Innovation System of Solar Photovoltaics in Thailand

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Abstract

Thailand is by far the most active country in the Southeast Asian region in terms of renewable energy (RE) policy support and technological adoption. Owning very much to its electricity supply industry reformation after the Asian financial crisis in 1997, Thailand's electric sector has been extended from government monopoly to market liberalisation, which is then accommodated the proliferation of RE projects. Through the lens of RE policy support development and RE technological adoption, solar PV technology—amongst alternatives—exhibited the highest market growth. Hence, this paper provides an in-depth analysis of solar PV adoption, aiming to enhance the understanding of PV project development and how future policy design can foster further PV adoption. Besides RE policy review and statistical analysis, the methodological framework is based on sectoral systems of innovation. So that a better understanding of PV industry structure, dynamics, and transformation can be discerned.

Keywords: sectoral systems of innovation, solar photovoltaics, PV adoption, Thailand

1. Introduction: Thailand's electric power sector

From 1998, a reform of the electricity supply industry has shaped the current structure of Thailand's electricity sector evolving, from a government monopoly to a semi-unbundled structure referred as the Enhanced Single Buyer model (NEPO, 1999). The government, via the National Energy Policy Council (NEPC), has the authority and duties to determine policies on energy industry management; while the Energy Regulatory Commission (ERC) has the authority and duties to regulate energy industry operations in compliance with the policy framework of the government. A state enterprise, the Electricity Generating Authority of Thailand (EGAT), is the major producer, the sole owner of transmission system, and the supplier of electricity mainly for state-owned distribution systems − namely the Metropolitan Electricity Authority (MEA), and the Provincial Electricity Authority (PEA) (EGAT, 2015). The amended law in 1992 allowed the private participation of Independence Power Producer (IPP) and Small Power Producer (SPP) in the electricity market, and

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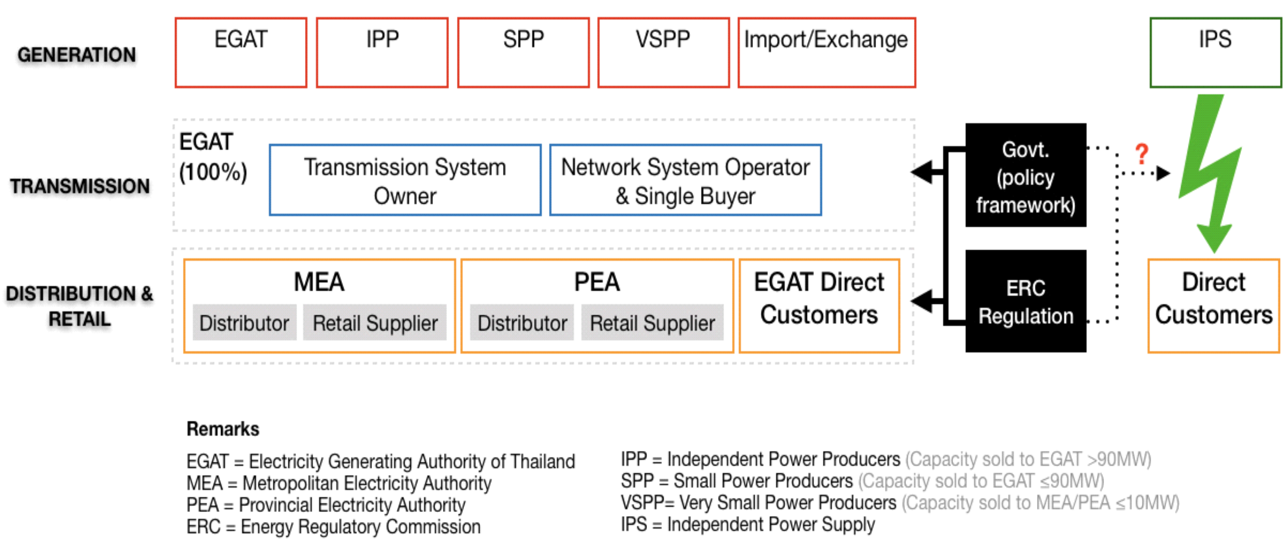
EGAT could purchase up to 90MW capacity from each SSP. During 1997 Asian financial crisis, the regulations on SPP was loosen so as to attract more private participation. The Very Small Power Producer (VSPP), within 1MW capacity, was initiated in 2002 and then increased to within 10MW capacity in 2006, in accordance with the Adder Program implementation to promote renewable energy (RE) utilisation. High upfront cost and long payback periods are major impasses of RE technology adoption. Thus, Thailand's first renewable energy development plan in 2007 and the Adder Program were designed to secure RE business viability. Regarding the long-term national energy policies, separate plans based on energy resources are overseen by different government divisions. The lack of policy integration urged on policy alignment and in 2015 Thailand Integrated Energy Blueprint was approved to promote RE and utilisation energy conservation for long-term plan 2015-2036 (MoE, 2017).

Amongst alternative RE technologies, solar PV has achieved the highest growth rate. An early PV technological adoption from 2008 took advantages from both the global PV price declination and government price-based market instrument. Adder programme can be claimed as a successful mechanism which has ignited domestic PV market and induced PV technological adoption to the fossile fuel-based power sector. However, due to the economies of scale, solar PV industry subsequently dominated by utility-scale projects (more than 97% of 2309.84MW PV operating capacity in 2016 (ERC, 2017; Tantiwechwuttikul, et al., 2019)). From national and international perspectives, however, more diversified and decentralised projects should be prioritised, and incorporate more public awareness and engagement. The Feed-in Tariff programme in 2013 helped encourage technological adoption in the residential and commercial sectors. Yet, the capped quota does limit market growth, and the financial burden incurred by the Thai society is amongst leading issues, which limit PV installation potential. In 2015, PV represented about 17.83% of total RE generating capacity in Thailand, and approximately 1.36% of total electricity demand (IEA PVPS & DEDE, 2016).

Figure 1. Structure of Thailand's electric power sector



Despite an ambitious goal, stated in the Power Development Plan 2015 (also known as PDP 2015-2036), of 6GW generating solar power by 2036 (MoE, 2017), no other government incentive programme has been executed since 2013 − which could imply an approaching grid-parity in PV utility market. Furthermore, the rise of PV adoption for self-consumption purpose and/or sell directly to off-takers without using national grid system has initiated a new type of power generator, the Independent Power Supply (IPS). A decentralised PV adoption through IPS sets a new platform for the near-future PV policy direction. Subsequently, the latest Power Development Plan 2018 (also kwon as PDP 2018-2037) targets for 10GW solar power by 2037 (MoE, 2019). The recent structure of Thailand's electric power sector is summarised in Figure 1. Because a regulatory framework in monitoring and reporting of IPS has yet to be established, the discussion of IPS is excluded from this paper.

2. Methodological framework

Methods used for gathering, collating, and analysing information cover both primary and secondary sources based mainly on official documents and other related publications. Nonetheless, inputs from key informant interviews, field observation and previous workshop engagement provide insights and complementary details to the analysis. Besides RE policy review and statistical analysis, the policy discussion is based on sectoral systems of innovation. This framework offers unique practicality in terms of covering a wide range of factors, considering major drivers from firms and learning process, and providing a dynamic perspective as well as a process view. This broad, flexible, and adaptable tool allows different levels of aggregation, which depend on the purpose of analysis.

The framework of sectoral systems is grounded on three areas of research in economics and innovation studies. Firstly, the industrial transformation addresses the dynamic process of innovative activities patterns and change in technological regimes. Secondly, the evolutionary theory emphasises economic transformation where learning and knowledge play crucial roles, also its dynamics and innovation processes. And thirdly, the innovation systems signify the interactive process involving firms and non-firm organisations (Malerba, 2002). Serving as a methodology for analysing the sectors' characteristics and for comparing the innovation drivers across different sector, sectoral systems of innovation define a sector as a set of activities associated with broad and related product groups which address similar existing or emerging demands and share common knowledge bases. Three main elements, each has its own characteristics and set of dynamics, are (Malerba & Adams, 2013):

Knowledge and technological domains: Specific knowledge base and technologies set different sectors apart and play a central role for this framework. The analysis seeks to understand how knowledge and technologies are created, how they flow and are exchanged, and how such transaction may redefine sectoral boundaries.

Actors and networks: Uniqueness and capability embedded within heterogeneous agents demonstrate their specific learning processes, competencies, and behaviours. In addition, their interactions and networks foster the generation and exchange of knowledge.

Institutions: No necessary bounded within national dimension or formal organisation, institutions provide conditions—by created or imposed on—actors and networks.

Table 1. List of interviewee's affiliations

Position	Affiliation
Director General	Energy Policy and Planning Office (EPPO), Ministry of Energy
Director	Office of Energy Regulatory Commission (ERC)
Researcher	Energy Research Institute (ERI), Chulalongkorn University
Energy scholar	Independent researcher and financial advisor
Researcher	LBNL (Lawrence Berkeley National Laboratory)
Researcher	NREL (National Renewable Energy Laboratory)
Investment Mobilization Lead	USAID Clean Power Asia
Energy Policy Specialist	USAID Clean Power Asia
Director	HyNAE (Center of Excellence on Hybrid Nanomaterials for Alternative Energy), School of Energy, Environment and Materials, King Mongkut's University of Technology Thonburi (KMUTT)
Group leader	HyNAE, KMUTT

Table 2. List of workshop engagements

Date	THEME	HOST & PARTICIPANT
15 Feb 2017	Quantifying Utility Revenue Impacts of Distributed Solar Photovoltaics in Thailand	ERI & USAID co-workshop having representatives from government entities (DEDE, EPPO, ERC), utility companies (EGAT, MEA, PEA), academia
23-24 Feb 2017	Renewables Readiness Assessment Review & REmap Analysis for Thailand	DEDE & IRENA co-workshop having government entities (DEDE, EPPO, ERC), utility companies (EGAT, MEA, PEA), academia, and NGOs
1-3 Feb 2018	Towards Sustainable Urban Energy Systems: Experiences from Asia and Latin America	Japan-Brazil Joint Workshop with international scholars

3. Sectorial systems of innovation: Thailand's solar photovoltaic industry

The solar photovoltaic (PV) value chain can generally be divided into two levels:

(1) Upstream: manufacturing of PV module and the balance of system (BoS)
(2) Downstream: project planning phase, implementation phase, and use phase

At present, Thailand's PV industry is focused on downstream deployment. Thus, analysis based on sectoral systems of innovation (SSI) framework emphasises the downstream activities—covering three phases from PV project planning and development, to PV system installation including engineering, procurement, and construction (EPC), and to project realisation including ownership transfer, and the operation and maintenance (O&M). Three component of SSI and challenges are discussed in the sub-sections below.

3.1 Knowledge and technological domains

The PV industry in Thailand relies heavily on PV technology imports, especially PV modules and BoS. The rapid PV market growth has encouraged both upstream and downstream activities, though the emphasis on the latter is more significant. Three areas of technological development can be distinguished as follows:

Technologies related to upstream activities. Despite limited R&D in silicon manufacturing domestically, silicon ingot/wafer is imported to be made into PV cells and modules. Imported PV module accounted for around 95% of total PV demands in 2014 (DEDE, 2014). However, domestic firms have developed their own in-house technologies for BoS which demand specifications to suit local climate and domestic power structure.

Technologies related to EPC and O&M of PV system employed in different scale. The analysis of PV market players reveals two groups of PV project owners: PV technical core and PV financial core (Tantiwechwuttikul, 2019). The PV technical core group consists of the earliest players (also known as first movers) who extend their existing expertise in EPC and/or other technologies, which can be applied to PV project realisation. The joint venture and business partnership foster the diffusion of these technologies.

Technologies related to grid system. In the broadest term, government strategies to promote alternative energy development accelerate the potential of RE generation, consumption and market. Amongst RE resources, solar PV is the leading technological contribution. Due to a national electric regulation for safety and security, all grid-tied PV projects need permission from either MEA or PEA. Thus, utilities (EGAT, MEA, and PEA) are required to secure and optimise grid system through the upgrade of existing infrastructures.

In addition to the aforementioned technological development in the existing PV market, R&D activities in PV materials, BoS, policy-related issues, and demonstration & evaluation are listed in Table 3, which are based on government reports, universities' websites, and interviews.

Table 3. Knowledge generation from different actors

	Research institutes and universities													DEDE	Utilities	Firms
	NSTDA	CMRU	CU	KKU	KMUTNB	KMUTT	NU	PSU	RMUTL	RMUTT	SUT	UBU	UP			
PV materials																
Silicon processing	/															/
a-Si, μc-Si	/															
CIGS			/													
DSSC			/	/	/	/		/				/				
PSC	/					/					/					
Tandem PV	/															

	Research institutes and universities													DEDE	Utilities	Firms
	NSTDA	CMRU	CU	KKU	KMUTNB	KMUTT	NU	PSU	RMUTL	RMUTT	SUT	UBU	UP			
Balance of system (BoS)																
Inverter																/
Charge controller																/
Policy																
PV policy research			/											/	/	
Demonstration and evaluation																
Demonstration projects	/	/	/			/	/		/	/			/		/	/
Environmental effects	/		/				/									
Evaluation of off-grid system														/		
Impact of PV penetration			/			/									/	
Improving PV performance	/					/										
Long term monitoring	/					/										
Electricity loss analysis	/														/	
PV floating plant						/									/	
PV systems monitoring & evaluation							/							/		
Smart (mini) grid	/					/	/						/		/	
Tracking system							/								/	

Note: National Science and Technology Development Agency (NSTDA), Chiang Mai Rajabhat University (CMRU), Chulalongkorn University (CU), Khon Kaen University (KKU), King Mongkut's University of Technology North Bangkok (KMUTNB), King Mongkut's University of Technology Thonburi (KMUTT), Naresuan University (NU), Prince of Songkla University (PSU), Rajamangala University of Technology Lanna (RMUTL), Rajamangala University of Technology Thanyaburi (RMUTT), Suranaree University of Technology (SUT), Ubon Ratchathani University (UBU), University of Phayao (UP), and the Department of Alternative Energy Development and Efficiency (DEDE)

3.2 Key actors and their linkages

3.2.1 Firms

Upstream (analysis based on government report and data as of Aug 2015 (DEDE, 2016))

Two silicon manufacturing firms have a combined capacity of 75000 tons/year.

In 2014, five PV manufacturing companies had a combined installation capacity of 234MW. In 2015, seven new manufacturing companies (mainly Chinese and Taiwanese firms) having 3634MW installation capacity were registered.

For inverter market, there were only one domestic inverter manufacturing company, until in 2015 another manufacturing company was established together with the new 36 inverter- imported companies.

Downstream (analysis based on ERC database of grid-connected projects by 2016 (ERC, 2017))

An oligopoly is observed in PV market structure having merely twelve parent companies whose own major shareholders of 62.83% of total PV operating capacity (Tantiwechwuttikul, 2019).

Based on PV segmentation, seven mega-utility (SPP) projects are owned by five companies covering 18.9% of total PV operating capacity; thirteen project owners account for 177 out of 463 non-SPP projects covering 46.8% of total PV operating capacity (Tantiwechwuttikul, 2019).

Some PV downstream firms—which include, but not limited to, PV project development, EPC, and O&M firms—are the members of Thai Photovoltaic Industries Association (TPVA). TPVA is a loose form of collaboration since 2012, but becomes inactive partly due to political uncertainty.

Utilities

The sole owner of grid transmission systems is a state enterprise, the Electricity Generating Authority of Thailand (EGAT).

EGAT is also the major power producer, and the supplier of electricity mainly for state-owned distribution systems: the Metropolitan Electricity Authority (MEA), and the Provincial Electricity Authority (PEA).

3.2.2 Government policy and supporting organisations

Under the Ministry of Energy (MoE), the Energy Regulatory Commission (ERC) regulates policies related to electric power, and the Department of Alternative Energy Development and Efficiency (DEDE) has the core mission to promote renewable energy and utilisation energy conservation which includes an implementation of the Alternative Energy Development Plan (AEDP 2015).

For fiscal incentives, the Office of the Board of Investment (BOI) operates under the Prime Minister's Office and is the principal government agency responsible for encouraging investment. PV support scheme is a subset within renewable energy investment.

Thai Industrial Standards Institute (TISI) is a national standards organisation which is established under the Ministry of Industry by a virtue of the Industrial Product Standards Act in 1968. The governing body of the Industrial Project Council controls TISI policy and implementation. TISI has yet to impose compulsory standards for PV systems and components which can ensure project quality of both the domestic PV manufacturing and the imports.

3.2.3 Universities and public research institutes

Concerning PV research themes on new PV materials and PV systems evaluation, the National Science and Technology Development Agency (NSTDA) is a key research centre. Many universities also have PV-related research clusters i.e. Chiang Mai Rajabhat University (CMRU), Chulalongkorn University (CU), Khon Kaen University (KKU), King Mongkut's University of Technology North Bangkok (KMUTNB), King Mongkut's University of Technology Thonburi (KMUTT), Naresuan University (NU), Prince of Songkla University (PSU), Rajamangala University of Technology Lanna (RMUTL), Rajamangala University of Technology Thanyaburi (RMUTT), Suranaree University of Technology (SUT), Ubon Ratchathani University (UBU), and University of Phayao (UP). Research clusters and themes are classified in Table 3.

PV policy and regulation research is mainly carried by Energy Research Institute (ERI) Chulalongkorn University. ERI also helps facilitate collaboration between domestic stakeholders (firms and non-firms) and international agencies.

3.3 Institutional factors and demand conditions

The high upfront cost of PV technology justified the rationale of market intervention by the government, particularly during an early technological adoption stage (2008-2013). Thus, solar power policy evolution has started from Adder programme (Feed-in Premium), to Feed-in Tariff (FiT), and geared towards self-consumption rooftop. Notably, PV deployment has relied heavily on institutional arrangements. The national strategic plan, government supporting policy, regulations, and industrial standards are prerequisite for PV technological exploitation and exploration. Since the Adder programme is no longer available for PV project from 2010, and a capped-quota FiT was briefly introduced in 2013, the lack of further direct government supporting policy (through market-based support mechanism) stresses the fundamental institutional changes in two ways. First, the financial burden from policy expense is avoidable, as PV project feasibility will be developed based on laissez-faire principle (with minimum government intervention). Market competitiveness is then determined by the private sector. Second, the role of government is shifted to being a market regulator, which can still lead PV market growth or get pushed aside based on future policy design and choices of policy instruments.

Considering the increasing affordability of PV systems and its positive public acceptance, rooftop PV for self-consumption has been promoted as an alternative power solution with positive financial prospect. Hence, the changes in demand conditions particularly in residential and commercial sector urge financial institutions to provide appropriate financing options for different demands.

4. Challenges

In less than a decade, the PV industry in Thailand has grown significantly, having more than 2000MW installation capacity by the end of 2016. Yet, PV penetration level shares less than 2% of total electricity demand. Domestic PV market growth is highly likely to continue, but many challenges remain:

4.1 PV project uncertainties after policy termination

Power purchase agreement (PPA) contract of PV projects under Adder programme is 10 years. If the cost of electricity from PV project is not competitive to conventional power plants by that time, PV project owners may discontinue PV projects by the end of their contract. Market conditions are thus likely to play a key role in the development of the sector.

4.2 Technical issues of grid integration

Impacts from grid-connected PV projects (include all PV system sizes that can be considered as power plants which sell electricity to the grid) affect the existing grid infrastructure and management, especially at the higher PV penetration level. PV project executors also prefer land areas exposed to more solar radiation to optimise PV performance, but cost of land acquisition and government fiscal incentives can outweigh project location. In addition, BOI has location-specific investment policy as a part of rural economy development: 5-year income tax reduction and 10-year expense rebate for projects located in the designated 20 provinces. Thus, unusual PV project growth in some regions and provinces is observed. Moreover, impacts from grid-tied PV system inherit different issues. Though a prosumer, concept of self-generation and self-consumption, will strengthen the notion of energy security, particularly on a household level, a broader perspective of national grid system security may not be positive. So far, no study has been done to forecast a threshold of PV penetration level which will have adverse effect on grid system due to either grid-connected or grid-tied PV systems.

4.3 Financial issues of the fixed cost of grid system

From the utility viewpoint, a distributed PV system employed for self-consumption purpose can be perceived as two primary business threats. First threat is the lower electricity demand; the reduce in electricity sales (assuming a business-as-usual of constant electricity demand). Second threat is about the fixed cost of standby grid system; in other words, the fixed cost of service shares amongst ratepayers, and PV adopters tend to be the free riders. Therefore, the interdependence of revenue and rate impacts of the future government supporting PV monetary scheme (e.g. net metering, net billing) requires delicate analysis to minimise possible negative effects on retail electricity prices.

4.4 PV prospects

PV industry in Thailand has been very active since 2008 and will surely continue to grow; but towards what directions? A roadmap of Thailand's solar power development to 2035 proposed three scenarios: (1) domestic market boom, (2) ASEAN market leader, and (3) open and innovative market (Tongsopit, et al., 2015). All scenarios are plausible given specific drivers, namely proactive consumers, institutional arrangements, and strategic repositioning of Thai policy and industrial competitiveness. The co-existence and further market growth of both rooftop PV in residential and commercial sector, and ground-mounted utility-scale PV system are attainable, but do require different sets of policy instruments and supporting systems.

5. Summary

Thailand is a leader in ASEAN countries in terms of RE policy, and particularly solar PV technological deployment. Thus, solar PV industry is analysed to emphasise the importance of policy design, implementation, and timely policy adaptation. Applying a framework of sectoral systems of innovation, the dynamics and co-evolution of three elements: (1) knowledge and technological domains, (2) actors and networks, and (3) institutional factors are studied, which revealed structure and interactions embedded within Thailand's PV industry. Indeed, policy-induced technological change plays crucial role in PV industry through national strategic development plan, institutional establishment and arrangement, and firm product and process innovations. But the knowledge and technological domains are often lack behind, particularly in developing countries like Thailand. Therefore, the PV policy needs a systematically, not a compartmentally, perspective and the balance of policy in technological exploitation and exploration with a timely policy adaptation. Furthermore, the systems approach analysis extends a discussion on PV industry development from focusing merely PV supply chain to involving collectively PV-related industries. Each nation does require to create the political and economic conditions for establishing a robust, multi-faceted policy to anticipate and accommodate such technological transition: not only for the purpose of short-term technological catch-up, but also for the long-term technological competitiveness through a vision of the knowledge-based society.

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