank became the first corporate financial green bond issuer with its ₹10 billion bond issued to support RE deployment in the country. The heterogeneous pool of corporate issuers who are tapping the green bonds market to finance their RE projects seems to highlight the different ways green bonds can help mobilise private finance into RE projects.

This study assesses the viability of green bonds to finance utility-scale RE projects in Asia. The restriction to utility-scale projects is given since these projects are typically closer to commercial viability, have more established business models, and typically have capital requirements that meet the bond issuance requirements.

A SWOT matrix, an assessment framework that is commonly used to evaluate the strengths, weaknesses, opportunities, and threats involved in a project, is used in this study. SWOT analysis generally involves specifying an objective and identifying the internal and external factors that may contribute to the achievement of such an objective. The objective of this study is the reduction of the financing gap for RE projects in the region. The chapter discusses the advantages and disadvantages of utilising green bonds using a multi-stakeholder framework, where the authors consider the interest of the relevant stakeholders – for example, RE project developers, financers, and policymakers.

3. Results and discussion

Table 12.2 provides a brief overview of the SWOT analysis. The ensuing section will discuss each component in detail.

Table 12.2: SWOT Analysis on Green Bonds

Strengths 1.Ability to highlight green attributes 2.Flexibility of the instrument 3.New low-cost financing channel 4.Aligned term structure 5.Increased efficiency in financial infrastructure	**Weakness** 1.Lack of robust definition of green 2.Uncertainties of a self-regulated market 3.Nascent financial instrument 4.High transaction cost 5.Lack of secondary market
Opportunities **1.**Strong investor interest (real/perceived) **2.**Strong momentum for growth **3.**Presence of favourable governmental policies	**Threats** 1.Unidentified investor base 2.Lack of green bond-related expertise/infrastructure 3.Lack of favourable climate 4.Uncertainty in future the outlook

4.1. Strengths

4.1.1. Ability to highlight green attributes

When referring to green bonds, it is important to differentiate between labelled and non-labelled green bonds. Labelled green bonds[48] refer to bonds being marketed as green bonds, while the non-labelled green bonds universe refers to bonds that are used for environmentally friendly projects but are not marketed as green bonds. Labelling provides an effective way to define and distinguish green bonds as a specific sub-universe of environmental or green bonds. Thus, a particular strength of the labelled green bond instrument to the issuer is the ability to highlight environmentally friendly attributes. Firstly, the ability to highlight an issuer's green attributes could potentially help it attract

[48] Henceforth, all references to green bonds refer to the labelled green bond segment, unless specified otherwise.

investors with an environmental social governance (ESG) mandate. Issuers were previously unable to tap this market effectively due to information asymmetry and the low visibility of their bond issuance. Issuing a green bond would also increase the visibility of the bond to conventional investors, as the pool of green bond issuances is much smaller than the pool of conventional bond issuances and the investor group for both asset classes are overlapping. The ability to highlight the green attributes of green bonds could also improve its overall publicity and improve an organisation's image, thereby broadening their access to capital.

However, to protect the integrity of green bonds, the issuer, more often than not, would have to conduct extra due diligence, particularly in the form of environmental assessment, to support its green claims. Given the flat pricing policy of green bonds, the additional costs related to a green bond issuance, notably in the form of environmental assurance, verification, and communication, would have to be absorbed by the bond issuer. To compensate for the higher costs involved, the appeal of green bonds to potential issuers lies in the fact that such ventures attract new investors.

The labelling process also acts as a form of discovery tool for investors to spot green attributes, which reduces the transaction costs, particularly for ESG-mandated investors. In addition, the ability to highlight green attributes also contributes to raising public awareness on environmental and climate change issues and the green asset class. Within the Asian investments sphere, there is a lack of awareness and emphasis on ESG concerns. This is evident from the lack of emphasis on transparency and disclosure requirements on environmental issues. Furthermore, climate change concerns are not widely discussed in Asia and have far less impact on the financial sector. By highlighting green attributes, green bonds can play an effective role in inciting investor interest in green and sustainable investments, especially if they are able to offer comparable rates of returns. Such publicity programmes could also help reduce perceived risks for financiers and correct the misconception that there is a trade-off between profits and environmental sustainability.

4.1.2. Flexibility of the instrument

One of the key strengths of the green bonds is the flexibility of the instrument. This flexibility is reflected in terms of the issuer requirements, the possible types of issuance, and the terms of issuances.

Firstly, it is important to note that any organisation is eligible to issue a green bond. The green credentials of a bond issuance are not attributed to the issuing organisation but to the underlying projects or assets linked to its issuance. While accrediting the green credentials to an underlying asset instead of an issuer opens up controversy, particularly in terms of safeguarding green claims, it serves to facilitate the active participation from a diversified spectrum of organisations. A strong argument for the case would be that all organisations would need to transit to a low-carbon society and as such, would require financing. Limiting the issuance of green bonds to 'green' organisations would therefore lock in business-as-usual operations for a variety of 'brown' organisations as they would lack the financing tools to shift to a low-carbon model. By opening up the financing channel to all organisations, it can be argued that both green and brown organisations would be better positioned and therefore have a higher likelihood to engage in environmentally friendly investments. Such an argument could be supported by green bond market dynamics, as currently a diverse group of organisations is seen tapping into the market to gain low-carbon financing.

Secondly, the flexibility of the instrument could be observed from the different types of issuance. Green bonds could be broadly classified based on the assets to which they are tied. Table 12.3 summarises the types of green bonds available.

Table 12.3: Types of Green Bonds

Types of Green Bonds	Definition
Green Use of Proceeds Bond	A standard recourse to the issuer* debt obligation in which the proceeds shall be ring fenced** to green projects.
Green Use of Proceeds Revenue Bond	A non-recourse to the issuer debt obligation in which the credit exposure in the bond is pledged cash flows of the revenue streams, fees, taxes, etc., and the Use of Proceeds of the bond goes to related or unrelated green projects.
Green Project Bond	A project bond for a single or multiple green projects in which the investor has direct exposure to the risk of the projects with or without potential recourse to the issuer.
Green Securitised Bond	A bond collateralised by one or more specific projects, including but not limited to covered bonds, asset-backed securities, and other structures. The first source of repayment is generally the cash flows of the assets.

Notes: *A debt in which the creditor has standard claims on the loan in the event of default. Terms of the claims allowed are often listed in the debt contract.
** The idea of ring fencing of proceeds refers to the fact that proceeds shall be moved to a sub-portfolio or otherwise tracked by the issuer and attested to by a formal internal process that will be linked to the issuer's lending and investment for the project.
Source: Adapted from International Capital Market Association (2015).

The diversity in the type of bond issuance ensures that a variety of financing channels could be tapped at appropriate costs. In the most direct way, renewable energy companies may wish to issue a corporate green bond to finance their projects. Other power generation organisations that wish to expand into the renewable energy sector may also issue a green bond that is tied to the renewable energy-related section of their operations.

Project bond finance presents a unique opportunity for small- and medium-sized utilities and renewable energy companies to gain financing. Project bonds allow debt to be paid off using project cash flow instead of writing it off balance sheets. As project bonds are typically asset-backed securitisation, with recourse tied to the assets of the project and to not the issuing project, they are evaluated on an individual basis and often fall beyond the investment grade of BBB.

Alternatively, renewable energy projects could gain financing indirectly through green financial bonds. Financial institutions, such as private banks, may issue green bonds that will be ring fenced to financing renewable energy. The ring fencing of an available pool of credit ensures the availability and stability of the flow of funds into green energy. Upon the discretion of the financial institutions, preferential interest rates may also be offered. Government agencies may also issue green bonds to support large-scale RE projects. Innovative green bond structures, such as the green sukuk (Sharia-compliant bonds), have also steadily emerged to target different investor groups.

Lastly, financial ingenuity allows for innovative term structures of the bond instrument. For example, the convertible bond allows for the potential exchange of debt to equity under pre-determined conditions. In addition, recent financial innovations have also allowed for the floating interest rate to be pegged to environmental-related indices. The flexibility of the green bond instrument could be clearly demonstrated by the PRC's CGN Wind which issued a CNY1 billion green bond with the floating component of its 'fixed and floating' coupon rates tied to China's certified emission reduction prices.

Such flexible mechanisms are beneficial for both the RE project developers and investors. The heterogeneity within and among the different types of green bond issuers also allows for a spectrum of risk and return profiles, along with diverse capital and funding needs, which extends the credit and maturity curves. This ensures a broad spectrum of market players is attracted into the market, which also serves to broaden the market.

4.1.3. New low-cost financing channel

As described earlier in the literature review, capital markets currently have a limited role to play in financing RE in the region. By promoting green bonds as a viable financing channel, another source of finance is raised for RE projects, increasing the pool of credit available. Moreover, green bonds can potentially offer lower cost capital terms. Green bonds, as debt instruments, are considered cheaper alternatives to equity investments. In addition, bonds are typically considered senior debt, and are therefore less costly compared to bank loans. RE project developers can thus capitalise on better financing terms provided by green bonds to improve the economic viability of their projects.

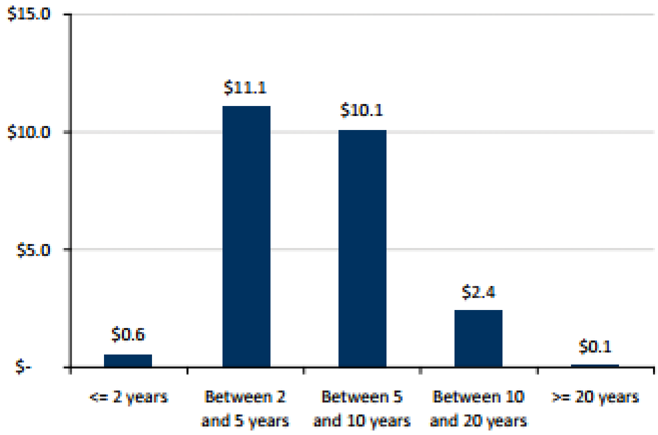
Furthermore, a large proportion of the issued green bonds are financial bonds. Financial green bonds issued would have to go into environmentally friendly projects, which eliminates or reduces financing competition from conventional fossil fuel power projects and could potentially ensure a steady flow of credit to support RE deployment.

An additional benefit of green bonds as a new low-cost financing channel is its ability to attract institutional capital. Large institutional investors, such as pension funds, insurance, and sovereign wealth funds, have approximately $80 trillion assets under management, of which more than half are held in fixed-income portfolios (OECD, 2014). These large institutional investors have a long-term risk outlook and are increasingly trying to limit their carbon exposure and climate risk exposure. An important element here is the large funds that have long-term liabilities, such as sovereign wealth funds and/or pension funds, which they would seek to balance with long-term assets. This allows institutional investors to become a more significant source of long-term investment in renewables. Green infrastructure investments, such as RE projects, offer investment opportunities for institutional investors that fit their long-term liabilities and investment mandates. The maximisation of green bond instruments to finance RE projects could drive regional and international institutional capitals that would not only offer larger pools of available credit to RE projects but also deepen the current financial system. Furthermore, the deepening of financial systems provides the additional benefit of closing the financing gap as financial intermediation services are improved.

4.1.4. Aligned term structure

Green bonds offer a more compatible term structure for RE projects compared to bank loans. Firstly, bonds are suited for long-term financing. Typical bond tenures range between 7–15 years, aligning with the typical payback periods for RE projects. According to a Royal Bank of Canada Capital Markets report, about 87% of all green bond issuances have tenures of between 2–10 years, which align with the simple payback of RE projects in Asia (Nanji et al., 2014).

Figure 12.2: Green Bond Issuance by Tenure Duration



Source: Nanji et al. (2014).

Secondly, the green bond debt structure is aligned to the project cash flow of RE projects. This allows easier compliance with debt terms on the part of the project developer. Typically, bond financing allows for delayed principal repayments. Unlike bank loans whereby payments are made throughout the due term for both principal and interest, the principal for bonds are paid at maturity of the bond. This fits the cost structure for RE projects and allows RE projects to generate returns and cover the capital costs across a range of payback periods. To illustrate, the typical simple payback period for a solar project in Singapore is 7–8 years, which translates into 7 to 8 years of cumulative negative cash flows. The use of bond instruments would allow the project to generate excess returns before the principal repayments begin. Should the project be financed by bank loans, the project would face additional fiscal constraints for debt repayment prior to the recovery of capital.

Since bonds offer the opportunity to disperse ownership of the debt across a group of investors, financiers find it easier to invest indirectly in RE through bonds as opposed to investing directly through loans or equity ownership. Furthermore, the presence of a secondary market promotes liquidity, thereby offering financiers a short-term exit strategy. These attributes of bond issuance increase the attractiveness of RE projects to investors as issues of long payback and high upfront costs are mitigated.

However, it has to be noted that there is suppressed secondary trading of green bonds in the market. As such, this theoretical strength of the green bond instrument is not reaped under current market circumstances.

4.1.5. Increased efficiency in financial infrastructure

At its core, the green bond concept is a market innovation allowing efficient capital intermediation between investors and green or climate-related projects. Raising capital through capital markets prevents moral hazards that might occur due to strong policy directives on renewable policy and favourable fiscal incentives, which may induce banks to take on riskier RE projects in their portfolio with an overreliance on public policy support. Financing RE projects through the capital market could promote transparency in the market, thereby minimising information asymmetry in the industry. The disclosure requirements of capital markets require both project developers and financiers to provide a greater diversity of perspectives from various stakeholders, such as investors and intermediaries that could provide independent evaluation and second opinions on the projects. Furthermore, the additional transparency and disclosure requirements of green bonds would help to strengthen price discovery, information identification and risk pricing for the projects. As the market deepens, related expertise could be built internally, thereby expanding and improving the financial services sector, enforcing the strength of related infrastructure, thus contributing to the building of the national capital markets.

Taking a policymaker's perspective, the utilisation of innovative financing mechanisms such as green bonds not only facilitates the flow of private sector finance into RE deployment, but could also promote diversification of the financial infrastructure. The overreliance on bank financing, which is the current situation, creates multiple self-feeding issues that may increase the vulnerability of the existing financial system. Firstly, the domination of one financing channel may crowd out the development of other financial markets, thereby limiting the total credit available. Secondly, the homogeneity of the financial system, with rigid risk and return structures, restricts both the borrower's and lender's pool. Thirdly, it introduces systemic risks into the financial system, thereby increasing risks of financial instability. This would, in turn, contribute to the problem of deterring active domestic private sector participation in the financial market, thereby impeding financial market development. This then, creates a self-fulfilling prophecy of a limited market. Fourthly, the heightened financial risks involved in the inherent homogenous financial system deter participation from international financial intermediaries with more sophisticated markets. Without foreign participation and the increased sophistication brought along by this participation, the developing Asian financial markets are likely to remain illiquid and small. The homogenous financial structure seems to promote a series of self-feeding reactions that could only serve to limit market growth and widen the financing gap of RE projects.

The development of green bonds could contribute to the growth of the local bond market. With the current nascent bond market in Asia, the introduction of new mechanisms may serve to deepen the market and increase interest and liquidity of the market. The growth of the capital market would also contribute to minimising the systematic financial risks. The effects of reduced systematic financial risks and more diversified financial channels would also serve to ensure the stability of financial flows into RE projects.

Lastly, green bonds could potentially help divert domestic capital back into the region. With high savings rates across the region, the region is not short of domestic capital. However, the current trend being seen is the outflow of large sums of domestic capital into the low-return less-risk overseas assets. Thus, it is important for policymakers to shift capital flows back into local investment projects. The creation of green fixed-income products, which creates investment instruments with a low-risk, steady returns paradigm, may serve to attract new domestic institutional investors, thereby facilitating the inflow of capital back into the region while expanding the available credit pool for RE projects.

4.2. Weaknesses

4.2.1. Lack of robust definition of green

A key point to note for green bond issuers is that green credentials of a green bond are based on the projects or assets linked to its issuance, not the green credentials of the organisation issuing the bond. This means that any organisation can issue a green bond, as long as they are able to prove that the bond proceeds are used for environmentally friendly purposes. This characteristic induces two main concerns regarding finances raised by green bonds: the transparency on the use of funds (referred to hereafter as financial integrity) and the environmental integrity of the bond. The financial integrity of the bond is usually ensured by earmarking the proceeds to finance environmentally friendly projects or by tying proceeds to a green underlying asset. While financial integrity does not present many areas of controversy, protecting the environmental integrity of the green bond issuance is highly ambiguous.

Although green bond issuances are mostly classified under the seven broad themes, which lay down broad categories for projects, the complex and integrated nature of environmental issues suggests that absolute definitions of what could constitute a 'green investment' may remain hypothetical and illusive. Thorny issues surrounding the discussion include what should be considered green and who should define greenness. Although there is likely to be no definite answer on what is to be considered green due to the inherent nature of environmental debates, stakeholders, in particular RE project developers and investors, are concerned given that controversies regarding the 'greenness' of the bond will likely manifest as market risks and reputational risks when they are seen to be engaging in such instruments. Other market participants viewed the lack of a robust definition of green as a potential trigger for loss of investor confidence in the green instrument.

The ambiguity surrounding environmental assessments has resulted in various controversies such as the use of green bond funding to finance a car park that resulted in environmental degradation and extensive costs. This has constantly been an area of concern for various stakeholders, with different parties attempting to provide solutions to overcome this difficulty.

4.2.2. Uncertainties of a self-regulated market

The current market situation in the international green bond market allows for any debt issuer to label its bonds green, as long as it is able to convince its investors of the environmentally friendly attributes of its underlying projects. While SSA issuances seem to generate investor confidence due to their existing project assessment criteria and transparency of reporting, corporate issuances are unable to command similar levels of investor confidence. In response to investor concerns, the green bond market entered a phase of market self-regulation.

The Green Bond Principles (GBPs) were introduced in 2014 by a consortium of financial intermediaries, with the intent of creating a governance framework to regulate and assess the environmental integrity of the green assets, thereby facilitating market development. The GBPs are voluntary process guidelines that recommend transparency and disclosure, and promote integrity in the development of the green bond market by clarifying the approach for issuance of a green bond. The GBPs are intended for broad use by the market and are meant to instil confidence into the marketplace. The voluntary standards, as set by the GBPs, are criticised as being too loose and not offering concrete standards setting purpose (see critic reports such as the ones from the Friends of the Earth and International Rivers Fact Sheet).

While commending the efforts of the GBPs in forming a broad framework that facilitates investor recognition of green bonds, the Climate Bonds Initiative (CBI) viewed the GBPs as lacking in environmental integrity assessment. As such, the CBI introduced the Climate Bond Standards and Certification Scheme as an evaluation tool for investors to assess the environmental integrity of bonds. The CBI engaged a team of technical analysts to provide expert recommendations on what could be considered environmentally friendly projects. Both market standards are constantly being examined and improved to ensure alignment with current market conditions.

To ensure the environmental integrity of the bond issuance, the engagement of third party verifiers who conduct environmental assessments of the projects was stated as best practice since the first green bond issuance by the World Bank. Third party verification was also recommended as best practice since the first version of the GBPs. Until 2014, the Center for International Climate and Environmental Research dominated all third party verifications for green bonds. As the market ecosystem expanded, environmental expertise deepened in the market. 2014 saw the emergence of various other third party verifiers such as Vigeo, Det Norske Veritas, KPMG, OEKOM, and CH2M Hill. The increase in expertise allowed more green bond issuances to be verified by external parties, thereby ensuring quality assurance. The introduction of competitors in the industry could also lower the costs involved in getting verified by a third party auditor.

Currently, independent advisory bodies are setting voluntary standards on transparency and disclosure requirements while third-party verification plays an auditing role. Thus, while there are no established mandatory criteria as to what constitutes green or which shades of green meet the threshold, and the level of disclosure remains a corporate decision, the market attempts to catalyse issuances and investor interest by issuing a voluntary set of guidelines developed by industry participants. Unfortunately, the green bond market remains a self-regulatory market, with no penalties for non-compliance. Self-regulation in the market underscores the potential misuse of lenient best practice guidelines, which may dissipate investor confidence in the instrument, thus killing the asset class. Self-regulation also implies that all disclosures on the environmental integrity of underlying projects are voluntary, and at the organisation's discretion. This has caused concerns from various investors that the lack of measurement, reporting, and verification on the environmental impact of those green projects could lead to questions on the strength of the green bond label. Disparate reporting standards also cause various challenges when attempting to quantify absolute environmental benefits of underlying projects and benchmark best performance. Although some may argue that green bond issuers run reputational risks if proper disclosure requirements are not followed, which may, to an extent, ensure the credibility of the green label, much more could be done to safeguard the green bond label.

4.2.3. Nascent financial instrument

Being a relatively new instrument, the legal basis remains immature. To ensure the potential scalability of the green bond market, market participants have been trying to reflect on the potential legal issues associated with green bonds. Various business summits organised by market participants have highlighted the potential legal complications of green bonds. Some areas of controversies cited by legal experts include the fact that green bonds do not have a legal basis and that the procedures for a 'green default' have yet to be established. While such concerns are noted, established guidelines have yet to emerge from the market and the potential legal risks associated with this product remains.

4.2.4. High transaction costs

A potential limiting factor in utilising green bonds to finance RE projects would be the high transaction costs involved. Compared to bank term loans, tapping the capital markets already entail higher transactions costs. Anecdotal evidence points to the fact that even SSA issuers such as the ADB view the costs of undergoing the additional disclosure requirements for the issuance of a green bond to be potentially restrictive.[49] For RE project developers in the region who are typically SMEs, the green bond issuance process may be a prohibitive option for them to pursue.

4.2.5. Lack of secondary market

The lack of a secondary market for green bonds may limit the extent to which the benefits of a green bond could be captured. Given that the liquidity benefits of a green bond, as compared to a bank loan, translate to longer debt tenures for RE project developers and shorter payback periods for financiers, the presence of a secondary market is critical for the successful use of green bonds to bridge the RE financing gap. However, a mature secondary market has yet to develop. A possible reason for this could be that the current investor pool for green bonds is made up of mostly buy-and-hold investors. The nature of green bonds, especially the alignment of financial structures and low credit risk of SSA issuers, attracts buy-and-hold investors. A limited secondary market may also reduce the uptake of green bonds given that a natural switching process is much easier for investors.

4.3. Opportunities

4.3.1. Strong investor interest (real/perceived)

The investor base of green bonds includes 'green' investors and other broad-based investors who consider these new bonds as part of their expanding investment choice set.

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[49] Maria Lomotan, ADB's head of funding, was quoted in an International Financing Review article saying: 'The process (of issuing a green bond) is a lot more demanding … and the cost is flat.' She also said 'All our projects have environmental components, so we had to evaluate that versus what would be required to do this to see whether it would be feasible for the institution.'

A clear distinction should be drawn between these two groups: the former is actively in search of value in the sustainability or the greenness of the project; whereas the later group is more motivated by the search for yield. There seems to be strong investor demand, both real and perceived, for green bonds in the market. The real investor demand is demonstrated by the consistent oversubscription for green bonds being issued in the market, while the perceived investor demand originates from a series of favourable market conditions present. Firstly, investors, in particular institutional investors, are increasingly interested to invest in RE projects, as in the results of a 2013 survey conducted by Ernst and Young. Nearly one-third of institutional investors surveyed expected to increase RE investments in the next three years, and 15% expected investments to increase by over 10% (Ernst and Young, 2013). Secondly, the growth of the socially responsible investment (SRI) movements, as represented by the increasing participation of financial institutions in the United Nations Principles for Responsible Investment, seems to signal strong potential investor interest in the asset class which is dominated by SRI investors (60/40 split).

Thirdly, financial institutions in Asia are also warming up to SRI initiatives in developing Asia. A recent report by the Association for Sustainable & Responsible Investment in Asia (ASrIA) highlighted that sustainable investment assets in Asia (except Japan) have been increasing year-on-year at a rate of 22% since 2011 (ASrIA, 2014). Furthermore, with Asia offering high returns on investments (UNCTAD, 2014), conventional investors will also be incentivised to tap on the high-growth markets here. Conventional international interest in developing Asia markets could also be inferred from the growing foreign direct investment inflows despite sluggish world economy in 2014 (UNCTAD, 2014).

4.3.2.Strong momentum for growth

Another favourable external factor is the strong growth momentum currently present in both the regional and international markets. In the regional markets, investors seem to be keen on both clean energy financing and green bonds as instruments. Such sentiments were reported by ASrIA based on its surveys of 97 institutional investors in the region (ASrIA, 2014). Green bonds could then capitalise on such favourable investor sentiments to help kick-start the market for green bond RE financing.

Internationally, the growth momentum seems strong as well, with issuances tripling from 2013 to 2014. The CBI estimates global green bond issuance to reach $1 trillion in 2020. Such estimates were supported by investor pledges to support the green bond instrument, as represented by the public pledges made by 13 financial institutions at the UN Climate Summit in September 2014 and the signing of the Investor Statement on Green Bonds and Climate Bonds by a group of 12 institutional investors with a combined $2 trillion assets under management (CBI, 2014; BNEF, 2014). RE industry players can capitalise on the international movement given that a proportion of financiers of green bonds remain European and North American financial institutions.

4.3.3. Presence of favourable governmental policies

With green bonds gaining market interest, policymakers are also becoming increasingly keen in exploring the potential of such innovative green instruments. Explicit policy support could be seen in the case of the PRC, whereby the government agencies have worked with various think tanks and non-profit agencies to draft a public white paper exploring the possibilities and key reforms to facilitate the growth of a green bond market in the PRC (Zadek and Chenghui, 2012). Similarly, Indonesia has highlighted the building of a green bond market as a possible direction in one of its recent policy guidelines (OJK, 2013). India has also expressed implicit support for the instrument recently when the Export and Import Bank of India issued a green bond to support low-carbon projects in the country (EXIM Bank of India, 2015). With such supportive policies in place, green bond issuers could definitely ride on such positive policy incentives to raise capital for RE projects.

4.4. Threats

4.4.1. Unidentified investor base

Unfortunately, although there seems to be potential investor demand in the region for the green instrument, such demand has not been clearly identified. Assessments of investor demand for green bonds remain largely anecdotal. Investor demand has traditionally been viewed as a matter of oversubscription for a certain bond. However, one might argue that oversubscription could be a function of other factors apart from the fact that it was a green bond. Similar concerns were raised as media representations of the investor interest for green bonds remain diverse in opinion. Media representations of investor demand range from ‘deep scepticism over green investments in Asia’ to ‘seeing interest from some funds’ (see for example, Garton, 2015). However, a general reluctance of investors to engage in green instruments seems to dominate media representations in the region, thereby questioning the hypothesis that there is strong investor demand for the product.

The SRI investors also represent a potential swing investor group. According to ASrIA’s 2014 Asia Sustainable Investment Review, a large proportion of the sustainable investment assets are identified as Islamic or Sharia-compliant assets (ASrIA, 2014). These assets, considered as SRI assets, do not have a strong environmental edge to them and thus may not be a strong potential source of financiers for RE-based green bonds. As such, although the market seems optimistic about future growth prospects, specific quantifications of investor demands remain uncertain.

Lastly, while there are dedicated green bond funds such as the Calvert Green Bond Fund (CGAFX) and the Nikko AM Shenton World Bank Green Bond Fund in the international green bond market, Asia lacks such dedicated funds, further signalling weakness in estimated demand.

4.4.2. Lack of green bond-related expertise/infrastructure

Another limiting factor would be the lack of related expertise in the region. Green bond-related expertise could be decomposed into financial expertise, environmental expertise, and legal expertise.

The role of financial intermediaries in building the green bond market is indispensable. Financial intermediaries, particularly the investment banks, reacted to the demand for green fixed-income products, thereby creating the green bond instrument. SEB, as part of its due diligence, pioneered the idea of ring fencing the proceeds of green bonds to ensure traceability and governance of the use of funds. Without the financial innovations and responsiveness of such financial intermediaries, the green bond market would never have taken off. Given relatively immature capital market development in Asia, related financial expertise such as financial intermediation experience, credit rating experience, and other ancillary expertise remain limited in developing Asian states. This could affect both the quantity and the quality of the green bonds being issued in the region. Furthermore, the lack of financial expertise in the region could potentially result in the bond issuer being unable to capitalise on the full benefits of the flexibility of the green bond issuance. Alternatively, financial expertise may come at a prohibitively high transaction cost, which may reduce willingness to opt for green bonds.

Developing Asian countries also seem to lack the related environmental expertise, in particular environmental assessment and third-party auditors for environmental reporting. Engaging international experts may increase cost, thereby adding to the already high transaction costs of issuing a green bond. Furthermore, international experts may not be able to fully capture domestic intricacies, especially when environmental issues are mostly localised in nature.

While the legal expertise is still taking formative shape at the international market level, regional legal expertise needs to develop alongside the tightening of domestic environmental law to maintain investor confidence in the green label.

While the international green bond market has moved towards standardisation and scalability in mid-2015, the Asian market remains nascent and relevant financial infrastructures are non-existent. Market standardisation is critical for the growth of a financial instrument, given that the ability to accurately assess the value of the financial instrument in comparison to a benchmark is critical for investors. The introduction of the Barclays, Merrill Lynch, and Standard and Poor’s green bonds was crucial in offering a global benchmark for investors. A recent report issued by the Bank of America Merrill Lynch stated that their green bond index was able to gain a cumulative, annualised return of 6.37%, outperforming the global government and broad market indices (BofA, 2014). Such information would be valuable to institutional investors, especially fund managers, when they are attempting to understand how investments in green bonds would affect their portfolio. Currently, the Asian financial landscape lacks such benchmarking indices.

4.4.3. Lack of favourable climate

Looking back at the growth of the international green bond market, a number of different socio-economic factors could explain the demand for institutional investors in environmentally friendly fixed-income products. Firstly, unlike the equity market, which explored the notion of sustainable investing a few decades ago, the market for sustainable investment in debt markets remained relatively nascent. Therefore, there seemed to be market for sustainable products catered to the fixed-income market in which large institutional investors have a heavy involvement.

The increasing proliferation of climate change concerns, accelerated by promotions by the media, academics, and non-government organisations, has moved climate and environment issues further up in the public agenda. The better understanding of climate-related risks has also motivated increased attention towards green energy, thereby prompting a change in investor behaviour, particularly the institutional investors that have long-term risk outlooks and are thus disproportionately affected by climate change.

Changes in the investment climate, particularly after the 2008–2009 global financial crisis, to a more risk-averse and stable growth strategy have resulted in the increased demand and expansion of relatively stable markets such as the fixed-income and sustainable investing markets. Increased regulation of financial institutions, particularly in terms of holdings in risky assets, further increased the demand for fixed-income products. These changes drove the market for green bonds. Such favourable conditions are not observed in the region, thereby drawing doubts on the viability of the green bond market taking off in the region.

4.4.4. Uncertainty in the future outlook

The last threat for green bonds pertains to the potential uncertainty in the future outlook of green bonds in the region. While 2014 could be viewed as a strong year for green bonds, market performance for the instrument in 2015 was sluggish. The total issuance to date in 2015 had mostly kept pace with issuances in 2014, far from the expected growth of $100 billion (CBI, 2015). Such slow growth rates seem to signal the dampening of both investor and issuer interest in the product. Furthermore, this slow growth is experienced during a time of strong conventional bond issuance. Such developments pose serious threat to the future outlook of green bonds as an asset class.

4.5. Discussion

Looking at the internal attributes of green bonds, the instrument seems well positioned to act as a financing channel for RE projects in the region. The debt structure of green bonds is especially favourable for RE projects as it mitigates against investor concerns of high capital cost and long payback periods. The flexibilities offered by green bonds could also help bridge the financing gap by allowing the structuring of the coupon to match investor requirements. Several other benefits pertaining to increased financial market sophistication and environmental awareness also contribute to making the green bond option attractive for policymakers. However, one should also note that the other benefit of green bonds is that of using traditional bond instruments. The additional benefits of the green bond as compared to the use of conventional bond instruments lie only in signalling green attributes and raising public awareness. When considered against the weakness of the instrument, the question then is, 'Is the trade-off valid?'.

The green bond instrument faces inherent challenges in ensuring environmental integrity. The uncertainties of ensuring environmental integrity could be mitigated, to a certain extent, with compliance with voluntary market best practices. Such compliance measures would have to come at an additional cost, which decreases the attractiveness of issuing a green bond. In addition, the risks associated with the lack of a robust definition of a green bond could not be mitigated in full. The stringency of the voluntary market best practices, such as the GBPs, has been challenged by various stakeholders. Furthermore, being a new market instrument with relatively fluid regulations and inadequate provision of ancillary services (such as benchmarking indices), the viability of a green bond market in place of a conventional bond market could be questioned. This is particularly true for bond issuers who see no pricing benefit for going green. Although the lack of a secondary market for green bonds is not viewed as a significant problem for Asian investors, given that most regional investors are hold-to-maturity buyers, the current analysis seems to suggest that the advantages outweigh the disadvantages when looking internally at the green bond instrument.

When accounting for the external environment, green bonds face additional challenges. Strong investor interest in the product used to be a strong driving force for the growth of the market. However, such investor interest remains unquantifiable and may be illusionary in the region. As such, the viability of introducing green bonds as a financing channel for RE projects may be questioned. While favourable government policies point to the possibility of kick-starting the market, support is seemingly implicit as these policies do not translate into explicit action.

Despite the current circumstances, this study offers a different opinion. This study argues that there remains a potential for green bonds to play a role in RE financing in the region. The differentiation boils down to whether one considers green bonds to be an alternative to or complementary to conventional bonds. Taking an RE project developer's perspective, the two instruments seem to be competitive in nature, as going for either one negates the need to pursue the other. However, this study argues that for investors and policymakers, the two instruments are complementary and there is no dichotomy in developing both instruments in parallel (i.e., the creation of the green bond financing channel should not negate the value of creating a conventional bond financing channel and vice versa). This is because the value of having a green bond market for investors is in its ability to facilitate the identification of green projects that may align with the interests of the investors. The ability to identify such projects creates benefits to both conventional and ESG-mandated investors. For conventional investors, investment in green instruments allows them to possibly promote a healthy corporate image and help them improve their corporate profile. ESG-mandated investors would benefit from the increased visibility of green attributes to find investable projects that align with their mandates. The value of creating a green bond market for the policymaker is its potential to open up new financing channels to tap on new low-cost financing channels for RE projects, which serves multiple policy objectives.

This study believes that parallels could be drawn from creating an Islamic banking sector within the existing conventional banking sector in the region and creating a green bond market alongside a conventional bond market. Similar to the process of building the Islamic banking sector, ventures for building a green bond market could be done alongside the strengthening of the existing bond market infrastructure, without much additional cost to the policymakers. In addition, the creation of a green bonds market, when pursued with policies to build conventional bond markets, would serve to maximise the benefits to both markets, given the complementary nature of both instruments.

Looking at current market developments, there seems to be a parallel development of both the green bond market and the conventional fixed-income market. Moving forward, it is likely to see the green bond market in Asia developing into two separate markets with different characteristics: one targeting international investors, which are likely to be dominated by SSA issuers and denominated in international currencies; and the other targeting domestic investors, which are likely to be dominated by corporate issuers issuing in domestic currencies. Corporate issuers seeking to tap the domestic market for RE capital investments are likely to remain a healthy mix of RE companies, conventional energy companies, and financial institutions, similar to the current situation.

5.Policy recommendations

Unlike the international experience with green bonds, the development of green bonds in Asia is likely to be more policy oriented. The international experience was very much motivated by market forces – the demand from the institutional investors that sourced supply via financial intermediaries such as the investment banks. The market then built on momentum with the active participation of various stakeholders. For the international green bond market, the market practically builds itself up.

The Asian investment scene has yet to achieve the level of financial and environmental sophistication of the international market. Thus, it is unlikely that the demand and supply dynamics that played in favour for green bonds will come into play in the Asian context within a short time frame. Furthermore, the current investment landscape does not provide an enabling environment for a green bond market to mature. Given the urgency of the required financing, the public sector would have to introduce policy incentives to nudge market players in the right direction.

This chapter's view is that for public policy to facilitate the creation of a green bond market for RE financing, it should entail a three-tiered approach (Table 12.3).

Table 12.3: Three-tiered Approach for Public Policies on Green Bonds

Create national standards and/or systems
Create incentives for green bond issuance
Create incentives for green bond investment

Source: Prepared by the author.

5.1. Create national standards/systems

One major shortcoming of the green bond instrument is its lack of robust definition of what constitutes green. The self-regulating nature of the international green bond market creates further implications, where a supranational entity should be responsible for regulating such an international market. The heterogeneity of geographical locations of green bond issuances creates further issues on establishing mandatory standards and practices. Such shortcomings could be limited at a regional and/or national level through the creation of national standards and/or systems. In developing Asia, especially after the 1997 Asian financial crisis, financial regulation by government authorities is commonplace and is thus a widely accepted practice. Thus, the relevant financial regulators could easily take on a regulatory role for green bonds.

A potential case study for the creation of national guidelines for green projects is the Green Credit Guidelines issued by the PRC. The guidelines build on the Banking Industry Regulation and Administration Law in the PRC and aim to encourage investment in green areas by mandating banks to adopt a pro-green strategy. Although, the guidelines provide advice on what banks and/or financial institutions need to do to identify green projects and establish a Board of Directors to ultimately approve the appropriate risk mechanism, as well as the financial institutions built in to identify green projects. The regulation stops short of clearly defining what could be regarded as green projects. This study deems that regulations for green bonds should adopt a similar approach. Although it may be argued that investors would prefer a clear definition of what is green, this study's view is that due to the lack of scientific consensus and the ambiguity surrounding environmental issues, financial regulators may lack the capacity and expertise to lay down such regulations. Environmental-related government agencies constantly face similar controversies during the setting of environmental regulations and standards. As such, the financial regulator is not expected to have the relevant expertise to set such definitive standards.

This study therefore suggests the creation of a procedural approach for regulating the green bond sector. This would entail creating a set of consistent step-by-step guidelines to ensure both the financial and environmental integrity of the green bonds being issued. Such guidelines could be based on international standards such as the GBPs, or a nationally recognised scheme for identifying green investments, should that be available.

By adopting a procedural approach to regulating the sector, investor confidence in the institution would not be compromised as consistency is achieved. Furthermore, the administrative costs of such a regulation could largely be passed on to financial institutions, reducing the strain on public resources.

Care should be taken when creating such a procedural systems approach. Firstly, the steps should not be onerous. An excessively onerous process may deter even the large SSA issuers. Thus, it is imperative that the process for green bond issuance be streamlined. As discussed in the earlier section, the market for Asian green bonds is likely to develop into two separate markets with different characteristics and different target investment groups. As such, a distinction may be made for the two groups. Secondly, the SSA green bonds are most likely investment grade bonds that target international investors. On the one hand, such bonds should require adherence to international best practice. On the other hand, corporate green bonds issued for domestic investors could abide by looser standards. Corporate issuances wishing to tap the international investor pool should also adhere to the more stringent standards. The justification of this proposal is twofold. Firstly, this conforms to existing investor expectations. International investors typically require higher standards for environmental claims. In contrast, consistent with the slower development of SRI in the region, regional and/or domestic investors seem to lack such awareness. Such an arrangement ensures that a minimum level of investor confidence is maintained, while not forcing restrictive covenants prematurely on SME issuers. Secondly, such a two-tiered approach could possibly align financial risk indicators with environmental risks. Issuers wishing to appeal to the international investor pool are likely to issue investment grade bonds. The investment grade label signals strong potential to meet financial obligations. By requiring stronger standards to be met for such bonds, the investment grade label could be extended to account for the ability to meet environmental obligations as well. This helps investors to familiarise with the instrument and also appeals to logic.

This chapter recommends that third-party environmental auditing be mandated for large issuers tapping the international market, while such restrictions be reduced to a recommendation for local investors. This way, international investor confidence is maintained, while not creating a prohibitively restrictive regime for local SMEs targeting the market. This chapter also suggests that other transparency and disclosure requirements be applied to all green bonds to maintain the integrity of the green bond label.

5.2. Create incentives for green bond issuance

The creation of a national standard and/or system puts the appropriate infrastructure in place to support the growth of a green bond market in the region. However, the existing market environment does not motivate potential bond issuers to tap the market. As such, additional incentives are needed to motivate them to enter the market. Policy support mechanisms should aim to increase awareness and interest in the green bond market, reduce additional costs associated with the issuance of green bonds, and facilitate the identification of potential investor demand. Some possible policy actions are described below.

5.2.1. Public messaging campaigns on the green bond instrument

Targeted public messaging campaigns could introduce potential issuers to the green bond instrument. Public sector agencies could also engage financial institutions to maximise the effect of public messaging campaigns. For example, government agencies could work with financial institutions to conduct seminars or roundtables discussing the use of green bonds for financing. Alternatively, the discussion could be expanded to cover climate change risk mitigation and other related topics that financiers may find interesting. Such activities not only raise awareness of the instrument to potential issuers but also create a setting for financiers and RE industry players to meet and exchange views. Such networking opportunities could indirectly facilitate more private finances flowing into the RE sector. Such activities also have the additional benefit of affecting investor demand.

Alternatively, public sector agencies can work with the investment community to map out specific and quantifiable investor demand in green bond instruments and publish related results in the public domain. Such publicly available information could spur discussions around the topic and ease concerns regarding illusionary investor demand. Moreover, such studies could help policymakers grasp the investment outlook of regional investors, which will have a knock on effect on other relevant areas of policymaking.

5.2.2. Subsidising additional costs associated with green bond issuance

One major factor inhibiting participants to tap the market would be the high(er) transaction costs associated with green bond issuance. This is particularly restrictive for corporate SME issuers. Thus, the public sector can play a role in subsidising the additional costs of issuing a green bond. It is not recommended that support beyond the additional costs be provided to ensure a level playing field for all potential issuers and the reasonable use of public finances.

5.2.3. Government-related issuances to kick-start the market

With lack of experience and expertise, additional costs related to the issuance of a green bond are likely to be high. Public sector agencies could then play a role in kick-starting the market by issuing green bonds themselves. As the number of issuances increase, related financial, environmental, and legal experiences are built up, thereby forming a pool of related expertise. As the pool of expertise deepens and a green bond-related services ecosystem forms, additional costs associated with green bond issuance will drop, thereby reducing the high transaction cost barrier for green bond issuances. In addition, public sector issuances would likely have to abide by stricter standards, thereby allowing expertise to develop based on the more stringent standards.

The experience of government-related green bond issuance could also raise interest from corporations as confidence in the instrument is built.

5.3. Create incentives for green bond investment

Investors also require a nudge to increase interest in the green instrument. Policymakers may use both carrot and stick methods to engage financial institutions.

5.3.1. Fiscal incentives

Policymakers may decide to use fiscal benefits, such as tax rebates or reduced capital and/or withholding tax, to increase the attractiveness of green bonds over other instruments. Such tax benefits increase the net returns for the investors, motivating them to take on green bond instruments. This is especially true if green bonds are perceived by investors to carry on more risk. It is important to note that green bond instruments do not carry any additional credit risk. The additional perceived risk arises due to investor uncertainty regarding the characteristics of the green instrument itself. Uncertainty may arise from two sources: the reputational risk due to uncertain green attributes; and the performance uncertainty arising due to lack of investor familiarity with the instruments.

Both uncertainties can be mitigated – the first, with the creation of national standards; and the second, with consistent and timely reporting. Similar to other fiscal incentives, the level of tax rebates is a crucial component and should be decided with care. An excessively high tax rebate may result in needless reduction in tax revenue, while a depressed tax rebate will not be able to incentivise the required action.

5.3.2. Establish green investment quotas

Alternatively, policymakers can establish green investment quotas on investors. Such a policy forcefully places a green mandate on investors, thereby ensuring a minimum demand threshold for green bonds. This ensures that there is consistent and quantifiable demand for green bond products, thereby allaying concerns from bond issuers on unsecured demand. However, this policy instrument also places an imaginary cap on the share of green bonds in the portfolio of investors as investors are seldom motivated to go beyond minimum mandates.

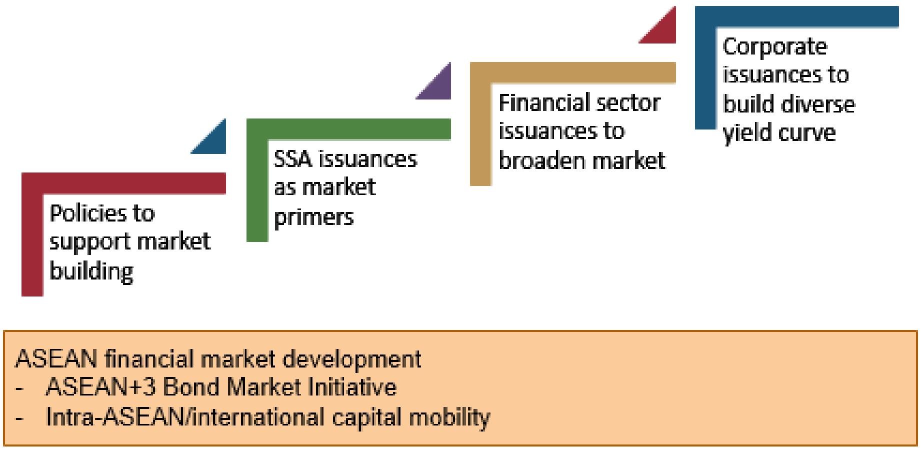
5.3.3. Long-term policy outlook

Should policymakers decide to implement the policies stated above to incentivise investor participation, it should be noted that a long-term policy outlook is needed before investors will act on such policies. Given that bond investments are typically medium- to long-term investments, short-term policies will not affect investor behaviour. This study recommends that a long-term policy outlook be provided to investors. For instance, the PRC has included the creation of a green bond market into its latest ten-year plan. Long-term policy commitments such as these are effective policy primers for investors.

5.4. Road map

Prior to large-scale issuances, favourable policies are required to create a suitable market environment for green bonds. Similar to the international development of the green bond market, SSAs should enter the market first, serving to gain experience and prime the market for future corporate issuances. As experience in green bonds builds confidence in the instrument, corporate issuers could enter the market. Financial institutions will be better placed to capitalise on this new instrument and thus enter the market after the SSAs. As financial institutions tapping the domestic investor pool achieve a degree of success, RE-based corporations can now enter the market, although other corporations will be quick to catch up.

Figure 12.3: Road Map of ASEAN Financial Market Development



ASEAN = Association of Southeast Asian Nations; SSA = supranational, sub-sovereigns, and agencies.
Source: Prepared by the author.

Underscoring the green bond issuances would be the development of the regional financial market, particularly in the fixed-income space. Intra-ASEAN capital mobility is critical to allow regional participation as capital-rich economies are able to inject into renewable resource-rich neighbours.

Development in this manner allows for expertise and confidence to be built gradually with high-quality issuances from SSAs. As both investors and issuers gain experience in the instrument and become willing to take on more risk, high-yield corporate issuances would benefit from the established investor interest. A rush to promote corporate issuances may introduce controversy and increase investor distrust of the market. Currently, corporate green bond issuances are already facing increasing scrutiny over greenwashing claims.

6. Conclusions

This chapter has demonstrated that RE financing in Asia faces various challenges, some of which may be addressed by green bonds. However, most of the challenges may be addressed with conventional fixed-income instruments. Taking into account the internal and external challenges in building a green bond market in the region, one might argue that the creation of such a market is redundant. Despite that, this chapter argues that the green bond market and conventional bond market are complementary in nature.

As such, the strengthening and/or creation of both markets in parallel will likely reap maximum benefits. Policy instruments to facilitate green bond growth and a possible road map to development are also proposed.

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Chapter 13

Renewable Energy Policies and the Solar Home System in Cambodia

Han Phoumin[50]

Abstract

Only about one-third of households in Cambodia have access to commercial energy. Full rural electrification remains far from being achieved, and energy services are mainly delivered through fuel-based engines or generators to produce electricity that can then be stored in batteries, while biomass rather than electricity is used to power many small industrial processes. The current electricity cost in Cambodia is very high, ranging from $0.15/kWh in Phnom Penh to $1.00/kWh in rural areas. This high cost of electricity in rural areas provides an opportunity for the Solar Home System (SHS) to be competitive, although the installed system price of SHS remains high despite a decline in global SHS prices. This study aims to (i) review the current renewable energy (RE) policies in Cambodia, and (ii) analyse the cost structure through the levelised cost of electricity (LCOE) of HSH compared with current electricity costs in rural areas. The results indicate that the LCOE of SHS (without any government subsidy) is about 50% cheaper than the current electricity price in rural areas. When factoring in a government subsidy of $100 per SHS unit, the LCOE of SHS drops to about one third of the current electricity price in rural areas. These results imply that promoting SHS would enable rural households to cut spending on electricity, thus increasing deposable incomes and social wellbeing of rural communities. Policy support for SHS is needed from the Royal Government of Cambodia to ensure that the upfront costs remain comparable to other countries. It is therefore important for the state-owned electricity utility, Electricité du Cambodge, and the Rural Electricity Department to look into the whole value chain of SHS from procurement through to installation. In order to achieve savings it may be necessary to make large purchases directly from manufacturers, and increase transparency in the bidding and procurement process, together with the removal of import taxes on Renewable Energy equipment, including SHS. Furthermore, providing training to local technicians and small business entrepreneurs will be necessary to promote the solar energy business in rural Cambodia. This will help to drive down the unit costs of SHS, and promote the widespread use and application of SHS in rural Cambodia.

Keywords: Government policy, Solar Home System, solar PV, rural electrification
JEL Classification: Q42, L11, Q48

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1. Introduction

Cambodia has achieved a stellar performance in terms of economic growth over the past decade, with an average annual gross domestic product (GDP) growth rate of 7.7% from 1994 to 2013, and an all-time high of 13% in 2005. However, growth also fell to a low of 0.1% in 2009 due to the global economic crisis.[51] This robust economic growth increased Cambodia's GDP per capita in purchasing power parity (PPP) terms from an average $1,797 per capita in 1993 to an all-time high of $2,945 in 2013.[52] Cambodia is expected to continue its rapid rate of GDP per capita growth, closing the gap with the Association of Southeast Asian Nations (ASEAN) peers such as Thailand and Viet Nam through the expansion of social, economic, and industrial development. Economic growth will be accompanied by an increase in energy demand across all sectors in Cambodia, but especially in the transportation, industry and services sectors (Kimura, 2014).

Cambodia's total primary energy supply (TPES) in 2011 stood at 5.33 million tonnes of oil equivalent (Mtoe), with oil representing the second-largest share of Cambodia's TPES at 26%, while coal was the third-largest at 0.2%, followed by hydropower at 0.1%. Others, mostly in the form of biomass, accounted for the bulk of about 74% of TPES (Lieng, 2014). Final energy consumption stood at 4.51 Mtoe in 2011. The country is dependent on imports of petroleum products having no crude oil production or oil refining facilities of its own. Cambodia's electricity supply is dominated by oil at 85%, with hydropower, coal, and biomass accounting for the remainder. However, Cambodia is still in the process of exploring for oil and gas, and it is expected that some off-shore oil production could be tapped by 2017 and one refinery may also be built.[53]

In 2013, only 34% of Cambodian households had access to electricity (IEA & ERIA, 2013), which is one of the lowest electrification rates in ASEAN. Rural electrification

[51] GDP annual growth rate in Cambodia is reported by the National Institute of Statistics of Cambodia.
[52] GDP per capita PPP in Cambodia is reported by the World Bank.
[53] The information obtained when the author had a discussion with a senior officer at the Ministry of Mines and Energy during his time providing assistance to the Ministry in the oil consumption demand in Cambodia 2014.

remains far from being achieved, and energy services are mainly delivered through fuel-based engines or generators to produce electricity that can then be stored in batteries, while biomass rather than electricity is used to power many small industrial processes. The current electricity cost is high, ranging from \$0.15/kWh in Phnom Penh to \$1.00/kWh in rural areas (MIME, 2005). The supply of electricity currently fails to meet basic demand, but is expected to grow from 1,643 megawatts (MW) in 2015 to 2,770 MW in 2020 (EDC, 2015). Although there is still considerable underinvestment in the sector, Electricité du Cambodge (EDC) aims to provide electricity services to all villages by 2020 and to 70% of all the rural households by 2030.

To accelerate rural electrification, off-grid solar systems are viewed by the Royal Government of Cambodia (hereafter, government) as a potential solution in providing rural people with access to electricity. Thus, the government established the Rural Electrification Fund (REF) in 2004 to attract and encourage the private sector to invest in electric power infrastructure so that rural areas can have access to electricity for lighting, commercial use, handicraft production and other purposes for improving standards of living and general wellbeing.

The government aims to promote renewable energy in its energy sector plan, targeting a 15% share of renewable energies (REs) by 2015. However, there has been no policy support to ensure that this target is achieved. No feed-in-tariff (FIT) system exists for REs and upfront costs remain a barrier in promoting REs. Currently, the government is looking into the possibility of the Solar Home System (SHS), but a long-term solar market has yet to be created.

This study aims to (i) review current RE policies in Cambodia, particularly on whether the policy on SHS is in line with policies to promote the energy access in rural areas, and (ii) explore various scenarios in the solar energy market by looking into the cost structure and estimating the levelised cost of electricity (LCOE) through SHS instalment. This will enable the involved authorities to decide whether such a project would be feasible and could be scaled up, given the fact that RE policies such as a FIT support policy are not yet in place.

The study found that Cambodia lacks an appropriate policy to promote renewable energy technology (RET). This means that policy support for RET, such as FIT and green certificates, among others, are absent and the solar energy business is expected to stand on its own feet. However, for SHS, a government subsidy is provided to reduce the upfront costs. Fortunately, the SHS in this study showed economic viability through its competitive LCOE. The results showed that the LCOE of SHS without any government subsidy is about 50% cheaper than the current electricity price in rural areas, but if including the government subsidy of $100 per SHS unit then the LCOE of SHS is about one-third of the current electricity price in rural areas. This study implies that promoting SHS would provide remote areas with energy access, and also enable residents in remote areas to reduce spending on electricity, thereby increasing deposable incomes and social wellbeing in rural communities.

This chapter is structured as follows. Section 2 describes the review of renewable energy policies in Cambodia, while Section 3 provides a review of agents funding and promoting SHS. Section 4 describes the methodology used in analysing the LCOE of SHS in the case of Cambodia. Section 5 analyses the results of the system price and the LCOE, and Sections 6 and 7 offer conclusions and policy recommendations.

2. Review of renewable energy policies in Cambodia

The Royal Government of Cambodia defined its energy sector development policy in October 1994 (Un Ning, 2010). Subsequently, this policy evolved into the Power Sector Strategy 1999–2016, with four objectives as follows: (1) to provide an adequate supply of energy throughout Cambodia at reasonable and affordable prices; (2) to ensure a reliable and secure electricity supply at prices that allow sufficient investment in Cambodia and the development of the national economy; (3) to encourage the exploration, and environmentally and socially acceptable development of energy resources needed as supply to all sectors of the Cambodian economy; and (4) to encourage efficient use of energy and to minimise detrimental environmental impacts resulting from energy supply and use. This strategy has guided the development and policy framework of all energy sectors in Cambodia, including the Rural Electrification by Renewable Energy Policy, Renewable Electricity Action Plan 2002–12 (REAP), and the Energy Efficiency and Conservation (EE&C) goals.

In early 2001, the Electricity Law was passed with the following aims: (1) to ensure the protection of the rights of consumers to receive a reliable and adequate supply of electricity power services at reasonable cost; (2) to promote private ownership of the facilities for providing electric power services; (3) to establish competition wherever feasible in the sector; (4) to establish the Electricity Authority of Cambodia (EAC) to regulate electricity power services, granting it the right to penalise, if necessary, the suppliers and consumers of electricity in relation to electricity generation and supply facilities; and (5) to create favourable conditions for investment in, and the commercial operation of, the electricity power industry in Cambodia.

The EAC is an autonomous body set up to regulate and monitor the electricity power sector throughout the country. Its duties include issuing licenses, approving and enforcing performance standards for licensees in order to ensure quality supply and better services to the consumers, and determining tariff rates and charges for electricity power services that are fair to both consumers and licensees.

The Electricity Law also seeks to promote private investment and ownership of power facilities, and to encourage competition in the sector. The Electricity Law establishes the EAC as a legal public entity with the power to act as the regulator of power sector business activities, and also defines the roles of the Ministry of Mines and Energy (MME), formerly known as the Ministry of Industry, Mines and Energy (MIME). The MME is responsible for the overall administration of the energy sector. It is responsible for developing policies and strategies, power development plans, electricity trade with neighbouring countries, major investment projects, and the management of rural electrification. Together with the Ministry of Economy and Finance (MEF), the MME is the joint owner of Electricité du Cambodge (EDC).

EDC was established in 1996 as a state-owned company responsible for generating, transmitting and distributing electricity throughout Cambodia. Its main functions are supplying electricity, developing the transmission grid and facilitating the import and export of electricity to and from neighbouring countries. The independent power providers (IPPs) are private companies that have received a licence from the EAC to generate electricity for public consumption. IPPs generate electricity and sell it on to EDC, which then distributes the electricity through the national grid.

In 2006, the government approved the Rural Electrification by Renewable Energy Policy. Its main objective is to create an enabling framework for renewable energy technologies to increase access to electricity in rural areas. The policy acknowledges the Master Plan Study on Rural Electrification by Renewable Energy in the Kingdom of Cambodia as the guiding document for the implementation of projects and programmes. The Master Plan envisions: (1) achieving full village electrification, including battery lightning, by 2020; and (2) providing 70% of households with electrification through the national grid by 2030. In addition, Cambodia aims to achieve 15% of rural electricity supply from solar energy and small hydro by 2015. The Master Plan also lays out clear targets, investments, and responsibilities, with 1,828,485 households to be connected to the national grid by 2020. An additional 260,000 households in very remote areas – too far from the planned grid extension – will be supplied through isolated mini-grids using diesel-generated power and/or renewable energy (220,000 households) and SHS (40,000 households). The total cost for expanding the rural grid is estimated at $1.37 billion. In the Master Plan, EDC will be responsible for the overall planning, development, investment, and operation of the rural medium-voltage (22 kilovolt [kV]) sub transmission lines and will partner with private rural energy enterprises (REEs) to expand, operate, and maintain low-voltage distribution and service lines (<0.4 kV).

The Energy Efficiency and Conservation (EE&C) goals submitted to the Fifth East Asia Summit Energy Ministers Meeting, held on 20 September 2011 in Brunei Darussalam, state that Cambodia will adopt the Final Energy Demand as its energy efficiency (EE) indicator, and aims at a 10% reduction from the 'business-as-usual' scenario by 2030. The action plans to achieve the EE&C goals cover the use of energy by industry, transportation, and commercial and residential users, such as the introduction of energy efficient equipment and EE labelling, as well as the promotion of EE awareness among the public.

3. Review of agents in funding and promoting solar systems

Currently, about 74% of energy demand is met by traditional biomass (Kimura, 2014). Rural areas are largely disconnected from the electricity grid and there is an urgent need to connect them through an off-grid power system. In this regard, SHS have been promoted since 2004 by the RGC. In Cambodia, there are few active agents involved in the promotion and marketing of SHS. These are listed below.

3.1. The government agent: Department of Rural Electrification Fund

The REF was established in 2004 by the government to accelerate the development of rural electrification. In 2005–2012, the REF utilised funds provided by the World Bank under the Rural Electrification and Transmission Project (RETP) and the government's counterpart fund. The RETP was a $46 million World Bank–funded project involving a $40 million loan from the World Bank and S$6 million provided by an International Development Association and Global Environment Facility Grant to the government (World Bank, 2012). The RETP aims were to (i) improve power sector efficiency and reliability, and reduce electricity supply costs; (ii) improve standards of living and foster economic growth in rural areas by expanding rural electricity supplies; and (iii) strengthen electricity institutions, the regulatory framework and the 'enabling environment' for sector commercialisation and privatisation. SHS is one of the sub-components of the project (roughly $5 million allocated for this sub-component) and involved the installation of SHS in 12,000 household during the project implementation.

The RETP was completed in 2012, at which point the SHS sub-component was assessed in terms of its economic return. The analysis shows that the LCOE from SHS is highly sensitive to under-utilisation. For example, with 4 hours of use per day, the 50 watt peak (Wp) and 30 Wp systems deliver electricity at around $0.75/ kilowatt hour (kWh) and $1.00/kWh, but these costs double if the system is used for only 2 hours per day.

To continue the work after the completion of the RETP, the government integrated the Rural Electrification Fund (REF) into Electricité du Cambodge (EDC) to allow the Department of Rural Electrification to perform its works independently using

Cambodian funding, while also continuing to receive grants and donations from external funding sources to assist in the development of rural electrification in Cambodia. In 2014 alone, EDC provided S$6 million for the operation of the REF and the implementation of three rural electrification development programmes consisting of: (i) the Programme for Power to the Poor (P2P); (ii) the Programme for Solar Home Systems (SHS); and (iii) the Programme for Providing Assistance to Develop Electricity Infrastructure in Rural Areas.

3.1.1. Power to the Poor (P2P) Programme

The purpose of this programme is to facilitate poor households in rural areas to have access to electricity for their homes from the national grid by providing interest free loans to cover: (i) the connection fees of the electricity supplier, (ii) a deposit payment to be deposited with the electricity supplier, (iii) the purchase of materials and labour for the installation of wires from the connection point to its house, and (iv) the purchase of materials and labour for the installation of in-house wiring. In 2014, 2,176 rural households were connected to electricity supply system.

3.1.2. Solar Home System (SHS) Programme

According to the World Bank (2012), the purpose of the SHS Programme is to facilitate remote rural households that may not have access to the electricity network for long periods to access electricity through SHS. SHS was one of the sub-components of the World Bank–funded REF project. However, the project was completed in 2012. In 2014–2015, the REF has resumed its function under the responsibility and oversight of EDC, and has sold and installed 13,240 SHS-50 Wp to rural households in remote areas (EDC, 2015). To facilitate the purchasers, ensure that the SHS installed in rural households operate well, and collect the payback amount in instalments from the purchasers, EDC has contracted BNP Power Green (Cambodia) Co., Ltd to provide transportation, installation, collection of payback in instalments, and maintenance of 4,000 systems.

3.1.3. Programme for Providing Assistance to Improve Existing and Develop Electricity Infrastructure in Rural Areas

The purpose of this programme is to facilitate private electricity suppliers in rural areas to obtain legal licenses to access funding for investing in the expansion of electricity supply infrastructure to fully cover their authorised distribution areas. In 2014, REF executed 72 contracts for providing assistance to improve existing and develop new electricity infrastructure in rural areas by 66 licensees.

3.2. Solar services providers

Based on a literature review, only a few agents exist to provide solar services in Cambodia. Currently, there are about a dozen agents but only a few of these are active, as follows.

Kamworks. This private company is a solar energy company that makes innovative products for off-grid populations in Cambodia and beyond. Kamworks has developed award-winning solar lighting, the Moon Light, as well as several other products. By setting up an assembly plant in Cambodia, Kamworks aims to transfer technology and provide better services to its clients. Kamworks was established in 2006 with an annual budget of $30,000. It has about 25 staff, with 1 to 5 volunteers. In 2006, it received seed funding of $175,000 from the World Bank, and later it won a contract from the World Bank worth of $500,000 to install 12,000 SHS in Cambodia.

Crédit Mutuel Kampuchea (CMK). This is a mutual saving and loans cooperative that provides credit for solar energy but has no specific loan products. However, CMK has a memorandum of understanding with the supplier Kamworks to provide products and services.

Up to now, only a few other organisations such as VisionFund, Yejj Solar (NGO), International Solar Solutions (Enterprise/Supplier), Khmer Solar (Enterprise/Supplier), and Kamworks (Enterprise/Supplier) are involved in funding solar energy, and no other institutions intend to enter the sector (World Vision, UNEP, and Frankfurt School, 2012).

4. Methodology of analysing LCOE from solar PV in Cambodia

A literature review into the financing of solar photovoltaic (PV) in Cambodia offers scant information on how solar PV might play a role in the country’s power generation mix. As is often the case elsewhere, in Cambodia the funding of SHS has been on a small scale with only modest subsidies from the government.

World Vision, UNEP, and the Frankfurt School (2012) conducted a detailed feasibility study of 401 clients on access to financing for RE appliances for the rural poor in Cambodia. This study found that despite the lack of awareness of RE in general, almost 70% of those interviewed were willing to take out loans to purchase solar energy systems. This suggests that solar energy could have a potential market in Cambodia. Based on these findings, the study will undertake further analysis of economic feasibility in terms of the LCOE provided by solar PV.

For the system cost of SHS, the study is based on the findings of a World Bank project implementation completion report (World Bank, 2012). The report indicates there are two sizes of SHS rooftop rated capacity, namely 30 Wp and 50 Wp, and the system costs are $260 and $333, respectively. When SHS was first introduced, no subsidies were available, but subsequently a $100 per unit subsidy was made available for the upfront cost of purchasing the SHS. Because of the high cost of electricity in Cambodia, this provided an opportunity for SHS to gain a foothold in the market. Average daily sunlight in Cambodia is about 5 hours. However, this study uses 4 hours per day to avoid overestimating annul electricity production from SHS.

Given that rural areas in Cambodia have limited access to finance this study uses a simple methodology by not considering discounting rates in the analysis of the LCOE. The rationale for using a simplified methodology is that the calculation adopted a 0.5% rate of annual degradation of electricity production while keeping a fixed tariff rate at $1.00/kWh. With this in mind, the LCOE could be derived as follows:

$$LCOE\ without\ subsidy = \frac{\sum_{year=1}^{10}(Overnight\ Capital\ Cost + O\ \&\ M\ Cost)}{\sum_{year=1}^{10} Electricity\ production \times Annual\ \deg radation\ rate}$$

$$LCOE\ without\ subsidy = \frac{\sum_{year=1}^{10}(Overnight\ Capital\ Cost + O\ \&\ M\ Cost) - Subsidy\ Cost}{\sum_{year=1}^{10} Electricity\ production \times Annual\ \deg radation\ rate}$$

Note that solar PV has no fuel costs. As such, $Electricity\Pr oduction = 8760 \times Capacity\ factor$.

The capacity factor is 4 hours per day to reflect average daily sunlight available. The annual degradation rate is set at 0.5%.

5. Results and analyses of the LCOE from solar PV in Cambodia

Using the above methodology, the study used the LCEO results to compare different system sizes, both with and without government subsidies. The results of the LCOE analysis in Table 13.1 show that the LCOE is \$0.61/kWh for a system size of 30 Wp without a government subsidy, and \$0.38/kWh for a system size of 30 Wp with a government subsidy of \$100 per unit to cover upfront costs. These results suggest that SHS is far more competitive than the current local diesel-engine service providers in rural areas that charge an electricity price of up to \$1.00/kWh.

Table 13.1: Comparisons of LCOE with and without Government Subsidies (system size of 30 Wp) over a 10-year period

System Inputs		**System Inputs**	
System Size (kW-DC)	0.03	System Size (kW-DC)	0.03
1st-Year Production (kWh)	44	1st-Year Production (kWh)	44
Annual Degradation	0.50%	Annual Degradation	0.50%
Direct Purchase Inputs Without Subsidy		**Direct Purchase Inputs With Subsidy**	
Cost (US$/W)	8.660	Cost (US$/W)	8.660
Initial Rebate/Incentive	US$	Initial Rebate/Incentive	US$ 0 10
O&M Cost (US$/kW)	10.00	O&M Cost (US$/kW)	10.00
O&M Escalator (%)	3%	O&M Escalator (%)	3%
Current electricity tariff		**Current electricity tariff**	
Tariff (US$/kWh)	1.00000	PPA Rate (US$/kWh)	1.00000
Tariff Escalator	0.00%	PPA Escalator	0.00%
LCOE		**LCOE with US$100 Subsidy for Upfront Cost**	
10 Years	US$ 0.6146	10 Years	US$ 0.3811

DC = kW = kilowatt; kWh = kilowatt hour; LCOE = levelised cost of electricity; O&M = operations and maintenance; PPA =purchasing power parity.

Source: Author’s calculation.

Table 13:2: Comparisons of LCOE with and without Government Subsidies (system size of 50 Wp) over a 10-year period

System Inputs		**System Inputs**	
System Size (kW-DC)	0.05	System Size (kW-DC)	0.05
1st-Year Production (kWh)	73	1st-Year Production (kWh)	73
Annual Degradation	0.50%	Annual Degradation	0.50%
Direct Purchase Inputs Without Subsidy		**Direct Purchase Inputs With Subsidy**	
Cost (US$/W)	6.66	Cost (US$/W)	6.66
Initial Rebate/Incentive	US$ 0	Initial Rebate/Incentive	US$ 100
O&M Cost (US$/kW)	12.00	O&M Cost (US$/kW)	12.00
O&M Escalator (%)	3%	O&M Escalator (%)	3%
Current Electricity Tariff		**Current Electricity Tariff**	
Tariff (US$/kWh)	1.00000	PPA Rate (US$/kWh)	1.00000
Tariff Escalator	0.00%	PPA Escalator	0.00%
LCOE		**LCOE with US$100 subsidy for the upfront cost**	
10 Years	US$ 0.476	10 Years	US$ 0.3360

DC = kW = kilowatt; kWh = kilowatt hour; LCOE = levelised cost of electricity; O&M = operations and maintenance; PPA =purchasing power parity.
Source: Author's calculation.

Likewise, the results in Table 13.2 show that SHS with a system size of 50 Wp is also highly competitive compared with the current diesel-engine electricity service providers in rural areas. With a system size of 50 Wp, the LCOEs are $0.33/kWh and $0.47/kWh with and without a government subsidy, respectively. With still larger system sizes, the LCOE becomes lower still, as seen in Tables 13. 1 and 13.2.

For this study, the calculated installed system price is $8.6/W and $6.6/W for 30 Wp and 50 Wp system sizes, respectively. However, global experience shows that the installed system price of solar PV (that is, below 10 kW) for residential and commercial use was about \$4.7/W in 2013, and expected to decline further to \$2–\$3/W in 2014 (Feldman et al., 2014). This indicates that the SHS installed system price remains excessively high in Cambodia and needs to fall over time to reflect the global market price of SHS.

In Cambodia, there is no policy support such as feed-in-tariff, net-metering, or green certificates. Thus, global experience offers Cambodia some examples of how solar PV business models can promote the uptake of solar PV and help more villages to become electrified.

6. Conclusions

Energy access remains a fundamental development issue for Cambodia, as electricity costs are high in both urban and rural areas. Because of prolonged underinvestment in the electricity sector, Cambodia's electrification rate as just 34% in 2013. Despite the passage of the Electricity Law more than a decade ago, Cambodia's electricity sector has not developed fast enough to meet demand in either urban or rural areas. The government, in its rural electrification master plan, has realised the adverse consequences of high electricity costs, as well as the importance of accelerating electricity access in rural areas. Based on the master plan, 70% of households will be connected to the national electricity grid by 2030. In the medium term to 2020, the master plan foresees an increase in mini-grids from small hydropower and solar PV systems, including SHS, to provide electricity access in rural areas.

About 12,000 households installed SHS in the period 2005–2012 under the Rural Electrification Fund (REF) established by the government to accelerate the development of rural electrification. However, the REF project was completed in 2012. In 2014–2015, the REF has resumed its work and sold and installed 13,240 SHS-50 Wp to rural households in remote areas. Electricity costs in rural areas charged by current electricity providers using diesel generators can be as high as \$1.00/kWh, which provides an opportunity for SHS to enter the market, although the upfront costs of SHS remain high compared with other countries. The study found that the LCOE of SHS without any government subsidy is about 50% cheaper than the current electricity price in rural areas. With a government subsidy of $100 per SHS unit, the LCOE of SHS falls to about one-third of the current electricity price in rural areas.

The installed system price of SHS is about $8.6/W and $6.6/W for 30 Wp and 50 Wp systems sizes, respectively. This is relatively high cost compared with global experience where installed SHS prices are only $2–$3/W. Given the high cost of electricity in rural areas, SHS remains competitive. These results imply that promoting SHS will provide remote areas with energy access, and also enable residents in remote areas to reduce spending on electricity, thereby increasing deposable incomes and the social wellbeing of rural communities.

7. Policy recommendations

The findings in this study point towards the following recommendations:

7.1 **High cost of installed SHS.** The high installed system price of SHS is one of the obstacles in promoting the uptake of solar PV. It is recommended that the involved authorities such as the Electricity Authority of Cambodia, Electricité du Cambodge, and the Department of Rural Electricity might look at the whole value chain of SHS from procurement through to instalment to ensure that transition costs are minimised in order to reduce the system price. It may be necessary to make large purchases of SHS directly from manufacturers, and create an effective and transparent procurement process in RE equipment, including solar PV and SHS.

7.2 **Mini-grids from solar PV.** The electricity authorities might consider attracting investment in mini-grids supplied by solar PV, as these would provide economies of scale compared with SHS. Mini-grids supplied by solar PV systems offer lower system costs than SHS. However, there is also a need to look at the whole value chain of mini-grids, from procurement through to instalment. The authorities should also explore the possibility of FIT or net-metering policies if they wish to promote this option.

7.2 **Competitive SHS.** Although the upfront system price remains high, the LECO suggests that SHS remains competitive given high electricity prices in remote areas. Thus, it is crucial to scale up SHS in remote areas. This will require promoting SHS in rural Cambodia through the capacity-building of local technicians and small business entrepreneurs.

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