

Thailand PV Status Report 2014-2015



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Energy Development and Efficiency
MINISTRY OF ENERGY

Thailand PV status report committee (2014–2015)

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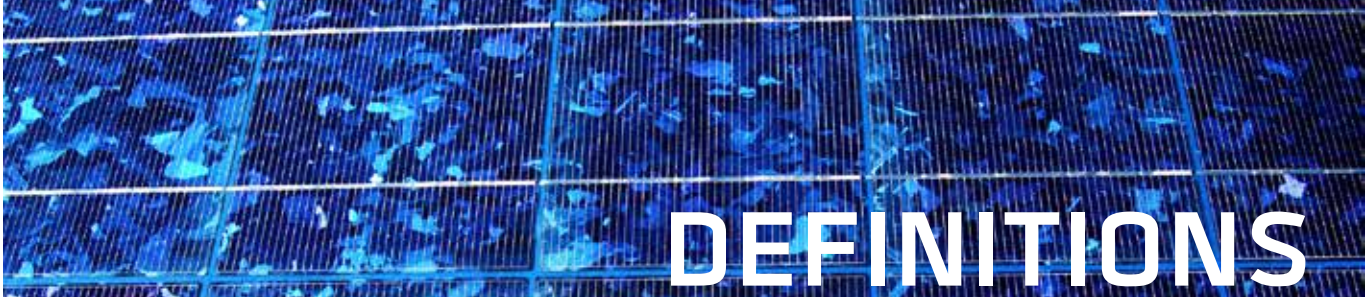
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Thailand PV status report *2014–2015*

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DEFINITIONS

Adder

An additional energy purchasing price on top of the normal prices that power producers (under the VSPP and SPP scheme) will receive when selling electricity to the Power Utilities for certain period.

FiT, Feed-in-Tariff

A fixed-rate of energy purchasing price that power producers (under the VSPP and SPP scheme) will receive when selling electricity to the Power Utilities for certain period.

Grid-connected centralized PV system

PV power production systems perform the function of a centralized power station. The power supplied by such a system is not associated with a particular electricity consumer. The system is not located to perform specific functions on the electricity grid other than the supply of bulk power, typically large scale ground mounted system, e.g. solar farm.

Grid-connected distributed PV system

PV systems installed on or integrated into consumers' premises usually on demand side of electricity meter, on public and commercial buildings to provide power to a grid-connected consumer or directly to the electricity grid, e.g. solar PV rooftop.

Off-grid domestic PV system

PV systems installed to provide power mainly to a household or village, not connected to the utility grid.

Off-grid non-domestic PV system

PV systems used for a variety of industrial and agricultural applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to the utility grid.

SPP

Small Power Producer supplying the electricity to the grid by using non-conventional energy including renewable energy but excluding natural gas, oil, coal and nuclear energy, waste energy, energy based on the cogeneration principle as a primary energy source with generating capacity more than 10 MW but not exceeding 90 MW.

VSPP

Very Small Power Producer supplying the electricity to the grid by using renewable energy source such as wind, photovoltaic, geothermal energy, mini-hydroelectricity, micro-hydroelectricity, biogas, agricultural waste, municipal waste, and biomass as a primary energy source with generating capacity not exceeding 10 MW.

Capacity Factor or CF

CF expresses the percentage of the total energy produced annually compared with a multiple of installed capacity and number of hours in a year (8,760 h).

Performance Ratio or PR

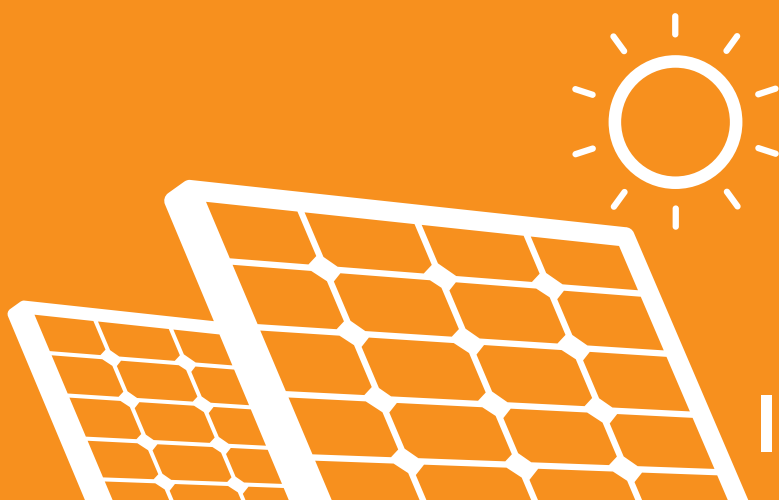
PR expresses the percentage of the total energy produced annually compared with the installed capacity and the total of solar energy annually compared with the standard solar energy, 1,000 W/m².

ABBREVIATIONS

AEDP	Alternative Energy Development Plan
BOS	Balance of System
CF	Capacity Factor
CIGS	Copper Indium Gallium Selenide
COD	Commissioning Operating Date
FiT	Feed-in-Tariff
GW	Gigawatt
kW	Kilowatt
GWh	Gigawatt-hour
kWh	Kilowatt-hour
MSW	Municipal Solid Waste
PPA	Power Purchasing Agreement
PR	Performance Ratio
PV	Photovoltaic
RE	Renewable Energy
REDP	Renewable Energy Development Plan
SPP	Small Power Producer
VSPP	Very Small Power Producer

ACRONYMS

BOI	Thailand Board of Investment
CSSC	CES Solar Cells Testing Center
CU	Chulalongkorn University
DEDE	Department of Alternative Energy Development and Efficiency
EGAT	Electricity Generating Authority of Thailand
EPPO	Energy Policy and Planning Office
ERC	Energy Regulatory Commission
KKU	Khon Kaen University
KMITL	King Mongkut's Institute of Technology Ladkrabang
KMUTNB	King Mongkut's University of Technology North Bangkok
KMUTT	King Mongkut's University of Technology Thonburi
MEA	Metropolitan Electricity Authority
NEPC	National Energy Policy Council
NSTDA	National Science and Technology Development Agency
NU	Naresuan University
OERC	Office of the Energy Regulatory Commission
PEA	Provincial Electricity Authority
PSU	Prince of Songkla University
PTEC	Electrical and Electronic Products Testing Center
PTT	The Petroleum Authority of Thailand
RMUTL	Ratjamangala University of Technology Lanna
SERT	School of Renewable Energy Technology
TISI	Thai Industrial Standards Institute
TPVA	Thai Photovoltaic Industries Association
UBU	Ubonratchathani University
UP	University of Phayao



INTRODUCTION

Developments in 2014-2015 paint an optimistic picture for photovoltaics, in both Thailand and the rest of the world. Crucial to world-wide deployment has been the manufacturing boom in China, making solar cells a competitive and viable option for producing electricity. Many records for photovoltaic installation were broken in 2014, including in Thailand.

By the end of 2014, worldwide cumulative photovoltaic capacity increased by more than 40 GW and reached approximately 178 GW, sufficient to supply 1% of the world's total electricity consumption. Major installers for 2014 remained China, followed by Japan and the United States. The UK emerged as new European leader ahead of Germany and France, while Germany still remains the world's largest producer of solar power with an overall installed capacity of 38 GW. The newcomers in 2014 were Chile and South Africa, which entered straight into the world's Top 10 ranking of added capacity. There are now 20 countries around the world with a cumulative PV capacity of more than one gigawatt. Thailand, the Netherlands and Switzerland, all crossed the one gigawatt mark in 2014.



Source : DEDE

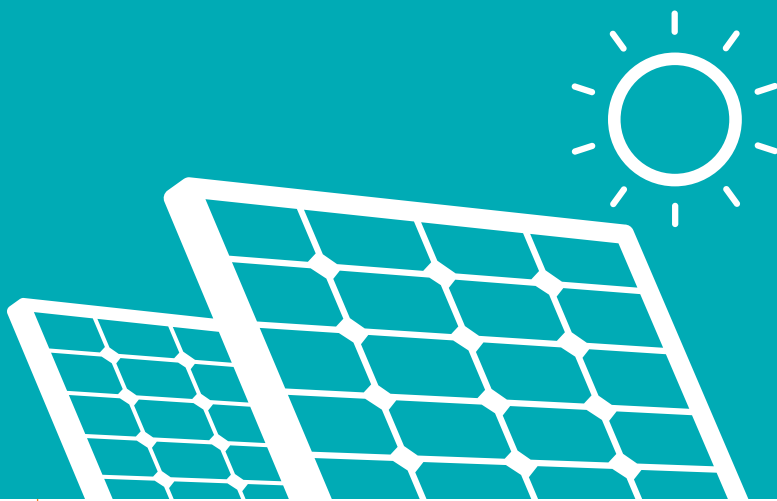
In 2015, Thailand's solar power capacity was more than all of ASEAN combined. This capacity is expected to rise to 2,500-2,800 MW by the end of 2015 from about 1,300 MW in 2014. Thailand aims to increase its solar capacity to 6,000 MW by 2036. That would account for 9% of total electricity generation. Currently, PV capacity in Italy, Germany and Greece is now sufficient to supply between 7 and 8% of their respective domestic electricity consumption. Sweden has also declared that it will work towards becoming 100% renewable. In 2015, solar power is predicted to supply 10% of California's annual power generation. Grid parity has arrived in 30 countries around the world, compared to 19 in 2014.

Various forecasts have predicted global solar photovoltaic installations to grow by 54-59 GW or roughly 30% in 2015. This corresponds to about half of the world's newly installed electricity generating capacity. Also predicted is accelerated growth for concentrator photovoltaics and an increase in the market-share of monocrystalline silicon technology over polycrystalline silicon. India is expected to install more than 2 GW, a tripling over the previous year, while the UK is forecast to reach 10 GW by early 2016.

Thailand is blessed with great solar potential. Around 14.3% of the country has a daily solar exposure of around 19–20 MJ/m²/day, while another 50% of the country gains around 18–19 MJ/m²/day. In terms of solar potential, Thailand lags behind the US, but is ahead of Japan.

Particularly noteworthy for Thailand is how the picture has changed so dramatically over the last decade. The early days of remote area and off-grid systems stood us in good stead to understand the technology and the reliability of photovoltaic systems and to introduce a new field of engineers and entrepreneurs. Installation in 2005 was almost 100% off-grid, to 2015 where it is almost 100% grid-connected. We can say with confidence that PV has arrived for Thailand.

This report highlights some of the achievements. Taking the next step will require continued strong government support, particularly in terms of incentive schemes. As can be seen from the map, considerable potential remains in the Northeast. To make best use of this potential, consideration must be given to the cost of transmission and all involved must continue working together to find practical solutions, to ensure that Thailand remains at the forefront of PV development in ASEAN. This leadership will translate into opportunities for our private sector over time.



1 | Executive SUMMARY

PV is one of the forms of renewable energy that has experienced dramatic growth in Thailand due to reduced system prices and support from government incentive schemes. Since 2010 Thailand has entered the grid-connected era and the installation of systems, particularly by the private sector, has been growing encouragingly.

PV systems in the megawatt range have been installed in the northeast and central regions taking advantage of the high potential for solar radiation. PV rooftop systems have seen the implementation of a 200 MWp project and the introduction of the FIT scheme at the end of 2013.

2014 saw a number of reforms for implementing both ground mounted and rooftop systems, through rearrangement of the 800 MWp target and the extension of commissioning dates.

2015 was the year in which many of the planned projects came into operation. Regulations covering PV systems were released and the second phase of the PV rooftop project was announced.

1.1 Installed PV power

PV installation reached 1,298 MWp cumulative capacity in 2014. This included 1,269 MWp of grid connected systems and 29 MWp of stand-alone systems. As of end-2015, cumulative capacity has reached 1,419 MWp including 1,311 MWp of PV power plants and 78 MWp of rooftop systems as well as 30 MWp of stand-alone systems.

1.2 Cost and pricing

In 2014, the majority of PV power plants were built with imported components. The average p-Si module price was 25-40 Baht/Wp and the average system price was 50-80 Baht/Wp. The range in price is established on a case by case basis, depending on the application. Module and system prices in 2015 are similar to the previous year.

1.3 Cell, component and module production

Most of the modules and grid connected inverters were imported in 2014 due to local manufacture being unable to compete with global prices. There were 5 local producers of cells and modules in 2014 and 2 companies manufacturing inverters. In contrast, 2015 has so far seen manufacturers increase locally to 14 companies, mostly involving investment from China and Taiwan.

1.4 Research and development activity

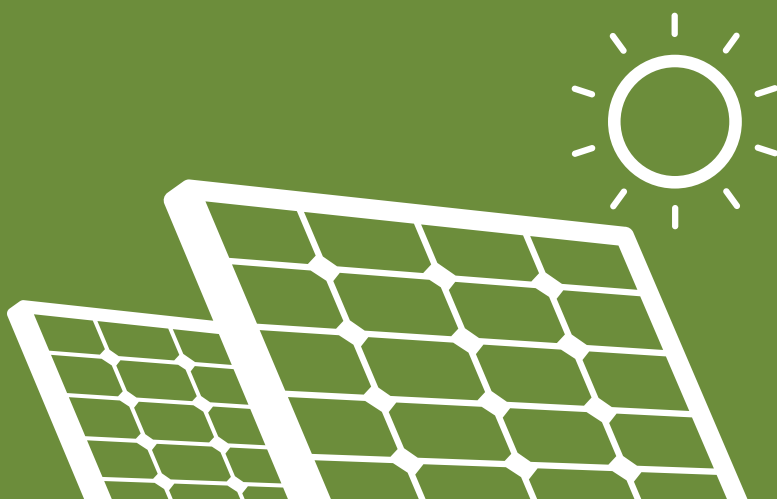
Given that Thailand has reached the gigawatt level for PV systems, focus is now turning to the implications this growth may have for the environment. Of particular concern will be electronic waste and research on the recycling of electronic waste from PV systems is being undertaken.

EGAT developed a demonstration project of a large scale PV power plant in order to better understand the behavior of electricity production using solar energy. The PEA also has plans to build a smart house using energy efficiency and renewable energy as a demonstration project.

1.5 PV business

The world market and prices resulting from mass production had a detrimental effect on local manufacturers who find it difficult to compete. It is expected that there will be an influx of foreign module manufacturers into Thailand, with about 3.5 GW production capacity.

There are currently around 35-40 companies in Thailand acting as distributors for grid connected inverters and 2 local companies manufacturing inverters.



2 | IMPLEMENTATION of PV Systems

2.1 Application of PV

Thailand has seen dramatic growth in the application of photovoltaic systems. From early beginnings with off-grid remote area power supplies, currently there are a number of commercial solar farms and the popularity of rooftop systems has also increased.

In the past, following two decades of PV application, there were approximately 30 MWp of off-grid systems comprising water pumping, battery charging stations, electricity supply for rural schools, solar home systems and hybrid systems. Grid connection encompassed only 20 MWp.

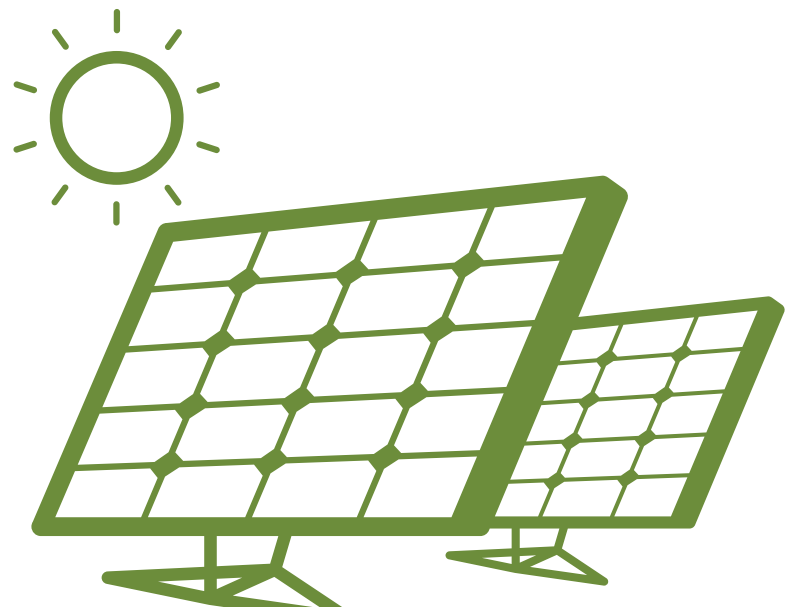
All of this changed in 2010, when manufacturing costs were down and incentives were up, encouraging private investors to enter the market for PV power plants. By 2014 power plants dominated installations, followed by rooftop systems. This was due in part to a resolution of the National Energy Policy Council in 2014 to further promote solar energy.

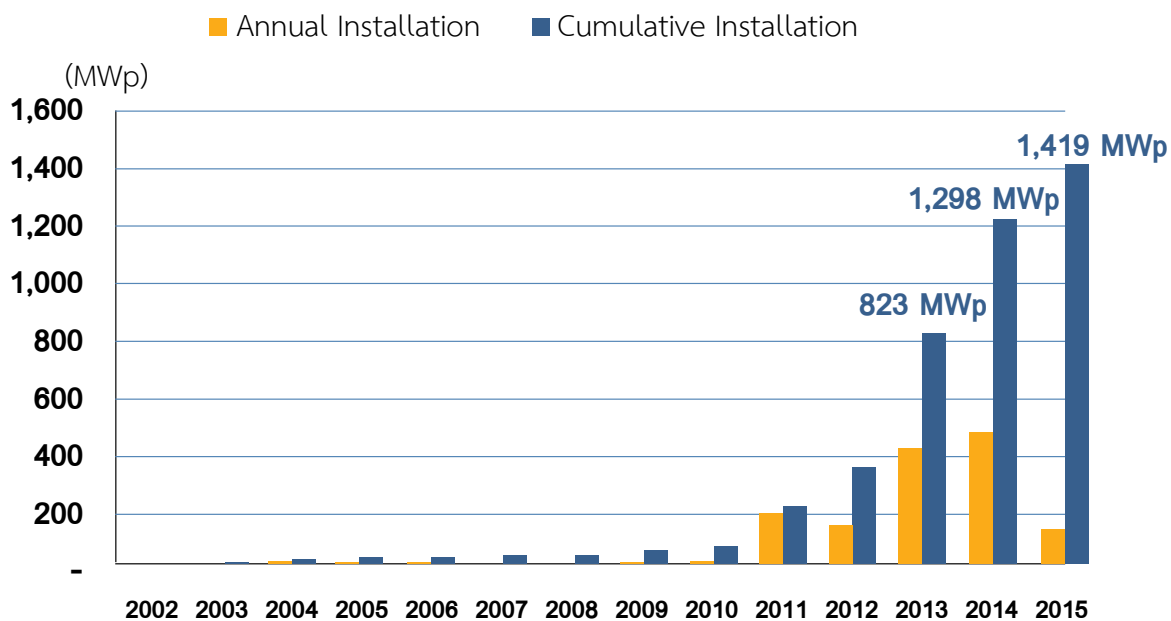
2.2 Installed Capacity of Photovoltaic Systems

In 2014, the total electrical energy generation capacity in Thailand was 35,668 MW and the cumulative installed capacity of PV was 1,298 MWp. In that year a total of 706 MW was installed from renewable sources (PV, wind, hydro, biomass, biogas and municipal solid waste), making up 12% of total generation. Biomass was the major source, followed by PV and biogas. 2014 also saw the end of the adder incentive.

For PV applications in 2014 there were 1,269 MWp of grid connected systems and 29 MWp of off-grid. The grid connected applications include power plants and rooftop systems, the latter promoted under a 200 MWp project. Annual installation was 475 MWp, about the same as the previous year. As at end-2015, installed capacity has reached 1,389 MWp of grid connected systems and 30 MWp of off-grid.

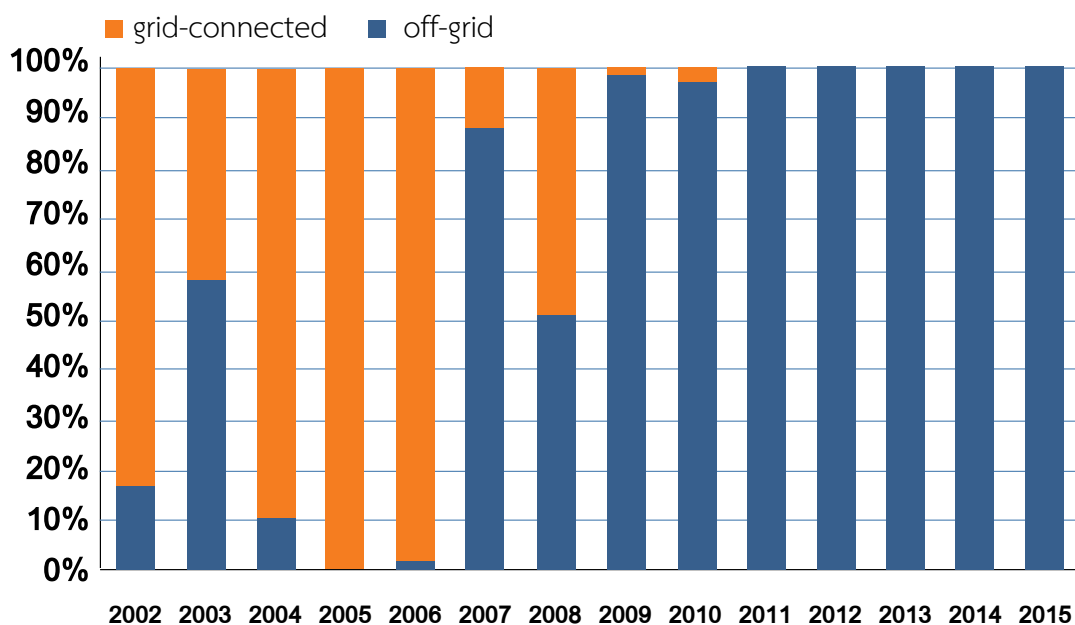
The Alternative Energy Development Plan revised targets in 2015, from 3,000 MWp to 3,800 MWp for PV installations. This was part of a new Power Purchase Agreement for PV power plants. Currently there are 800 MWp of government and agricultural cooperative ground mounted systems. A new target of 100 MWp for residential systems was also announced in February 2015.





Source: This data was provided by DEDE, EGAT, PEA, MEA and OERC.

Fig.2.1 : Cumulative PV systems installation in Thailand as of end-2015



Source: This data was provided by DEDE, EGAT, PEA, MEA and OERC.

Fig.2.2 : Cumulative Grid Connected and Off-grid PV systems installation in Thailand as of end-2015

2.3 Electricity Generated from Grid Connected Photovoltaic Systems

Total electricity consumption in 2014 was 168,656 GWh, while generation was 180,945 GWh. Of this, generation sourced from renewable resources was 7,647 GWh, with PV contributing 1,928.66 GWh. This included 368.33 GWh from SPP and 1,560.33 GWh from VSPP.

2.3.1 SPP Projects

SPP incorporates large PV systems as power plants, with generation capacity between 10-90 MWp. It was first introduced on a commercial basis in December 2011 following the installation of a 55 MWp plant by Natural Energy Development (NED). This was followed in 2012 by a 30 MWp plant operated by Bangchak Solar (BSE) and a larger plant of 126 MWp by Absolute Solar, located in Nakhon Sawan. Both NED and BSE have since increased their capacity to 73.16 and 35.64 MWp, respectively.

In January 2015 Sarm Sam Palung Ngaun commenced commercial operation with a 52 MWp plant in Lopburi. In February of the same year, EA Solar commenced production with a 128.39 MWp plant in Lampang. Tables 2.2 and 2.3 show PV SPP installation from 2011 – 2015 and their annual electricity production, respectively

Table 2.1 : PV electricity generation capacities between 2012 and 2014 (Gwh)

Year	SPP	VSPP	Total
2012	120.37	319.48	439.85
2013	161.37	781.60	942.97
2014	368.33	1,560.33	1,928.66
Total	650.07	2,661.41	3,311.48

Source: SPP electricity generation from EGAT, VSPP and PV rooftop electricity generation from PEA.

Table 2.2 : SPP Power Plants of PV in Thailand, 2011 – 2015 (MWp)

PV Plant	Location	Installation Capacity (MWp)	COD date
NED	Lopburi	73.16	Dec 2011
BSE	Ayutthaya	35.64	Jul 2012
EA Solar	Nakhon Sawan	126.12	Dec 2013
Sarm Sam Palung Ngaun	Lopburi	52	Jan 2015
EA Solar	Lumphang	128.39	Feb 2015
Total		415.31	

Source: This data was provided by OERC and EGAT.

Table 2.3 : Electricity production of SPP for PV Power Plant in Thailand (GWh)

PV Plant	Location	Year			Total
		2012	2013	2014	
NED	Lopburi	97.71	108.43	114.44	320.58
BSE	Ayutthaya	22.66	52.93	55.37	130.96
EA Solar*	NakhonSawan	-	-	198.50	198.50
Total		120.37	161.36	368.31	650.04

Source: This data was provided by EGAT. EA Solar* commenced commercial operation in December 2013.



Fig. 2.3 : 35.64 Mwp at Bang Pa-In district, Ayutthaya, which commenced commercial operation in July 2012 (Photo: Bangchak Solar Energy Co., Ltd.)

2.3.2 VSPP Projects

VSPP includes smaller power plants where less than 10 MWp is produced. In 2014 VSPP produced a total capacity of 965.80 MWp (incorporating 242 projects). VSPP holds the major market share with 80.5% of total PV capacity. Table 2.4 ranks the top 10 VSPP producers for 2014, taking up 732.46 MWp of capacity and incorporating 111 projects. Only minor change is expected in this ranking for 2015.

In July 2015 the total capacity for VSPP increased to 1,126 MWp, including 967.33 MWp of commercial operations (244 projects). Agreements for power purchase still outstanding include 10 MWp (signed) and 148.67 MWp (awaiting signature).

Table 2.4 : Top 10 PV VSPP Power Plants in Thailand (MWp).

Company	Ranking in 2014 (2013)	2013		2014	
		Capacity (MWp)	Project	Capacity (MWp)	Project
Solar Power	1 (1)	129.48	23	228.91	36
BSE	2 (4)	32	4	124.78	10
Siam Solar Energy	3 (2)	40	5	91.16	10
EGCO Engineering	4 (6)	30	4	72.40	6
Gunkul Engineering	5 (5)	30.90	6	61.70	10
Solarta	6 (3)	35	8	35.22	8
Bangkok Solar Power	7 (7)	27.25	12	33.38	13
Thai Future Energy	8 (-)	-	-	30.23	6
Rojana Energy	9 (-)	-	-	28.62	3
Siam Solar Generation	10 (9)	22.5	9	26.06	9
Total				732.46	111

Source: This data was provided by OERC.



Fig. 2.4 : 6.12 MWp at Non Song district, Nakhorn Rachasima province commenced commercial operation in April 2010. (Photo: Solar Power Co., Ltd.)

2.3.3 Rooftop Systems

PV rooftop systems have been introduced in urban areas since 1997. The systems were constructed and installed by EGAT following subsidy from the National Energy Planning Office. The first phase of the rooftop project was 23.76 kWp covering 10 houses, while the second phase is 154.34 kWp for 50 houses. The net metering scheme applied to these systems.

In September 2013, rooftop systems were promoted using the FiT incentive, with a target of 200 MWp installation capacity. Initial acceptances totaled 133 MWp by January 2014, following which some applications were cancelled. Generally, both the government and the private sector found that civic legislation had not kept pace with energy developments, while they were also faced with other technical issues. The commissioning operating date was extended to the end of June 2015 while these problems were addressed.

As of August 2015, the capacity of rooftop systems, including COD, PPA and acceptance of power purchasing totaled 113.86 MWp. This comprised 20.12 MWp for residential buildings, 13.81 MWp for small and medium commercial buildings and 79.93 MWp for large commercial factories. Table 2.5 shows the status of PV rooftop systems to mid-2015.

The second phase of the rooftop program commenced in February 2015. This phase aims to facilitate the installation of residential systems (< 10 kWp) under the previous target of 200 MWp. These systems were expected to be operational by the end of 2015.

PV rooftop systems have the option of selling electricity direct to the grid or using the electricity produced directly, such as that shown in Figure 2.5.

Table 2.5 : The 1st phase of PV rooftop system with FiT incentive in the middle of 2015

	Residential (≤ 10 kWp)	Small and Medium commercial (>10 – 250 kWp)	Large/ Factory (>250 – 1,000 kWp)	Total
Target, MWp	100		100	200
Signed contract 2013:	31.78		100	131.78
MEA, 80 MWp	40		40	80
August 2015 (Project)	3.37 (514)		36.87 (98)	40.16 (612)
Total		8.92 (63)	27.95 (35)	
: COD	2.43 (369)	8.79 (61)	26.24 (33)	37.46 (463)
: PPA	0.94 (145)	0.13 (2)	1.70 (2)	2.70 (149)
PEA, 120 MWp	60		60	120
July 2015 (Project)	16.75 (2,020)		56.87 (86)	73.63 (2,106)
Total		4.89 (29)	51.98 (57)	
: COD	3.69 (462)	3.36 (19)	34.31 (37)	41.36 (518)
: PPA	13.06 (1,558)	1.53 (10)	17.67 (20)	32.26 (1,588)
Total 200 MWp	20.12 (2,534)		93.74 (184)	113.86 (2,718)
Total		13.81 (92)	79.93 (92)	
: COD	6.12 (831)	12.15 (80)	60.55 (70)	78.82 (981)
: PPA	14 (1,703)	1.66 (12)	19.37 (22)	35.03 (1,737)

Source: This data was provided by PEA, MEA and OERC.



Fig. 2.5 : 49 kWp of PV rooftop system on the business building, at Tha laan district, Saraburi province and operated in June 2014 (Photo: Sci Eco Services Co., Ltd.).

2.4 Off-Grid Systems

More than 20 years ago, off-grid systems were introduced to rural areas to produce electricity for lighting, water pumping and various appliances. These systems met various needs in remote areas such as battery charging, pumping and solar home systems. As these areas are connected to the grid, PV systems are usually relocated to other areas, so capacity may vary from year to year. In 2014, Thailand had 29.15 MWp of off-grid systems installed and these applications are shown in Table 2.6.

Other off-grid applications in Thailand include hybrid systems, commonly used in remote areas. These include PV-wind-diesel generators and PV-micro hydro-diesel generators. Quite a number of demonstration projects using this type of system are installed in national parks and wildlife sanctuaries. Table 2.7 illustrates some examples of hybrid systems, totaling 100 kWp for PV in 2014. It is expected that in 2015 a number of mobile type hybrid systems will be introduced in the national parks. These should include about 20 kWp of PV.

Table 2.6 : PV off-grid systems applications in 2015

Applications	Project number (systems)
Rural school (2.5-5 kWp)	326
National parks and forests	75
Community learning center	226
Royal project	158
Battery charging systems	367
Solar pumping systems	134
Total	1,286

Source: This data was provided by DEDE.

Table 2.7 : Typical PV hybrid systems application in rural areas

Location	PV (kwp)	Wind turbine (kw)	Diesel generation (kw)	Battery (kwh)
Bann Kohjig, Chanthaburi province	47.5	10	50	240
Ramkhamhaeng National Park, Sukhothai province	2	-	3	30.6
Khao Nang Ram, Uthai Thani province	2.4	-	10	38.4
Phu Kra Dueng National Park, Loei province	25	2.5	50	240
Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani province	10.5	-	46	234
Tarutao National Park, Satun province	12.5	10	46	234
Total	99.9	22.5	205	1,017

Source: www.cesi.kmutt.ac.th



Fig. 2.6 : Stand-alone PV system, (Left) battery charging station at Doi Tung district, Chiang Rai. (Right) PV pumping system at border patrol police school at Phupan, Sakon Nakhorn. (Photo: KMUTT)

3 | INDUSTRY and Growth

Many PV power plants developed through private sector investment are now coming online and there is recognition that PV is now a reality in Thailand. Local cell and module manufacturers still await their market opportunity, more likely to be filled by government supported projects. This growth has been aided by demonstration projects, research on long term performance for megawatt scale installations, as well as research on improving system performance.

While PV system application, especially grid connected power plants, is a relatively new experience for Thailand in terms of incentive schemes, the technology has been familiar for some time. Local module manufacturers have suffered due to the number of turn-key power plant installations and the upstream and downstream aspects of the industry not being balanced. Some relief for local manufacturers is expected in 2015 with the introduction of a number of government projects.

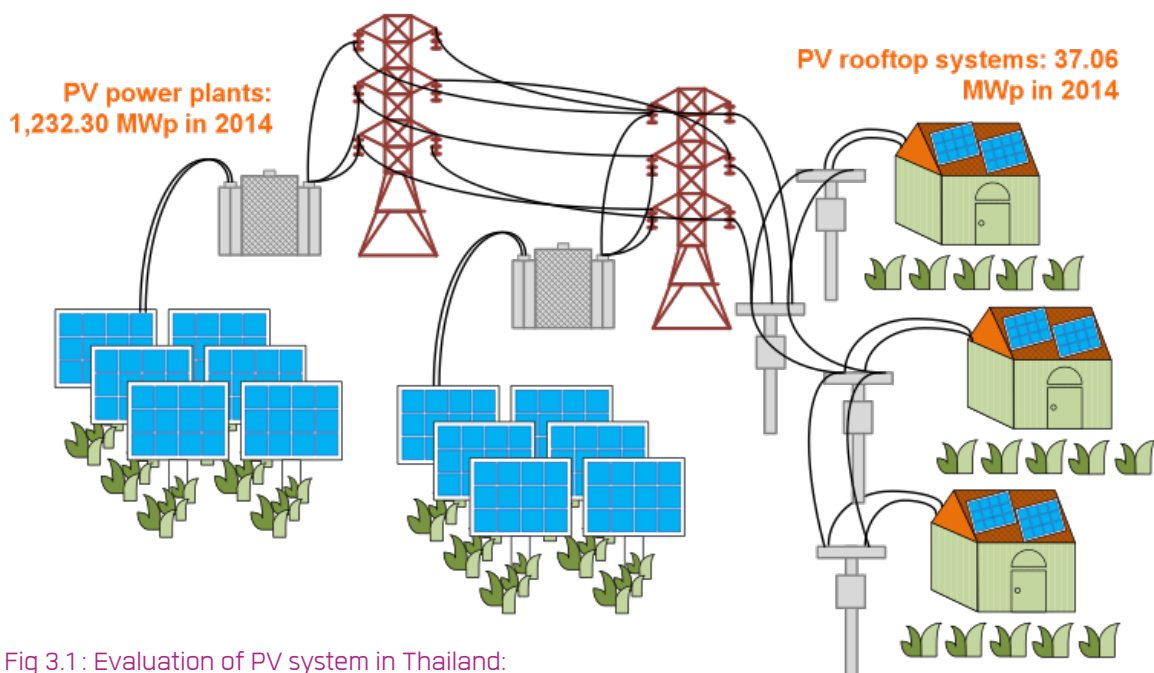


Fig 3.1: Evaluation of PV system in Thailand: from PV power plants to PV rooftop systems

PV installation capacity is totaling 1,269 MWp in 2014 and 1,389 MWp in 2015.

3.1 Development of PV Cell and Module Production

Local module manufacturers were established in Thailand some 10 years ago in anticipation of government support for widespread solar home systems. Unfortunately this initiative stagnated for some time until power plants became popular in 2011.

In 2013, Thailand had a total of 6 module manufacturers and this was reduced to 5 in 2014 when Sharp Thai ceased production. It is expected that there will be 7 new module manufacturers entering the Thai market in 2015. Table 3.1 shows cell and module production in 2014-5.

While Thailand has some metallurgical grades of silicon for export, most local manufacturers import wafers and cells. Local production of feedstock, ingots and wafers are not available.

Table 3.1: Cell and module production in 2014 – 2015

Manufacturer	Silicon	Total Production (MW)			Module production capacity (MW/yr)
		PV Cell	Wafer-based module	a-Si* module	
In 2014 :					
Bangkok Solar	-	-	-	2	65
Ekarat Solar	-	12	10	-	50
Fullsolar	-	-	0.8	-	25
Solartron	-	45	55	-	70
Spot	-	-	2	-	25
			67.8	235	
G.S. Energy	Metallurgical grade	-	-	-	45,000 tonne/yr
Siga New Meterials	Metallurgical grade	-	-	-	30,000 tonne/yr
In 2015 : new PV module manufactures					
Gintech		n/a	n/a	-	1,000
G.K.		-	84	-	84
Jetion Solar		✓	✓	-	250
Schutten Solar		n/a	✓	-	500
Sunpower Solar		n/a	n/a	-	800
Trina Solar		700	500	-	500
Yingli Solar		n/a	n/a	-	500
		700	584	3,634	

Source: This data provided by local manufacturers and BOI as of August 2015.

* means amorphous a-Si.

3.2 Module and System Pricing

The major components of PV systems in Thailand are imported. Most modules are imported from China (poly-Si), Japan (poly-Si and CIGS), Taiwan (a-Si), and Germany (mono-Si and poly-Si).

Module prices in 2014 were 35-50 Baht/W and this dropped in 2015 to 25-40 Baht/W. Pricing is established on the installation capacity. Table 3.2 shows the evolution of PV pricing between 2012-5 for small (typical) and large (best price) orders.

Table 3.3 illustrates the system prices for different applications between 2010 and mid 2015. The variations in system pricing are due to maintenance cost, warranty of product output, as well as data monitoring systems.

Inverters are also a major component of systems. Thailand had one manufacturer of inverters or balance of system (BOS) which was Leonics, who are also well known in the Malaysian market. In 2014, Thai Tabuchi Electric also started manufacturing BOS.

When the government announced the 200 MW target for rooftop systems in 2013, providing FiT incentives for up to 25 years, a considerable boost was given to the market for BOS and a total of 36 companies have so far entered the Thai market.

Table 3.2 : Typical module prices for a number of years

Year	2012	2013	2014	2015
Typical module price (THB/Wp)	70-80	50-60	35-50	25-40
Best price (THB/Wp)	50-60	35-45	20-25	

Source: This data provided by power plant owners and PV module distributors. This module price is for poly-Si type.

Table 3.3 : Trend of system prices for different application

Year	2010-2012	2013	2014	2015
Residential PV systems (<10 kW, THB/Wp)			65-100	60-100
Commercial and industrial PV system (> 10 – 1,000 kW, THB/Wp)	n/a	90-150	60-65	50-55
system (> 1 MW, THB/Wp)	110*	60-100	40-60	30-50

Source: This data provided by PV module distributors. This module price is for poly-Si type including the installation cost. * is the installation capacity over 30 MWp.

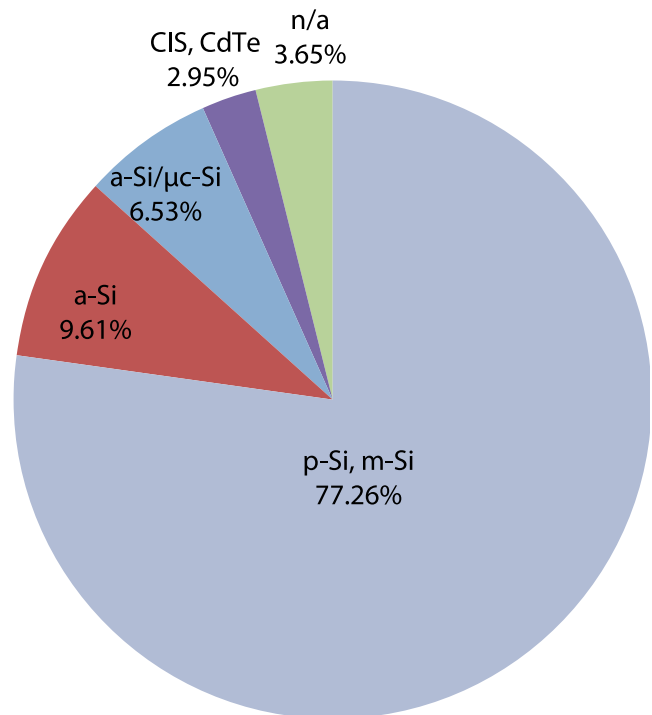
3.3 PV Industry

The PV industry in Thailand had 1,419 MWp of installation capacity, as at end 2015, mostly power plant and imported systems.

Research has also been supported by the private sector whose focus has been on cell and module production, as well as improving performance. The focus of government research institutes has been more on building a knowledge base, particularly for applications, monitoring, as well as new materials for cells and modules.

Currently the focus of PV activities in Thailand is on power plants or solar farms, while there is also a smaller focus on rooftop systems. EGAT has already commenced a project to improve transmission lines in support of renewable energy generators. Distribution lines have also been improved by PEA and MEA. Rooftop systems are particularly attractive due to the double benefit of energy saving through reduced heat gain into the building via the roof.

Figure 3.2 shows the share of PV technology currently employed by power plants in Thailand. The most popular modules incorporate crystalline silicon technology, both mono and poly crystalline. Amorphous silicon is the second most popular, followed by copper indium selenide, cadmium telluride and micromorph.



Source: This data provided by OERC.

Fig 3.2 : Share of PV module technology in PV power plant in 2015

*p-Si : polycrystalline silicon,
m-Si : monocrystalline silicon
a-Si : amorphous silicon
a-Si/μc-Si : amorphous silicon
on microcrystalline silicon,
CIS : copper indium selenide
CdTe : Cadmium Tellurine*

3.4 Research, Development and Demonstration Activities

With the introduction of commercial power plants, the private sector is playing an increasing role in RD&D. Activities are divided into 4 major groups; solar cells and related materials, components, applications and policy.

Cells and related materials covers mainly silicon ingots, TCO glass, thin film silicon, silicon hetero-junctions and CIGS, as well as organic and dye sensitizing.

Research on PV components focuses on grid and stand-alone hybrid systems and inverters. Applications RD&D includes powers systems evaluation, as well as techno-socio-economic management of systems in rural areas. In addition, research was undertaken for the government to produce a Solar PV Road Map.

Much of the research undertaken by the private sector focused on improving their productivity of both solar cells and module production, as well as system evaluation. Government research institutes and universities worked more towards building a knowledge base, such as analyzing performance and degradation of systems under tropical conditions.

With the rapid expansion of commercial power plants, consideration is now being given to the potential environmental effects of electronic waste. The Thailand Research Fund (TRF) has joined with EGAT initiating a project to investigate the potential for PV recycling, as well as best practice for maintenance of power plants.

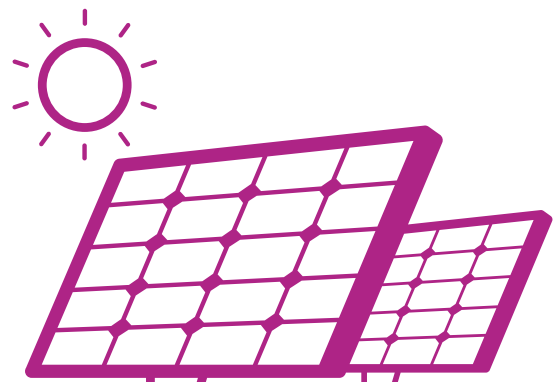


Table 3.4 : R&D activity in PV

Research topics	Company/Agency
Solar cells and related materials	
- Silicon ingot	UEE
- Silicon Hetero-junction solar cell	NSTDA
- Thin film Si (a-Si based and Micromorph)	NSTDA
- CIGS	CU
- Organic and dye sensitized	CU, KKU, UBU, PSU, KMUTNB, KMUTT
- Perovskite solar cell	NSTDA, SU
PV components	
- Inverters in grid and stand-alone hybrid systems	Leonics
- Inverters in grid-connected systems	Thai Tabuchi Electric, Leonics
PV applications	
- PV systems demonstration and assessment	NSTDA, KMUTT, NU, RMUTL, RMUTT, UP, CMRU, EGAT, PTT
Policy and measure	
- Solar PV roadmap	CU

Source: This data provided by NSTDA, KMUTT and DEDE.

PV has also been given a considerable boost due to EGAT's 5 MW demonstration project. This is not only a system demonstration, it is a renewable energy learning centre as it incorporates power generation from solar, wind and biogas. The demonstration house developed by PEA is aimed at encouraging consumers to adopt a 'smart life' using renewable energy.

In addition, the implementation of numerous power plants of various design has enabled the establishment of monitoring and evaluation systems research to improve performance and efficiency through the estimated 25 year life cycle. Table 3.5 shows research topics over the last two years on PV systems.

Table 3.5 : PV system demonstration and assessment research

Research topics	Organization
Environmental effects	NU, NSTDA, CU
Evaluation of off-grid system	DEDE
Impact of PV penetration	CU, EGAT, PEA, KMUTT
Improving the PV performance	KMUTT, NSTDA
Long term monitoring	NSTDA, KMUTT
Loss analysis	NSTDA
PV floating plant	EGAT, KMUTT
PV systems monitoring and evaluation	NU, DEDE, KMUTT, NSTDA, UP, EGAT
Smart grid and smart mini grid	PEA, NU, NSTDA, KMUTT, UP, EGAT
Tracking system	NU, EGAT

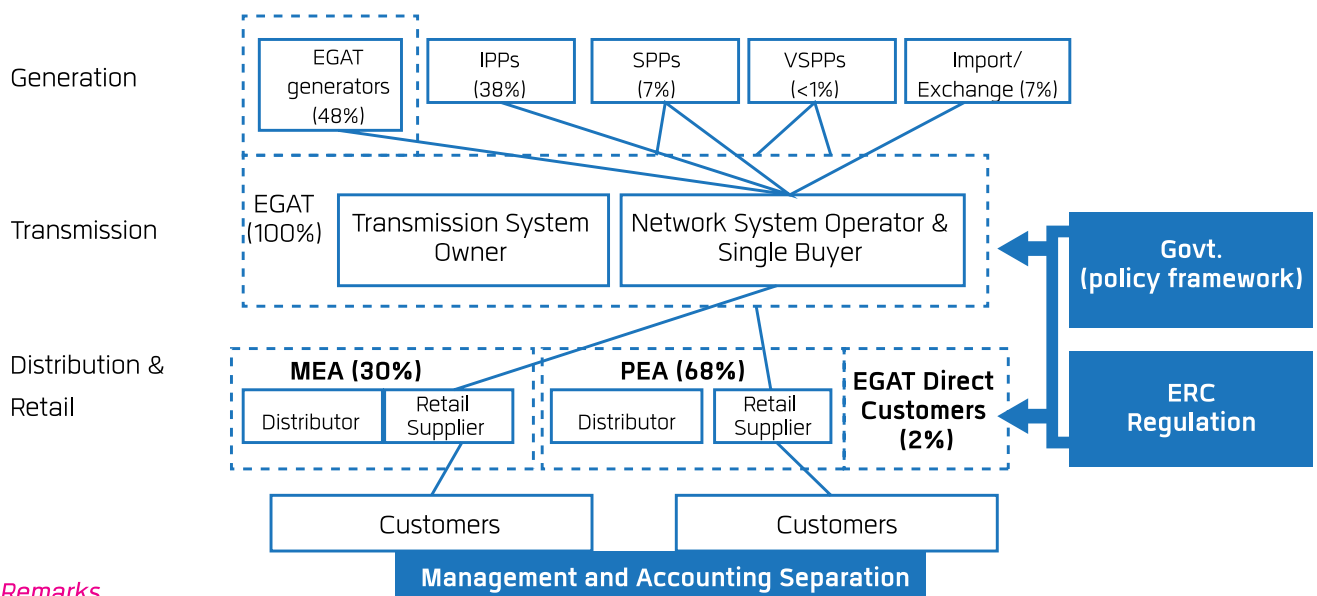
Source: This data provided by NSTDA, CSSC and DEDE.

3.5 Electricity Power Systems

The electrical system in Thailand (Fig. 3.3) consists of generation, transmission and distribution. Generation includes Independent Power Producers, Small and Very Small Power Producers, EGAT and import from neighbouring countries. Transmission systems are the sole responsibility of EGAT.

Distribution systems are managed by two other utilities with the Metropolitan Electricity Authority servicing Bangkok, Nonthaburi and Samut Prakarn, while the Provincial Electricity Authority is responsible for the rest of the country.

In addition there is an Energy Regulatory Commission overseeing the interests of power producers as well as consumers, including quality monitoring, compliance and networking.



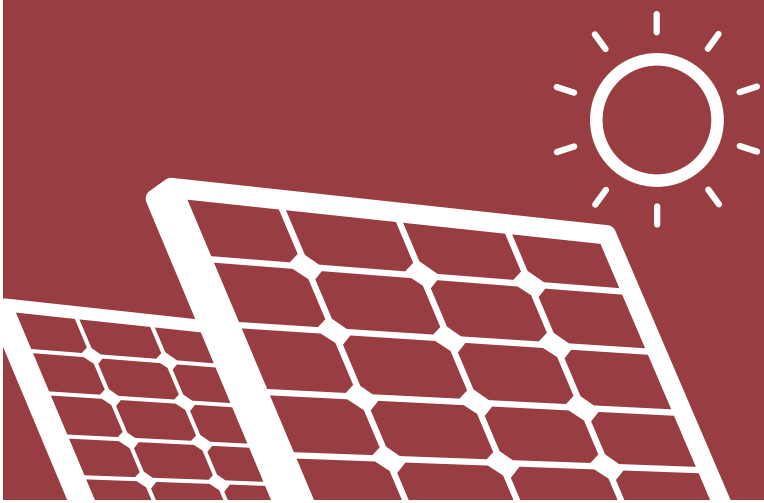
Remarks

EGAT = Electricity Generating Authority of Thailand
 MEA = Metropolitan Electricity Authority
 PEA = Provincial Electricity Authority

IPPs = Independent Power Producers (Capacity sold to EGAT > 90 MW)
 SPPs = Small Power Producers (Capacity sold to EGAT ≤ 90 MW)
 VSPPs = Very Small Power Producers (Capacity sold to MEA/PEA ≤ 10 MW)

Source: This data provided by OERC, DEDE and EGAT, and market share as of December 2014.

Fig 3.3 : The structure of the electricity power system in Thailand.



4 | Framework for DEPLOYMENT

The July 2013 updated target of PV system installation was increased to 3,000 MW under the 10-year Alternative Energy Development Plan (AEDP 2012-2021). Under the first phase of the PV rooftop program with FiT scheme, the deadline was also extended to June 2015.

Following a NEPC resolution, a new FiT scheme for PV power plants was introduced. The new scheme was applied to power plant developers who had submitted applications, but had not yet received a power purchasing agreement (adder). The NEPC suspended all new applications in June 2010 and the adder scheme has since been phased out.

The adder, or feed-in premium, for solar energy was an incentive scheme where the adder was paid on top of the normal tariff for 10 years. This scheme concluded at the end of 2013. The adder scheme was originally rated at 8.00 Baht/kWh in 2007. In 2012, the rate of this adder was reduced to 6.50 Baht/kWh, while the 10-year support duration remained intact. Eventually the adder scheme was replaced by the FiT scheme for PV. The FiT scheme is also applied for other forms of renewable energy with competitive bidding.

The 2nd phase of the PV rooftop program commenced in 2015 with a new FiT rate for residences with <10 kWp capacity. Also in 2015, the target for PV installation was increased to 3,800 MW.

To support these initiatives, the FiT scheme was introduced and adopted for PV rooftop and ground mounted systems with 25 years duration. The rates for both systems are Baht 6.01-6.85 per kWh and Baht 5.66 per kWh, respectively. At the same time, the commercial operation date for 1st phase projects was postponed to June 2015, due to problems faced with regulations for grid connection.

Other ground mounted systems attracting FiT incentives are projects of government agencies and agricultural cooperatives, which attract Baht 5.66 for the 25 year duration. This target of 800 MWp was also changed from ground mounted units for communities.

4.1 Policies and Incentives

A new resolution from the NEPC was launched on 15 August 2014, announcing a new FiT scheme with new rates in support of PV installations. This is shown in Table 4.1 and includes:

- A new phase for PV power plants whose applications had been suspended since July 2010. The new commercial operation date now finishes in December 2015.
- The introduction of the 2nd phase of the PV rooftops program. Only systems of less than 10 kWp are eligible and the commercial operation date ends in December 2015.
- The Government Agency and Agricultural Cooperatives Program, with a target of 800 MWp, replaced the solar community project. Commercial operation also ends in December 2015.

Table 4.1: New feed-in tariff of PV systems

	Installation Capacity	FiT rate (THB/W)	Capacity Factor** (%)	Supporting duration (year)
PV power plant	≤ 90 MWp	5.66	16	25
PV rooftop:				
Residential	≤ 10 kWp	6.85*	14.84	25
Small and medium commercial	> 10 – 250 kWp	6.40*		
Large commercial /Factory	> 250 – 1000 kWp	6.01*		
PV ground mounting (Government Agency and Agriculture Cooperative)	≤ 5 MWp	5.66	16	25

Source: This data is according to the NEPC Resolution of August 15th, 2014

* FiT Premium (0.5 Baht/kWh) plus normal FiT rate, only for Southern border provinces, and 4 districts (Jana, Thapa, Sabayoi and Natawee) in Songkla province.

** Capacity Factor or CF expresses the percentage of the total energy produced annually compared with a multiple of installed capacity and number of hours in a year. All exceeding kWh will be remunerated with a 12 months average of the wholesale electricity rate that EGAT sells to PEA plus fuel tariff surcharge average wholesale (averaged Ft).

Table 4.2 : Renewable energy target evolution between 2007 and 2015 (Mwp)

RE Technology	15 Year REDP	10 Year AEDP (2013)		Draft AEDP 2015
	2007 – 2022	2012 – 2021		2015 – 2036
	Target	Target	New Target*	Target
Biomass	3,700	3,630	4,800	5,570
Biogas	120	600	600	600
Biogas from energy crop			3,000	680
Solar	500	2,000	3,000 (3,800 in 2014)	6,000
Wind	800	1,200	1,800	3,002
Waste (MSW)	160	160	400	500
Small/Microhydro	324	1,608	324	376
New Energy	3.5	3	3	0.3

Source: This data provided by DEDE.

4.2 Indirect Policy Issue

While PV power systems development has been growing at a dramatic rate due to government policies and incentives for renewable energy, at the same time a number of indirect policies have also influenced this development.

- The Department of Industrial Works (DIW) announced an amendment to regulations for factory operation wherein PV power systems with a capacity of less than 1,000 kWp installed on the rooftop, deck or integrated into the building, are not considered as being part of the factory. System owners are required to register with the ERC to benefit from the FiT incentive scheme.

- A number of lessons have been learnt by owners and utilities that are beneficial to future installations. In May 2014 a Code of Practice for PV power systems was released by ERC. This provides recommended processes for project preparation, installation and operation, as well as environmentally friendly end-of-life management.

- To promote the local industry, the Board of Investment announced incentives waiving import duty on PV-related manufacturing machinery, as well as an 8 year corporate income tax holiday for 100% of investment cost (excluding land and working capital). Tables 4.3 and 4.4 show the BOI investment support for PV activities, including solar cells and related equipment, solar power plant and for the manufacture of solar cells, fabrication of modules and related equipment, respectively.

- The Department of Industrial Works is working on a new ministerial regulation for commercial building modifications. Under this proposal, a building will not be considered for modification unless it has a license incorporating PV rooftop installation. This is expected to be introduced towards the end of 2015.

Table 4.3 : BOI investment support for solar cells and related equipment and solar power plant

Year	Solar power plants			Solar rooftop systems		
	Project	Capacity (MW)	Capital cost (million THB)	Project	Capacity (MW)	Capital cost (million THB)
to 2011	107	541.4	63,742	-	-	-
2012	78	621.5	57,073	-	-	-
2013	35	139.0	18,661	10	6.2	62
2014	1	1.0	80	129	70.8	4,053
Total	221	1,302.9	139,556	139	77.0	4,115

Source: This information was provided by BOI.

Table 4.4 : BOI investment support for manufacture of solar cells and fabrication of modules and related equipment

Year	Projects	Capacity (MW)	Capital cost (million THB)
2004	2	30	500
2005	2	25	100
2006	2	40	2,400
2007	2	39	2,000
2008	1	30	1,800
2012	1	8	10
2013	-	-	-
2014	1	120	690
2015 (as of August)	4	2,438	34,439.1
Total	15	2,730	41,939.1

Source: This information was provided by BOI.

4.3 Standards, Code and Testing Service

The Thai Industrial Standards Institute announced three volunteer standards affecting module testing, design qualification and type approval, as well as safety qualification. The three standards are TISI 1843-2553, TIS 2210-2555 and TIS 2580-2555.

The following standards from TISI have been applied to system installation, particularly for government projects:

- TIS 2606-2557 (IEC 61727 adapted) and TIS 2607-2557 (IEC 62116 adapted) for grid connected systems.
- Utilities Grid Code: MEA and PEA.
- TIS 2603:1-2556 (IEC 62109-1 adapted) for the safety of power converters used in PV power systems – Part 1: General requirements.
- TIS 2603:2-2556 (IEC 62109-2 adapted) for the safety of power converters used in PV power systems – Part 2: Particular requirements for inverters.

Recommendations for PV system installation correspond with IEC standard IEC 60364-7-712 (TIS 2572-2555). This is the same as IEC 62446: Grid connected photovoltaic systems – minimum requirements for system documentation, commissioning tests and inspection. In addition, grid converters have to be certified as complying with utility codes, which usually includes a combination of IEC 61727:2004 and IEC 62116:2008 or IEEE 1547 and UL 1741, or others accepted by the utility.

PV modules and inverters are the main target for testing in grid connected systems as they require a test report or certification as a requirement for financing by banks and for inclusion in the terms of reference for government sponsored projects. Battery testing is also requested for off grid systems.

Table 4.5 : TISI standards for PV modules and grid-connected inverters

	TIS standard	Harmonization standard	Announce in the royal gazette
PV module	TIS 1843:2553	IEC61215:2005	2011
	TIS 2210:2555	IEC61646:2008	2013
	TIS 2580-1:2555	IEC61730-1:2004 and am.1:2011	2013
	TIS 2580-2:2555	IEC61730-2:2004 and am.1:2011	2013
Grid-connect inverter	TIS 2606:2557	IEC 61727	2014
	TIS 2607:2557	IEC 62116	2014
PV systems installation	TIS 2572:2555	IEC60364-7-712	2012

Source: This data provided by KMUTT, according to TISI standards.

There are numerous international standards for PV modules, the ones being referred to most being IEC. However, local standards and testing (mostly based on IEC) are required in certain local government projects. Qualified local PV module testing facilities are the CSSC (accredited laboratory complying with ISO/IEC 17025) at KMUTT and the PTEC at NECTEC.

Inverter testing is undertaken according to IEC standards, as well as regulations provided by MEA and PEA. This testing may be provided by CSSC of KMUTT, KMITL or SERT at Naresuan University. Table 4.6 shows the locally available testing facilities for PV and their scope.

For testing service, PV module and inverter are the main equipment in grid connected PV system that need to have the testing report or certification due to requirement of bank and term of reference in government projects while battery testing is requested for off-grid PV system.

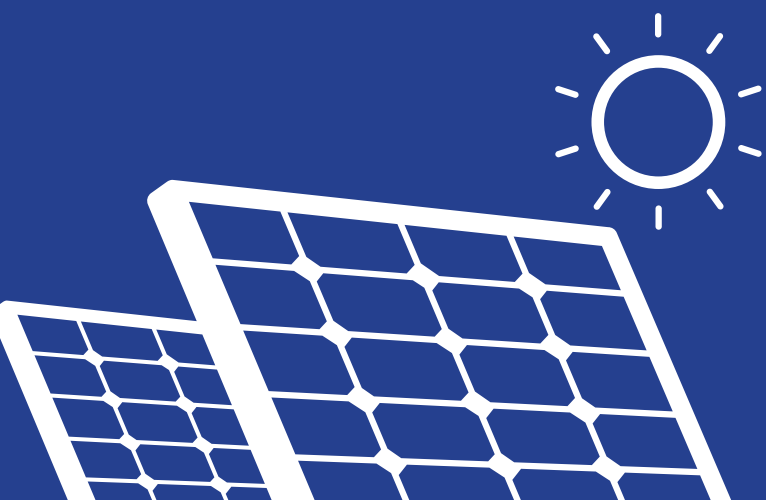
There are many the international standard testing and certification for PV module according to IEC standard which is world-wide standard. While the local standard testing need to apply in some event such for government project. Local PV module testing facilities are the CSSC (an accredited laboratory complying with ISO/IEC17025) of KMUTT and PTEC of NECTEC.

Inverter testing according to IEC standard and the regulatory measures of grid connected inverter that was announced by PEA and MEA provides by as CSSC (an accredited laboratory complying with ISO/IEC17025) of KMUTT, KMITL as well as SERT of NU. Table 4.6 illustrates testing facilities of PV and scope of local testing services.

Table 4.6 : Local testing services for PV by equipment

Equipment	Agency	Standard / Test method
PV module	CSSC	IEC 61215, IEC 61646, IEC 61730-1/2* and TISI standard
	SERT	IEC 61646
	PTEC	IEC standard
	SGS	IEC 61215, IEC 61646, IEC 61730-1/2
Grid connect inverter	CSSC	IEC 62093**, IEC 61727, IEC 62116, IEEE 1547**, PEA's regulatory measures and MEA's regulatory measures
	KMILT,SERT	PEA's regulatory measures and MEA's regulatory measures

Source: This data provided by KMUTT, according to TISI standards.



5 | Highlights and PROSPECTS

5.1 Highlight

PV installation capacity has seen significant growth in 2014 and 2015. This has been mainly in the area of PV power plants. Most of the installed systems, both modules and inverters, are imported. Up to 2014, local manufacturers have faced difficulty with competition for sales, due mostly to the cheaper components now mass produced in China.

The first phase of the rooftop projects also faced some problems, due to regulations and technical issues governing connection to the grid. The government postponed the commissioning date to June 2015, while the second phase commenced in February 2015, with the COD to be completed at the end of 2015.

PV module production capacity of local manufacturers was 235 MW in 2014. This will be severely affected in 2015 with the growth of new foreign manufacturers in Thailand expected to reach a capacity of 3.5 GW. Despite this, local manufacturers are pressing ahead with production capacity. Solartron, the largest of the local manufacturers has decided to increase the capacity of their production line to 200 MW. Bangkok Solar will open a new production line of 5 MW for c-Si PV modules. Ekarat, FullSolar and SPOT will also increase their capacity in response to government policy promoting PV.

At the end of 2014 the renewable energy policy was again adjusted by the NEPC, with the target for PV electricity production increased to 3,800 MWp for 2014-5. The new AEDP 2015, a 20 year plan, increases the target yet again to 6,000 MWp.

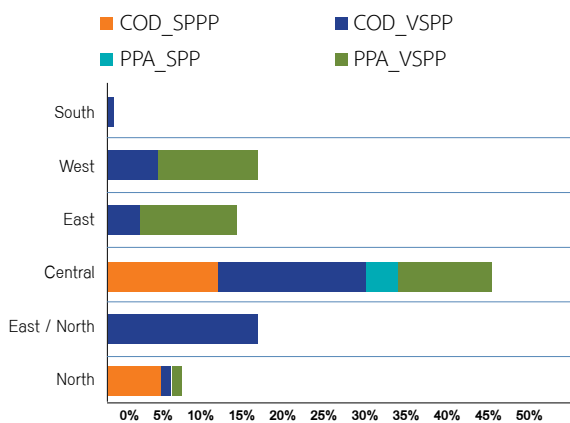
5.2 Future Trends

FiT incentive schemes currently in place include:

- 800 MWp of ground mounted systems for government and agricultural cooperatives. This will commence with 600 MWp for the first phase in November 2015, with the remainder commencing in 2016.
- Approximately 1,000 MWp for PV power plants (formerly under the adder scheme). Much work has been undertaken to resolve regulatory and technical issues and it is anticipated this project will be seeing smoother operation in 2016.
- The introduction of the 2nd phase of the PV rooftop program aimed at residences with capacity <10 kWp commenced in February 2015 and is currently ongoing.

Table 5.1 shows the development of VSPP and SPP schemes.

Table 5.1: Status of PV power plant development and operation (as of July 2015)



Source: This data from OERC website.

List of Company

Bangchak Solar Energy Co., Ltd.	BSE
Bangkok Solar Power Co., Ltd.	Bangkok Solar
EGCO Engineering & Service Co., Ltd	EGCO Engineering
Energy Absolute Solar Co., Ltd.	EA Solar
Ekarat Solar Co., Ltd.	Ekarat Solar
Fullsolar Co., Ltd.	Fullsolar
Gintech (Thailand) Co., Ltd.	Gintech
G.K. assembly Co., Ltd.	G.K.
G.S. Energy Co., Ltd.	G.S. Energy
Gunkul Engineering Co., Ltd.	Gunkul Engineering
Jetion Solar (Thailand) Co., Ltd.	Jetion Solar
Natural Energy Development Co., Ltd.	NED
Rojana Energy Co., Ltd.	Rojana Energy
Sarm Sarn Palung Ngaun Co., Ltd.	Sarm Sarn Palung Ngaun
Schutten Solar (Thailand) Co., Ltd.	Schutten Solar
Sci Eco Services Co., Ltd.	Sci Eco
SGS (Thailand) Ltd.	SGS
Siam Solar Energy Co., Ltd.	Siam Solar Energy
Siam Solar Generation Co., Ltd.	Siam Solar Generation
Siga New Materials Co., Ltd.	Siga New
Solar Power Co., Ltd.	Solar Power
Solar Power Technology Co., Ltd.	Spot
Solarta Co., Ltd.	Solarta
Solartron Public Co., Ltd.	Solartron
Sunpower Solar Co., Ltd.	Sunpower Solar
Thai Future Energy Co., Ltd.	Thai Future Energy
Trina Solar (Thailand) Co., Ltd.	Trina Solar
Universal Energy Engineering Co., Ltd.	UEE
Yingli Solar (Thailand) Co., Ltd.	Yingli



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