Department of Alternative
Energy Development and Efficiency
MINISTRY OF ENERGY

THAILAND
PV STATUS
REPORT
2016 - 2017

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Department of Alternative
Energy Development and Efficiency

MINISTRY OF ENERGY

Thailand PV status report committee (2016-2017)

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Thailand PV Status Report 2016 - 2017

Department of Alternative Energy Development and Efficiency

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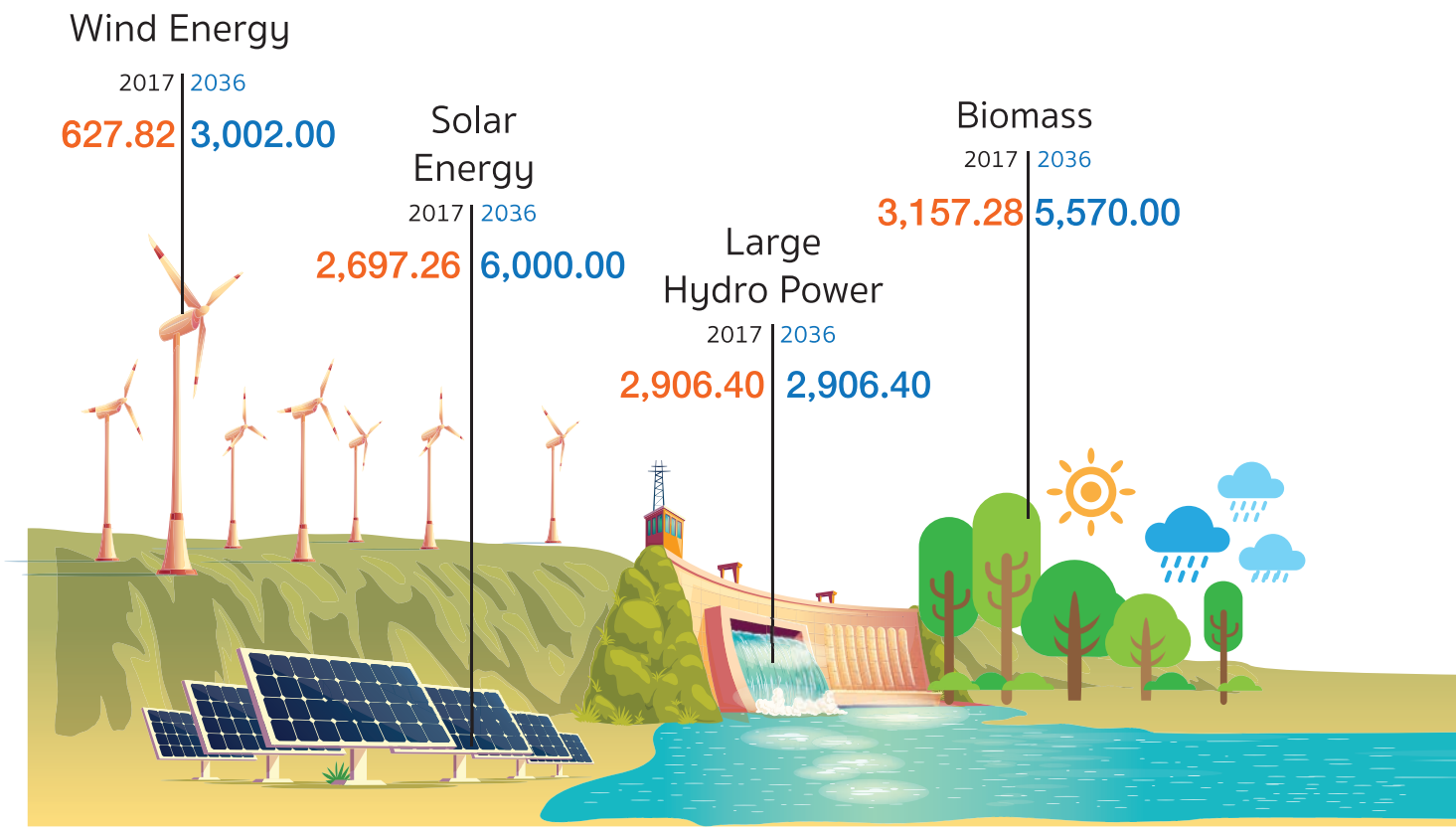
Alternative Energy Development Plan (AEDP 2015)

AEDP



	2017	2036
Total	10,237.93	19,684.40

2015

Industrial Waste / Municipal Solid Waste

2017 | 2036

191.47* | 50.00 (Industrial Waste)

500.00 (Municipal Solid Waste)

Small Hydro Power

2017 | 2036

182.28 | 376.00

Biogas

2017 | 2036

475.42 | 600.00 (Wastewater/Waste)

680.00 (Energy Crop)

*191.47 MW includes industrial waste and municipal solid waste in 2017.

(Unit : MW)

1

Executive Summary

EXECUTIVE SUMMARY

1.1 Installed PV Power

Thailand had 251 MWp of annual installation and 2,697 MWp of cumulative installation capacity in 2017. SPP and VSSP share 23 and 77 percent of total installation capacity, respectively. In the next two years the growth of ground mounted PV systems installation will slow down due to the construction of improvements to the transmission system by EGAT.

Self-consumption PV systems are becoming more popular and the growth rate of this application is driven by the private sector. In 2017, the average p-Si module price was 16 – 20 Baht/Wp and the average system price was 51 – 73 Baht/Wp.

1.2 PV Industry

In 2017, Thailand had 13 PV module manufactures and a production of 4,029 MW. Most investments are for export. Grid-connected inverters have to be approved according to MEA or PEA regulation for grid-connected systems.

The energy storage systems business is at the initial state following the national program for electrical vehicles. Most local manufactures for energy storage are lead-acid battery.

1.3 Supporting Measures

Thailand had the incentive programs such as Adder for 10 years and FiT for 25 years.

The finished projects in 2017 are :

1 Ground-mounted solar PV projects for government agencies and agricultural cooperatives Phase 1
2 Rooftop solar PV project for residential
3 Ground-mounted solar PV project for the applicants from the previous Adder incentive scheme
4 Pilot Project of Freely Rooftop Solar PV System Installation 2016
5 Ground-mounted solar PV projects for government agencies and agricultural cooperatives Phase 2

In 2017, the new scheme of incentive program as firm and semi-firm renewable energy were introduced. The renewable energy hybrid systems consist of biomass, biogas, wind energy and small hydro power as well as PV systems. Target is 300 MW and commercial operating date is the end of 2021. Meanwhile, semi-firm renewable energy does not include PV systems.

1.4 Energy Reforming

Thailand energy reforming is one of six directions for national reforming. PV systems involve the reforming of electricity and of renewable energy. The majority of energy reform of electricity consists of 3 issues. These are :

1. To improve the Power Development Plan (PDP) of Thailand
2. To support the electricity business competition and
3. To reform the structure of electricity power system.

Energy reform of renewable energy consists of 5 issues. These are :

1. To manage the biomass fuel from fast-growth for biomass power plant.
2. To support and eliminate the obstacles for solid waste collection for power plants.
3. To support the liberalization of PV rooftop systems installation.
4. To restructure energy consumption in the transport sector.
5. To support the prosumers trend in terms of regulation, infrastructure and energy conservation standards.

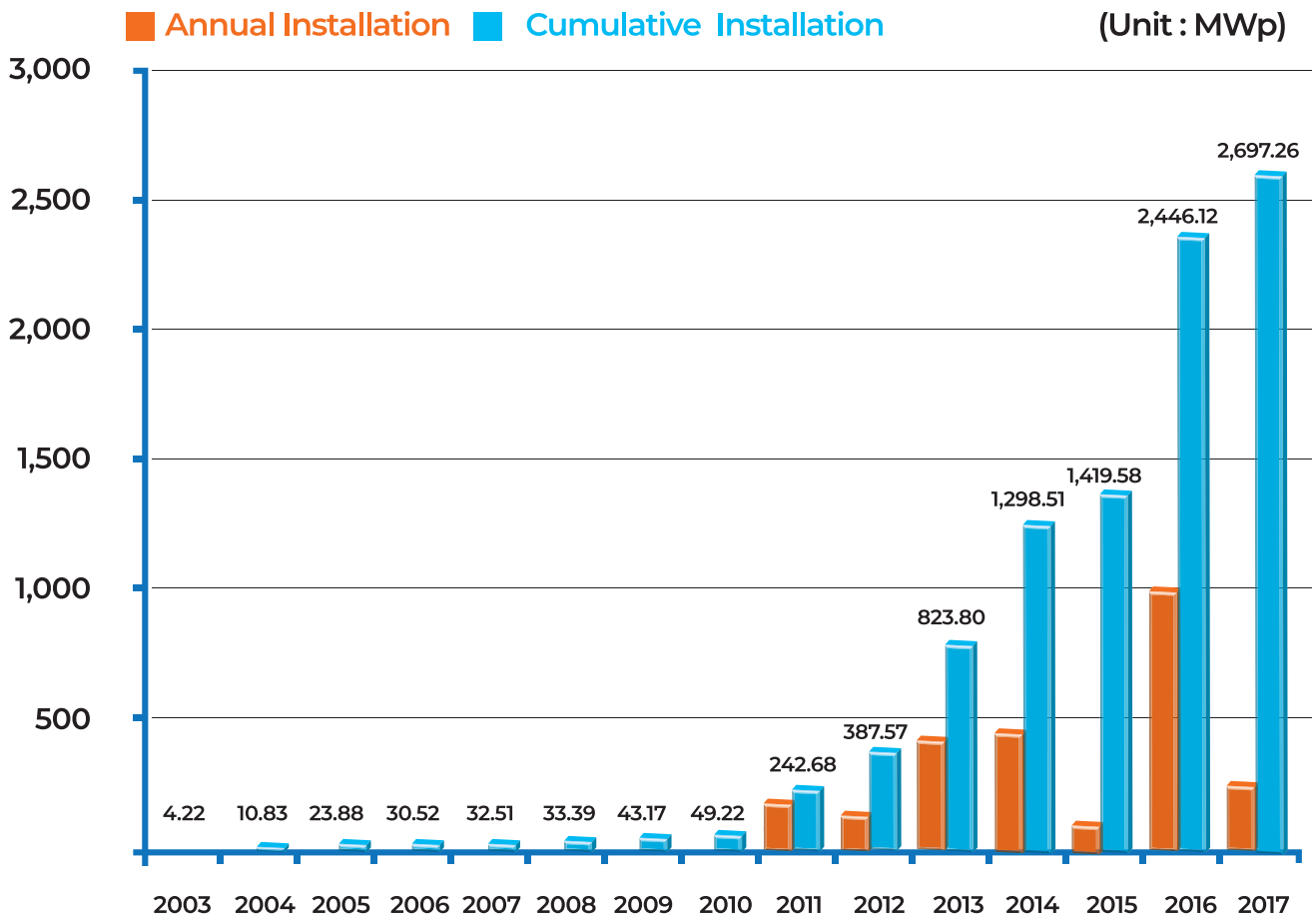
2

Implementation of PV systems

2.1 Installation Capacity of PV Systems

At the end of 2017, the cumulative installation of PV systems in Thailand reached 2,697.26 MW. The fast growth of PV systems during 2011 to 2017 reflects the importance of continuously promoting government policy. Much effort was paid for the development of PV applications in the country to confront the barriers from non-technical and technical issues especially the limitations from grid interconnection.

Fig. 2.1 : Cumulative PV systems installation in Thailand as of end-2017



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

Table 2.1 : PV systems installation from 2011 to 2017 (Unit: MWp)

Year	Cumulative Installation (MWp)			Annual Installation (MWp)		
	On-grid	Off-grid	Total	On-grid	Off-grid	Total
2011	212.80	29.88	242.68	193.23	0.23	193.46
2012	357.38	30.19	387.57	144.58	0.31	144.89
2013	794.07	29.73	823.80	436.69	-0.46	436.23
2014	1,269.36	29.15	1,298.51	475.29	-0.58	474.71
2015	1,389.55	30.03	1,419.58	120.19	0.88	121.07
2016	2,412.32	33.80	2,446.12	1,022.77	3.77	1,026.54
2017	2,663.12	34.14	2,697.26	250.80	0.34	251.14

Remark: (-) means the PV systems was uninstalled.
Source: This data was provided by DEDE, EGAT, PEA, MEA, and OERC.

2.2 Grid-connected PV Systems

2.2.1 Small Power Producers (SPPs)

The first three SPPs contracting with EGAT were Natural Energy Development Co., Ltd. (NED) with COD held in December 2011 followed by Bangchak Solar Energy Co., Ltd. (BSE) in July 2012, and EA Solar Nakornsawan Co., Ltd. in December 2013.

Larger SPPs with COD held during 2015 to 2016 were, for example, Serm Sang Palang Ngan Co., Ltd., EA Solar Lampang Co., Ltd., SPP Six Co., Ltd., and EA Solar Phisanulok Co., Ltd. In April 2016, OERC announced the termination for the granting of Licenses in Energy Industry Operation for ground-mounted PV systems and wind power due to the lack of clear supported policies and regulations and to avoid possible disadvantages. Consequently, at the end of 2016, the SPPs with PV system were capped at 588.47 MWp.

Table 2.2 : SPP power plants of PV systems in Thailand, Year 2011-2017 (MWp)

PV Plant's Owner	Location	Installed Capacity (MWp)	COD
NED	Lopburi	72.59	Dec-11
BSE	Ayutthaya	34.44	July-12
EA Solar Nakornsawan	Nakornsawan	126.13	Dec-13
Serm Sang Palang Ngan	Lopburi	52	Feb-15
EA Solar Lampang	Lampang	128.39	Feb-15
SPP Six	Lopburi	41	Dec-15
EA Solar Phisanulok	Phisanulok	133.92	Apr-16
Total		588.47	

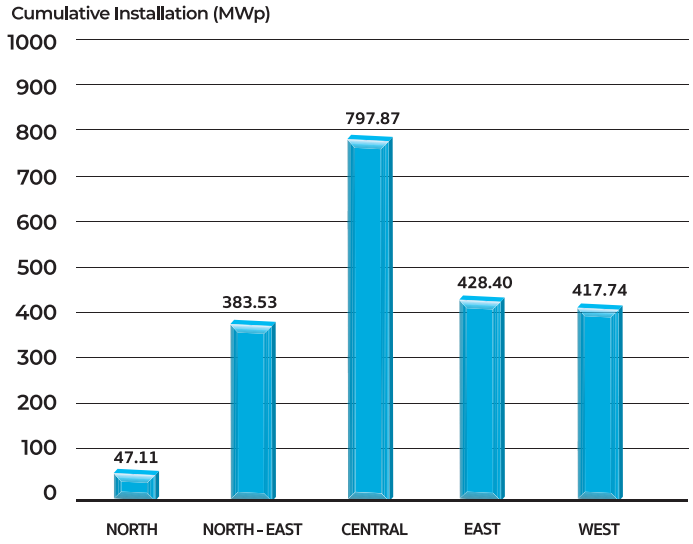
Source: This data was provided by OERC.

2.2.2 Very Small Power Producers (VSPPs) of Ground Mounted PV Systems

The cumulative installation of ground mounted PV systems as power plants with generation capacity between 1 and 10 MWp was 2,074.99 MWp, totaling 352 projects in 2017. These projects are under the incentive programs of the Adder and the FiT. The Adder was applicable during 2008 to 2013 with the top up of 8.00 baht/kWh over retail electricity price for 10 years and later reduced to 6.50 baht/kWh according to the decreasing of PV system price. The FiT was applicable during 2014 to 2015 with the fixed rate of electricity price at 5.66 baht/kWh for 25 years based on the capacity factor of 16 percent.

Fig. 2.2 illustrates the share of installed capacity of VSPP ground mounted PV systems in Thailand in 2017. From this figure, the majority of the PV systems are not larger than 8 MWp restricted by the capacity of feeder according to the regulation of PEA. The systems larger than 8 MWp are exceptional allowed to compensate energy loss in the system due to environmental conditions under the Adder incentive scheme. Share of installation of VSPP with ground-mounted PV systems by regions of Thailand in 2017 is also represented in Fig. 2.3.

Fig. 2.2 : Installation capacity of VSPP ground mounted PV systems by regions of Thailand in 2017



Source: This data was provided by OERC.

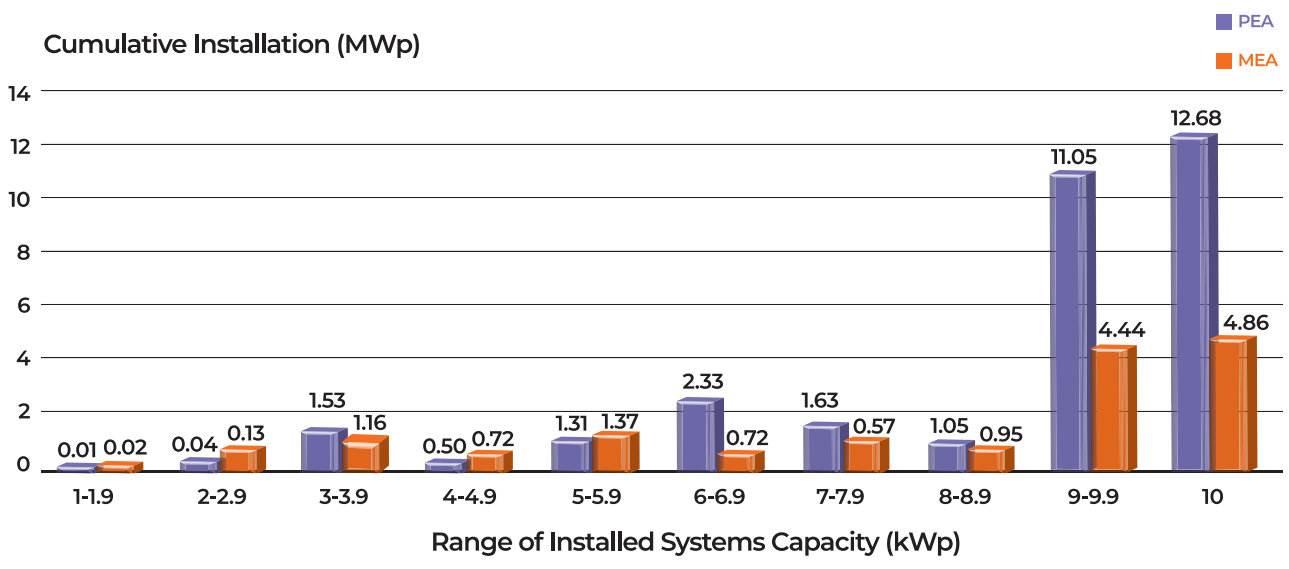
2.2.3 Very Small Power Producers (VSPPs) of Rooftop PV Systems

In 2013, the PV promotion program with FiT incentive was launched to purchase electricity from rooftop solar PV projects totalling 200 MWp. The generation capacity of PV system from 1-1,000 kWp was 129.68 MWp which consisted of 40 percent in responsibility of MEA (50.98 MWp for 2,163 projects) and 60 percent of PEA (78.70 MWp for 3,972 projects).

For residential, the rooftop PV projects in responsibility of MEA are 14.93 MWp and 2,067 projects meanwhile of PEA are 32.12 MWp and 3,894 projects.

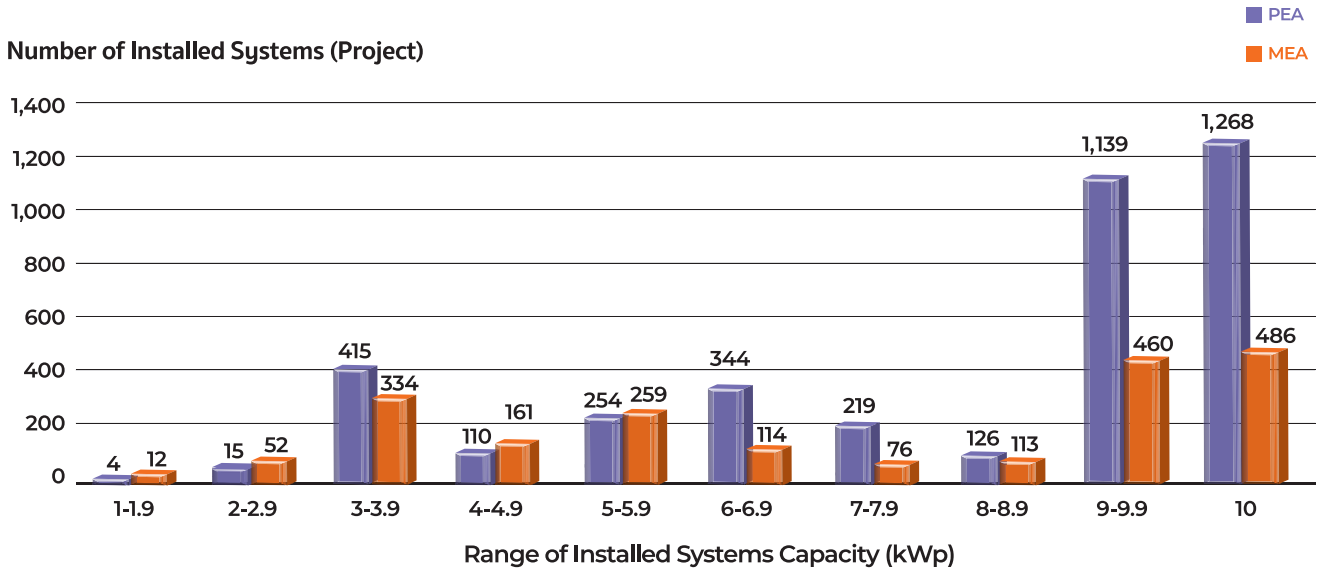
The systems with installed capacities of 9-10 kWp are mostly found as shown in Fig. 2.3 and Fig. 2.4. For commercial and factory, the systems in responsibility of MEA are 36.05 MWp and 96 projects meanwhile of PEA are 46.57 MWp and 73 projects. The majority are larger than 250 to 1,000 kWp as shown in Fig. 2.5 and Fig. 2.6.

Fig. 2.3 : The distribution of rooftop PV projects of residential by installed capacity for residential under FiT2013 program



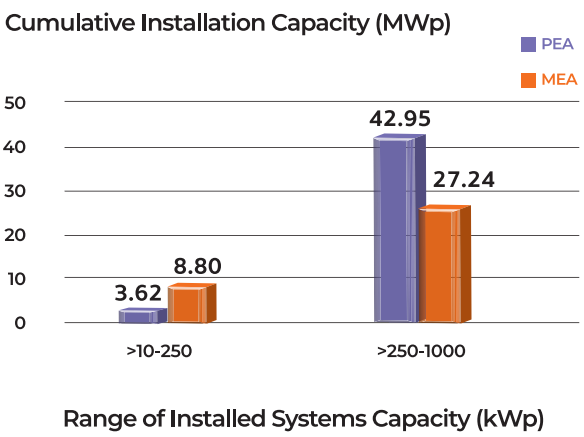
Source: This data was provided by OERC.

Fig. 2.4 : The distribution of rooftop PV systems of residential by number of project for residential under FiT2013 program



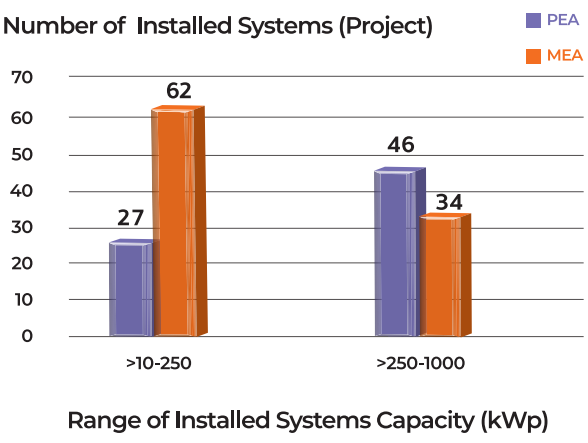
Source: This data was provided by OERC.

Fig. 2.5 : The distribution of rooftop PV projects of commercial / factory by range of installed system capacity for commercial / factory under FiT2013 program



Source: This data was provided by OERC.

Fig. 2.6 : The distribution of rooftop PV systems of commercial / factory by number of project for commercial / factory under FiT2013 program



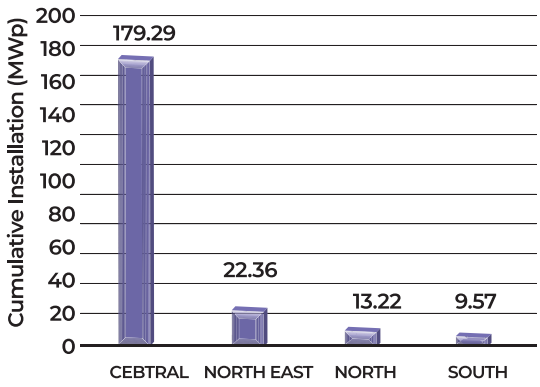
Source: This data was provided by OERC.

2.2.4 Self-consumption PV Systems

The continuous promotion with FiT incentive of government for rooftop solar PV projects since 2013, together with the declining price of PV system bring the PV technology more widespread and affordable even for self-consumption to reduce electricity charge. In 2017, the self-consumption PV systems were 224.48 MWp for total 383 projects.

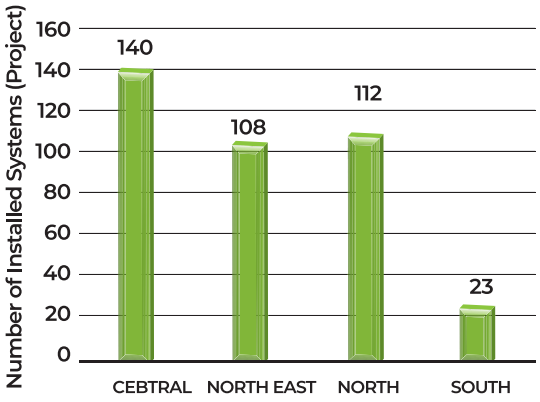
It is found that most of the self-consumption PV systems or about 80 percent of all projects are located in the Central region of Thailand followed by the Northeast, North, and South regions as shown in Fig. 2.7.

Fig. 2.7 : Self-consumption using PV systems under PEA in 2017



Source: This data was provided by PEA.

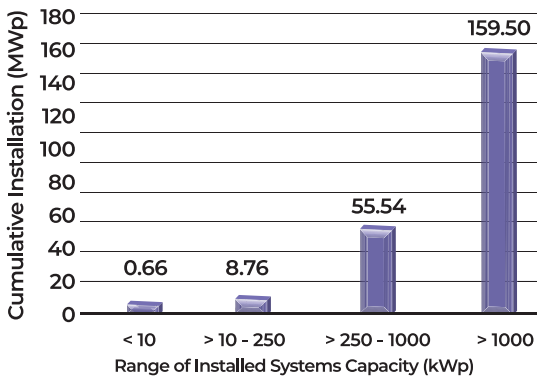
(a) The installation capacity by region



Source: This data was provided by PEA.

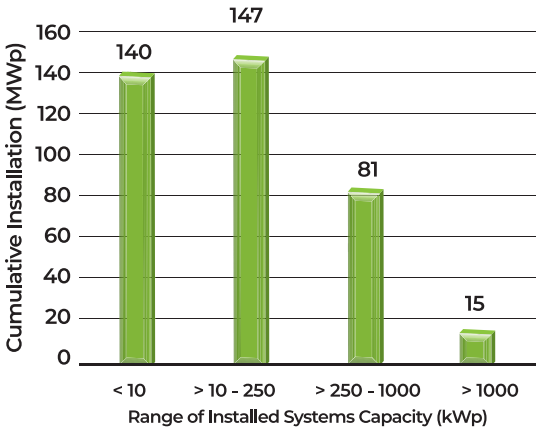
(b) Number of project by region

Fig. 2.8 : PEA self-consumption using PV systems by range of installed systems capacity in 2017



Source: This data was provided by PEA.

(a) The installation capacity by range of installed systems capacity

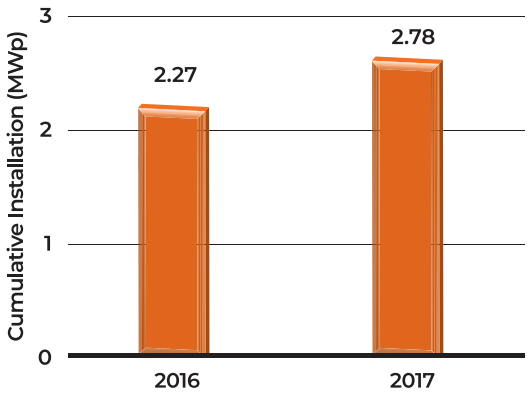


Source: This data was provided by PEA.

(b) Numbers of installed system by range of installed systems capacity

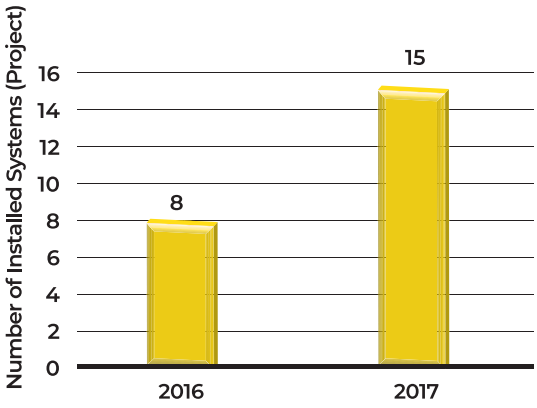
In addition, the self-consumption systems under PEA, the cumulative installation and the numbers of installed systems with the range of installed systems capacity are represented in Fig. 2.8. Fig. 2.8 (a), about 71 percent is the installed capacity of the systems larger than 1,000 kWp. Follow by 24.63 percent of the systems 250 to 1,000 kWp, 3.91 percent of the systems larger than 10 to 250 kWp, and 0.39 percent of the systems less than 10 kWp. However, the numbers of projects as shown in Fig. 2.8 (b), mostly found are the systems less than 10 kWp and the systems larger than 10 to 250 kWp with 36.55 and 39.43 percent of all projects, respectively. The systems larger than 250 to 1,000 kWp are 20.30 percent while the systems larger than 1,000 kWp are 3.81 percent.

Fig. 2.9 : Self-consumption using PV systems under MEA between 2016 and 2017



Source: This data was provided by MEA.

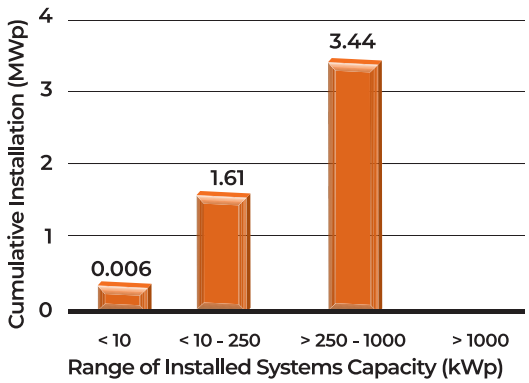
(a) The installation capacity in 2016-2017



Source: This data was provided by MEA.

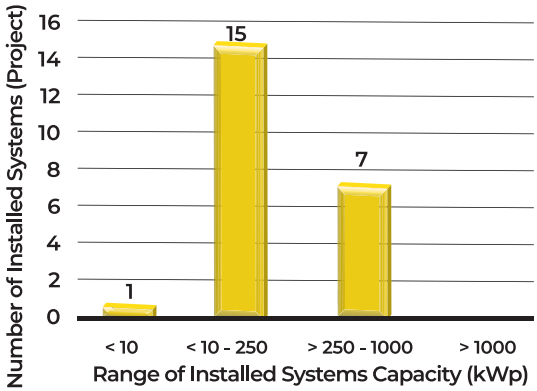
(b) Number of installed systems in 2016-2017

Fig. 2.10 : MEA self-consumption using PV systems by range of installed systems capacity in 2016 - 2017



Source: This data was provided by MEA.

(a) The installation capacity by range of installed systems capacity



Source: This data was provided by MEA.

(b) Numbers of installed system by range of installed systems capacity

Fig. 2.9 and Fig. 2.10 show the self-consumption of PV systems under MEA since it was started in 2016. In 2017 the cumulative installation of this scheme was 5.06 MWp and 23 projects. Most range of installed systems capacity is > 250 – 1,000 kWp by 68.03 percent. Followed by 31.83 percent for >10 – 250 kWp and the rest is 0.12 percent for < 10 kWp. Meanwhile, most of the number of installed systems capacity is > 10 – 250 kWp by 65.22 percent followed by 30.43 percent for > 250 – 1,000 kWp. For residential, < 10 kWp is 4.35 percent.

2.2.5 Floating PV Systems

The application of floating PV systems (FPV) in Thailand focuses on the use of areas over large reservoirs initiated by EGAT. The first FPV system of EGAT is the 249.6 kWp system at the Sirindhorn Dam, Ubonratchathani Province. It was also planned to expand the FPV totally to 45 MWp. Besides, Siam Cement Group (SCG) has developed the floating PV system from the use of HDPE material and demonstrated at SCG Chemicals, Rayong Province.

Fig. 2.11 : Demonstration of 249.6 kW_p FPV at Sirindhorn Dam, Ubonratchathani Province

Source: Photos were provided by EGAT.

Fig. 2.12 : Demonstration of 978.7 kW_p FPV at Rayong Olefin Ltd., Rayong Province

Source: Photos were provided by DEDE.

2.3 Off-Grid PV Systems

The off-grid PV systems in Thailand have been introduced for mobile medical units in the remote areas since 1977. The PV applications in remote areas were supported by government continuously; totaling 3.787 MWp in 1999. However, the off-grid PV systems have been promoted continuously by DEDE since 1993. The target was to bring the electricity to the rural areas, for instance, schools in the rural area, community learning centers, national parks and forests, sub-district health promoting hospitals, the royal development projects, military operations base, and including the solar pumping systems for the drought areas as shown in Table 2.3, which was supperted by DEDE In 2017 Thailand had 34 MW of off-grid PV systems.

PV hybrid systems are the other off-grid systems applications which have been introduced in the island and forest areas. Table 2.4 illustrates the typical PV hybrid system applications. PEA, NU and KMUTT as well as Leonic Ltd. have been carried out the PV hybrid systems.

Table 2.3 : Typical Off-Grid PV systems application in 2017

Applications	Project Numbers (project)	Installed capacity (kWp)
Rural schools	389	1,543.25
Community learning centers	56	384
National parks and forests	92	298
Sub-district health promoting hospitals	110	236
The royal development projects	1,110	600.18
Military operations base	636	514.38
Solar pumping systems	100	200
Battery charging station	61	968.5
Mini-grid systems	5	50
Border protection base	19	57
Demonstration of grid connected system	9	196.2
Total	2,787	5,047.51

Source: This data of cumulative off-grid PV systems was provided by DEDE.

Table 2.4 : Typical PV hybrid systems application in 2017

	Installed capacities			
Locations	PV (kWp)	Wind (kW) turbine	Diesel Generator (kW)	Battery (kWh)
Baan Koh Jig, Chanthaburi	47.5	10	50	240
Ramkhamheang National park, Sukhothai	2	-	3	30.6
Khao Nang Ram, Uthai Thani	2.4	-	10	38.4
Phu Kradueng National Park, Loei	24.78	2.5	48	240
Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani	10.5	-	46	234
Tarutao National Park, Satun	7.14	10	32	234
Sustainable Power System for The Guardian Unit of Khlong Lan National Park at KL.2 (Khlong Nam Lai), Kamphaeng Phet	5	1	13	28.8
Sustainable Power System for The Guardian Unit of Than Bok Khorani National Park at TB.1 (Koh Hong), Krabi	5	-	13	29.3
Tat Mok National Park, Petchabun	5.76	1	26	28.8
Thong Pha Phum National Park, Kanchanaburi	5.76	1	26	28.8
Mae Moei National Park, Tak	5.76	1	26	28.8
Mae Wong National Park, Nakhornsawan	1.98	-	6	14.4
Total	123.58	26.5	299	1,175.9

Source: This data was provided by KMUTT.

2.4 Micro-grid with PV Systems

Micro-grid or Micro Power Grid System is a localized power system with the group of electricity sources (and loads) such as diesel engine power plant, small hydro power plant, biomass power plant, wind power plant, and solar power plant. Its advantages are to improve reliability and security of the power system, to be useful for the rural electrification, to reduce the electricity cost from various sources, and to avoid the loss of load situation. The micro-grid system can control the sources in concert with the electrical loads and can be classified into the non-isolated (on-grid) and isolated (off-grid) systems (according to the standard IEC TS 62898-1:2017 Microgrids-Part 1: Guidelines for micro-grid projects planning and specification).

Non-isolated micro-grid system can operate in both the grid-connected mode and the island mode. It can be used together with the energy storage system and can be controlled to suit local energy sources such as solar and wind.

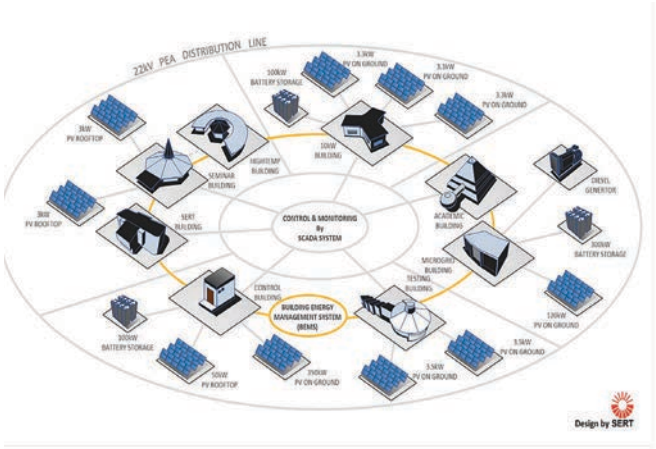
Isolated micro-grid system is designed not to connect with the grid but always consist of the diesel engine generator and the energy storage system for the use in the remote areas such as islands. The advantages of the isolated micro-grid system are the continuity and reliability resulting from the energy storage system.

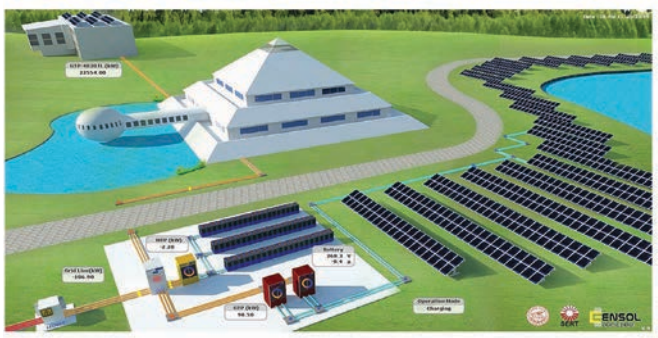
Table 2.5 : Typical PV based micro-grid systems in Thailand

Project	Location	Organization
KhunPhae power plant	Chom Thong, Chiang Mai	PEA
	PV system	7.3 kWp
	Hydro power	96 kWp
	Diesel generation	56 kWp
The Electrification Improvement by The Micro-grid System	Mae Sa Riang, Mae Hong Son	PEA
	PV system	VSPP
	Battery storage system	3 MW / 1.5 MWh Type: Li-Ion
Smart Grid at the School of Renewable Energy of Naresuan University	Muang, Pitsanulok	Naresuan University
	PV system	400 kWp
	Battery storage system	100 kWh (type: SLA)
PTT Gas Station	Sam Kok, PhathumThani	PTT Plublic Co., Ltd.
	PV system	550 kWp
	Battery storage system	2,000 kWh (type: SLA)
BCP Gas Station	Sri Nakarin Road, Bangkok	BCPG Public Co., Ltd.
	PV system	270 kWp
	Battery storage system	1,023 kWh (type: Li-Ion)

Source: This data was provided by PEA and TISI Technical Committee 1016.

Fig. 2.13 : Demonstration of micro-grid of PV systems at SERT, NU





Source: NU

3

PV Industry and Growth

3.1 Development of PV Cell and Module Production

Solar electrification and PV manufacturing in Thailand has been encouraged gradually during the period 2007 to 2017, the exponential growth of PV worldwide has rapidly changed the PV market in Thailand. Since 2015, many new module manufacturers have entered the Thai market. At the end of 2017, module production capacity increased to be 4,009 MW from a total of 13 manufacturers, 361 MW from 6 local manufacturers and 3,268 MW from 7 foreign manufacturers, as shown in Table 3.1.

Table 3.1 : PV cell and module manufacturers in Thailand in 2017

No.	Manufacturers	Location, province	Production Capacity (MW)		Remark
			Cell	Module	
1	Canadian Solar	Si Racha, Chon Buri	1,000	800	Export
2	Ekarat Solar	Pluak Daeng, Rayong	n/a	25	-
3	Fullsolar	Si Racha, Chon Buri	-	25	-
4	G.K.	Bang Kruai, Nonthaburi	n/a	80	-
5	Gintech	Nava Nakorn, Pathum Thani	n/a	1,000	Export
6	Irradiance Solar	Mueang, Samut Sakhon	-	6	-
7	Jetion Solar	Si Racha, Chon Buri	140	250	Export
8	Schutten Solar	Si Racha, Chon Buri	-	18	Export
9	Solar Power Technology	Sam Khok, Pathum Thani	-	25	-
10	Solartron	Pak Chong, Nakhon Ratchasima	180	180	-
11	TaleSun	Pluak Daeng, Rayong	n/a	800	Export
12	Trina Solar	Pluak Daeng, Rayong	700	500	Export
13	Yingli Solar	Pluak Daeng, Rayong	n/a	300	Export
Total			n/a	4,009	

Source: This data was provided by manufactures.

Table 3.2 shows the PV cell and modules production capacity by technology as of 2017. These module manufacturers receive the Thai Industrial Standard for crystalline silicon modules, namely TIS 1843:2553, TIS 2580-1:2555, and TIS 2580-2:2555.

Table 3.2 : PV cell and module production capacity (MW) by technology in 2017

No.	Manufacturers	Cell production (MW)	Module production (MW)		
			Crystalline-Si	Mono-Si	Poly-Si
1	Ekarat Solar	n/a	0.75	0.04	0.71
2	Fullsolar	-	5	3.5	1.5
3	G.K.	-	80	4	76
4	Irradiance Solar	-	2	-	2
5	Jetion Solar	140	250	-	250
6	Schutten Solar	-	12	1.2	10.8
7	Solar Power Technology	-	2	0.6	1.4
8	Solartron	180	180	9	171
Total		n/a	531.75	18.34	513.41

Source: This data was provided by manufactures.

3.2 PV Module and System Pricing

PV module price is always determined within the context of government support policies. In the past, expensive PV modules made the investment impossible by private sector without corresponding investment by the government through subsidies such as demonstration and research programs. The timeline of the prices of PV module and system from 1997 to 2017 are illustrated in Tables 3.3 and 3.4, respectively.

Since 2011, the number of megawatt PV systems has increased rapidly until 2017. The growth of large-scale PV systems slowed down after that due to the limitations on the transmission and distribution systems which are undergoing improvement. However, the kilowatt-scale or rooftop solar PV systems continues to increase progressively.

Table 3.3 : Typical module prices for a number of years

Year	1997-1998	1999-2000	2002-2003	2011	2012	2013	2014	2015	2016	2017
Typical module price, kW-scale (THB/Wp)	180 - 200			110	70 - 80	50 - 60	35 - 50	25 - 40	16 - 22	16 - 20
Best module price, MW-scale (THB/Wp)	-	-	-		50 - 60	35 - 45	20 - 25	20 - 25	15 - 20	15 - 17

Source: This data was provided by manufactures.

Table 3.4 : Trend of system prices for different applications from 1997 to 2017

Year	1997-1998	1999-2000	2002-2003	2011	2012	2013	2014	2015	2016	2017
Residential PV systems (<10 kWp, THB/Wp)	210 - 250		200 - 220	n/a	n/a	90 - 150	65 - 100	60 - 100	52 - 73	51 - 64
Commercial / Factories PV systems (>10-1,000 kWp, THB/Wp)	-	-	-	n/a	n/a		60 - 65	50 - 55	43 - 57	45 - 54
Ground mounted PV systems (> 1,000 kWp, THB/Wp)	-	-	-	110		60 - 100	40 - 60	30 - 50	42 - 57	41 - 48

Source: This data was provided by manufactures.

3.3 Research, Development and Demonstration Activities

The research, development and demonstration (RD&D) of PV technology in Thailand can be classified into 6 categories. They are (A) Fabrication of solar cells and materials, (B) Invention and application of system components, (C) PV applications, (D) Policy support research, (E) Integrated research, (F) Energy storage systems. Table 3.5 shows the RD&D activities and organization between 2016 and 2017, according to the (A) to (F) categories.

Table 3.5 : RD&D activities and organization between 2016 and 2017

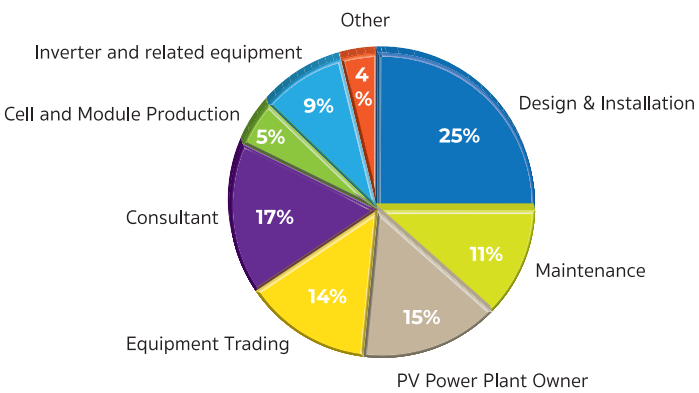
Research Topics	Organization
(A) Fabrication of solar cells and materials	CMU, CU, KU, KKU, KMITL, KMUTT, MU, NPU, NSTDA, PCRU, SNRU, SU, SWU, SUT, UBU
(B) Invention and application of system components	CU, NU, NIDA, PCRU, RMUTK, SWU, SUT
(C) PV applications	CMRU, DEDE, EGAT, KMITL, KMUTT, NRRU, NU, NSTDA, PCRU, PEA, RMUTK, RMUTT, SWU, UBRU, UP
(D) Policy support research	DEDE, CU, KMUTT, NIDA
(E) Energy storage systems	KKU, NSTDA
(F) Integrated research	BRU, KMUTT, NSTDA, RMUTSB, SNRU, SU, SUT

Source: This data was provided by NRCT, TRF, NSTDA, EGAT, PEA, DEDE and KMUTT.

3.4 Solar Electricity Business and Services

Solar electricity business and services have high market value and can be an important source of job creation with high income. In 2017, the Thai Photovoltaic Industries Association (TPVA) with 113 members reported that the PV system design and installation business share 25 percent of the market, followed by 17 percent from solar consultants, 15 percent from electricity purchasing of PV system owners, 14 percent from materials and components business, 11 percent from maintenance services, 10 percent from inverter and components production, 5 percent from solar cells and modules production, and 4 percent from others such as finance, construction, quality assurance and energy business, as shown in Fig. 3.1

Fig. 3.1 : Share of solar electricity business and services in 2017, only TPVA member



Source: This data was provided by TPVA.

Apart from PV modules, the main equipment of PV systems, there are inverter and battery. Inverter transforms the direct current from PV into an alternate current for appliances or to connect with the grid. The poor power quality from the electrical output of inverters can be risky and may harm appliances, utility instruments, or even power system operation. Therefore, before connection of the inverter to the grid, permission must be granted by MEA or PEA according to the Grid Code and relevant regulations. The inverters that are permitted by MEA and PEA are Fig. 3.2 and Fig. 3.3, respectively.

Fig. 3.2 : QR code for list of inverters that are permitted by MEA

Fig. 3.3 : QR code for list of inverters that are permitted by PEA

Battery is an electrical energy storage device that has often been used for stand-alone PV systems for a long time. Recently, batteries play an important role for grid-connected PV systems, especially in 2017, as equipment helping improvement on the reliability and security of the RE power system. Most of the batteries for PV systems in Thailand is lead-acid battery with special lead plates designed to be regularly deeply discharged.

Table 3.6 : Typical Local Battery Manufacturers for PV and RE systems

No.	Manufacturer (Thai)	Country	Brand
1	Dit Thana Chot Co.,Ltd	Thailand	APPLEGREEN
2	Siam Battery Industry Co.,Ltd	Thailand	BOLIDEN, TRANE SMF, CROWN, VICTORITE
3	Siam Furukawa Co.,LTD.	Japan	FB
4	Siam GS Battery Co., Ltd.	Japan	GS
5	Thai Storage Battery PCL	Thailand	3K
6	NV Battery Ltd., P.	Thailand	N.V. BATTERY
7	Yuasa Battery (Thailand) PCL	Japan	YUASA, THUNDERLITE, YUCON

Source: This data was provided by manufactures.

4

Framework for Deployment

4.1 Policies and Incentives

National measures to support PV systems installation between 2016 and 2017 are shown in Table 4.1. There are 4 projects finishing in 2017 and only the ground-mounted solar PV projects for government agencies and agricultural cooperatives Phase 2 is ongoing.

Table 4.1 : PV Supporting Projects during 2016-2017

Projects	FiT (THB/kW-hr)	Commercial Operation Date (COD)				Contracted capacity
Year: 2016	Duration (Year)					
1 Ground-mounted solar PV projects for government agencies and agricultural cooperatives Phase 1	5.66	DEC 2015	JUN 2016	SEP 2016	DEC 2016	217.87[1] MW of 52 projects
: Capacity ≤ 5 MWp	25					
2 Rooftop solar PV project for residential	6.85	DEC 2015	JUN 2016			48[2] MW of 6,002 projects
: Capacity ≤ 10 kWp	25					
3 Ground-mounted solar PV project for the applicants from the previous Adder incentive scheme	5.66	DEC 2015	JUN 2016			969 MW of 165 projects
: Capacity ≤ 10 MWp	25					
4 Pilot Project of Freely Rooftop Solar PV System Installation 2016	Self-consumption	JAN 2017				5.63[3] MW of 180 projects
: Capacity ≤ 10 kWp						
5 Ground-mounted solar PV projects for government agencies and agricultural cooperatives Phase 2	4.12	JUN 2018	DEC 2018			PPA 154.52 MW of 35 projects (Mar 2018)
: Capacity ≤ 5 MWp	25					

Source: This data was provided by EPPO, OERC, and DEDE.

Remark

[1] Information on December 30, 2016. Later on June 7 in 2017, the additional 33.95 MW of 8 projects had passed agreement while the other 9.5 MW of 3 projects were during request for agreement base on the FiT 5.377 baht/kWh with contract term ended on December 30, 2041.

[2] On June 30 in 2016, the 130 MW (from target 200 MW) of total 6,166 rooftop solar PV projects as 48 MW of 6,002 projects for residential could supply electricity into the grid and 82 MW of total 164 projects for commercial and factory.

[3] Operated on August 22, 2016 - January 31, 2017 for 5 months under self-consumption scheme.

[4] According to ERC's resolutions on May 15 in 2017 to purchase solar electricity for 100 MW from government agencies and 119 MW from agricultural cooperatives and then terminate the program.

Solar PV development in Thailand has dramatically grown due to the reasonable module and system prices. However, an important barrier is the impact of RE on the reliability and security of the power system and the need for more back-up generation capacity to balance the power against the intermittent renewable energy sources. Therefore, the energy storage system and new incentive program were promoted to overcome this problem. In 2017, the National Energy Policy Council (NEPC) agreed to use the competitive bidding method with new FiT rates for SPP Hybrid Firm and VSPP Semi-Firm and allowed the energy storage system. Table 4.2 shows the supporting programs of SPP Hybrid Firm and VSPP Semi-Firm.

Table 4.2 : SPP Hybrid Firm and VSPP Semi-Firm in 2017

Supporting programs	RE sources	Target (MW)	New FiT rates (baht/kWh)	SCOD
1. The purchase of electricity from SPP Hybrid Firm year 2017 Installed capacity > 10 MW but not exceed 50 MW	Hybrid : Biomass Biogas (wastewater/waste) Small hydro (0.1 – 10 MW) Biogas (energy crop) Wind energy Solar energy	300 (Zoning)	FiT_F : 1.81 $FiT_{V,2017}$: 1.85 FiT^1 : 3.66 Duration : 20 years	1-Jan-2020 to 31-Dec-2021[2]
2. (Draft) The purchase of electricity from VSPP Semi-Firm year… Installed capacity ≤ 10 MW Firm for 6 months from Mar to Jun and the remaining 6 months are Non-Firm	Choose one : Biomass Biogas (wastewater/waste) Biogas (energy crop)	269 (Zoning)	Biomass[3] : FiT_F : 2.39 - 2.61 $FiT_{V,2017}$: 1.85 - 2.21 FiT^1 : 4.24 - 4.82 Duration : 20 years Biogas : FiT_F : 2.79 (energy crop) - 3.76 (wastewater/waste) $FiT_{V,2017}$: 2.55 (energy crop) FiT^1 : 3.76 (wastewater/waste) - 5.34 (energy crop) Duration : 20 years	31-Dec-2019

Source: This data was provided by EPPO, and OERC. SCOD is scheduled commercial operation date.

Remark :

1 This FiT rate is applicable in 2017. After 2017, the FiT will continuously increase following the core inflation.
2 The SCOD is planned starting from 2020 due to the readiness of transmission system and may change as appropriate and in accordance with the state of the facts.
3 The lower is for installed capacity > 3 MW and the higher is for installed capacity ≤ 3 MW.

FiT_F is the fixed electricity purchase rate (THB/kWh).
FiT_V is the variable electricity purchase rate in accordance with the core inflation (THB/kWh)
SCOD is the Scheduled Commercial Operation Date

4.2 Investment Promotion for PV Industry

To promote the local industry, the Board of Investment announced incentives waiving import duty on PV-related manufacturing machinery and raw materials, as well as an 8 year corporate income tax holiday for 100 % of investment cost (excluding land and working capital). According to an announcement of BOI No.2/2557 (Date: 3-Dec-2014). Table 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, respectively.

Table 4.3 : BOI investment support for manufacture of solar cells and fabrication of modules

Year	Projects	Production 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	2	53	91
2016	2	900	331
2017	2	3,100	1,650
Total	17	4,345	9,572

Table 4.4 : BOI investment support for solar power plant

Year	Solar Power Plants		Solar Rooftop Systems	
Cumulative until 2011	Capacity (MW)	Capital cost (million THB)	Capacity (MW)	Capital cost (million THB)
2012	541.4	63,742	-	-
2013	621.5	57,073	-	-
2014	139.0	18,661	6.2	62
2015	1.0	80	70.8	4,053
2016	1,065.5	69,958	7.9	489
2017	241.6	13,453	6.2	266
	16.5	785	35.4	1,288

Source : This information was provided by BOI.

Remark :

In 2016 and 2017, there were floating PV systems 1 and 2 projects, respectively, with total capacity of 2.5 MW and capital cost of 104 million THB.

4.3 Soft Loan Programs for Renewable Energy

The Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy has implemented the Revolving Money for Energy Conservation by Financial Institutions project for the purpose to improve the energy efficiency of Thailand. The project is currently in phase 6 starting from December 2015 to 2017 with interest rate not exceeding 3.5 percent per year, installment period not exceeding 5 years and credit line not exceeding 50 million baht. There are 8 banks participating in the phase-6 project which are (1) Bangkok Bank, (2) Krung Thai Bank, (3) Bank of Ayudhya, (4) Kasikorn Bank, (5) CIMB Thai Bank, (6) Siam Commercial Bank, (7) Export-Import Bank of Thailand, and (8) Land and Houses Bank. In addition, the soft loan programs to promote energy saving and renewable energy projects by commercial banks are represented in Table 4.5.

Table 4.5 : The soft loans of energy saving and renewable energy by Thai banks

Products	Details	Credit line	Installment period (years)
KTB Green Loan	For alternative energy, renewable energy, and clean energy projects with self-consumption, energy business and including investment on environmental improvement. This loan covers investment in construction, machinery or equipment for such purposes.	According to the bank's regulations	Maximum not excess to 10 years
K-Energy Saving Guarantee Program	A loan program that supports investment in energy efficiency projects through service from an energy management company with 2 types of Loan Term, for K-Equipment Leasing and for Long-term loan.	Maximum 100% of capital investment	Maximum not excess to 5 years
The K–Energy Saving Guarantee Program (Solar Rooftop)	To reduce costs and increase revenue by selling electricity to the government. Enhance financial liquidity and competitiveness in the long run.	Maximum 100% of capital investment	Up to 12 years

Source: This information was provided by Thai banks.

4.4 Standards, Codes and Regulations

PV module, Inverter and PV system standards of Thailand are under the responsibility of Thai Industrial Standards Institute (TISI). The TISI is a member of the International Electrotechnical Commission (IEC) as a representative of Thailand, had announced in the Gazette on TIS of PV modules and inverters as follows:

Table 4.6 : TISI standards for PV modules, related equipment and PV systems

Product	TIS Standard	Harmonization Standard
PV Module	TIS 1843:2553	IEC 61215:2005
	TIS 2210:2555	IEC 61646:2008
	TIS 2580-1:2555	IEC 61730-1:2004-10 and
		IEC 61730-1 am1 (2011-11)
	TIS 2580-2:2555	IEC 61730-2:2004-10 and
		IEC 61730-2 am1 (2011-11)
Grid-connected Inverter	TIS 2603 No. 1-2556	IEC 62109-1 Ed.1 (2010-04)
	TIS 2603 No. 2-2556	IEC 62109-2 Ed.1 (2011-06)
	TIS 2606:2557	IEC 61727 Ed.2 (2004-12)
	TIS 2607:2557	IEC 62116 Ed.1 (2008-09)
Solar photovoltaic (PV) power systems	TIS 2572:2555	IEC 60364-7-712

Source: This information was provided by TISI.

In Thailand, there are 10 brands of PV module that received the certified No. TIS 1843:2553 (Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval) and 9 brands that received the certified No. TIS 2580-2:2555 (Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing).

In addition to TIS standards, the grid-connected PV inverters have to be approved according to the power network system interconnection code of PEA and MEA as follows:

- The power network system interconnection code of MEA in consistent with IEC 61727-2004, IEC 62116-2008, IEEE 1347-2003, IEEE 1547.1-2005 and AS 4777.3-2005
- The power network system interconnection code of PEA B.E. 2559 (2016)

4.5 Electric Vehicle Promotion

The electric vehicle (EV) promotion is one of the energy reformation policies of Thailand for fuel saving in transportation sector which is one of the highest consuming sectors and also to indirectly reduce air pollution. The electricity to be used in EV can come from various sources including renewable energy, especially solar PV systems.

The standards for rooftop solar PV system installation consist of the TIS 2572:2555 (published in 2012) and Thailand Electrical Installation Standard: Solar Rooftop Power Supply Installations which focus on the installtion regulation and safety.

The energy storage device for solar PV system or battery involves the following standards :

- IEC 60896-11:2002 Stationary lead-acid batteries - Part 11: Vented types - General requirements and methods of tests
- IEC 60896-21:2004 Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test
- IEC 60896-22:2004 Stationary lead-acid batteries - Part 22: Valve regulated types - Requirements
- IEC 61427-1:2013 Secondary cells and batteries for photovoltaic energy system (PVES) - General requirements and methods of test

The 20-Year Energy Efficiency Development Plan (2011 - 2030) targets to promote the use of electric vehicles in transportation sector to save energy of 15,100 kTOE and to reduce carbon dioxide of 53 million tons per year. Thailand is in a transitional phase for the electric vehicle society in future. The target is to increase EV to be 1.2 million EVs within 2036. Table 4.7 shows the 20-year plan of electric vehicle promotion.

Table 4.7 : Electric Vehicle Promotion Plan in 20-year

Plan	Activities
Phase 1: 2016 - 2017	• Law and regulations preparation • Support for battery research for electric vehicles • Piloting electric public buses of the Bangkok Mass Transit Authority (BMTA) • Imported EVs with exemption of import duties. • EV charging station preparation • Draft announcement on the regulating of electric motors power used in accordance with the Motor Vehicle Law. • Draft guidelines for the use of small electric vehicles safely.
Phase 2: 2018 - 2020	• intensive and continuous research on the performance of motor and battery. • Increase the number of EV. • Set up a service charge / service station standards. • Investment incentives
Phase 3: 2021 - 2035	• Improve and disseminate the study results to promote individual EVs. • Development of electricity demand management system of the country
Phase 4: From 2036 onwards	• Expected that EVs will fully replace the conventional cars

Source: This information was provided by EGAT, PEA, MEA and Electric Vehicle Association of Thailand.

In Phase 2: 2018 – 2020, according to an announcement of the BOI No. 5/2017 for the investment promotion policy on electric vehicles, parts and accessories, it was planned to stimulate an investment in electric vehicle production that is valuable to the technological development of the automotive industry in the country. This announcement, for metal products, machinery and transport equipment, specified that: 4.8.3 Manufacturing for Automobiles Hybrid, Battery Electric Vehicles (BEV) and Plug-In Hybrid Electric Vehicles (PHEV), Incentives : **Group A2**. That are

4.8.3.1 Battery manufacturing
4.8.3.2 Traction motor manufacturing
4.8.3.3 Air-conditioning systems or parts manufacturing using electricity
4.8.3.4 Battery Management System (BMS) manufacturing
4.8.3.5 Driving Control Unit (DCU) manufacturing
4.8.3.6 On-Board Charger manufacturing
4.8.3.7 Battery charger cable with outlet manufacturing
4.8.3.8 DC/DC Converter manufacturing
4.8.3.9 Inverter manufacturing
4.8.3.10 Portable Electric Vehicle Charger manufacturing
4.8.3.11 Electric Circuit Breaker manufacturing
4.8.3.12 EV Smart Charging System manufacturing
4.8.3.13 Front / Rear beam manufacturing for electric bus

Table 4.8 : List of Electric Vehicle Promotion by BOI according to BOI No.2/2557

Business type	Incentives
4.16 Hybrid Electric Vehicles – HEV manufacturing and parts	Group B1
4.17 Plug-In Hybrid Electric Vehicles-PHEV manufacturing and parts	Group A4
4.18 Battery electric vehicles manufacturing and parts	Group A3
4.19 Battery Electric Bus manufacturing and parts	Group A4
7.27 The EVs charging station	Group A3

Source: This information was provided by BOI.

5

Highlights and Prospects

5.1 Energy Reform of Thailand

During 2015 – 2017, the electricity generation from renewable energy had increased continuously with electricity from conventional power plants, such as from EGAT, IPP, and Imported power, remaining constant. The growth of renewable energy sources for electricity production in Thailand are biomass and PV systems. This is due more to the reasonable cost of PV installation and modernization trends, rather than changing of electricity consumption behavior.

Fig. 5.1 : Electricity generation capacity in Thailand between 2015 and 2017

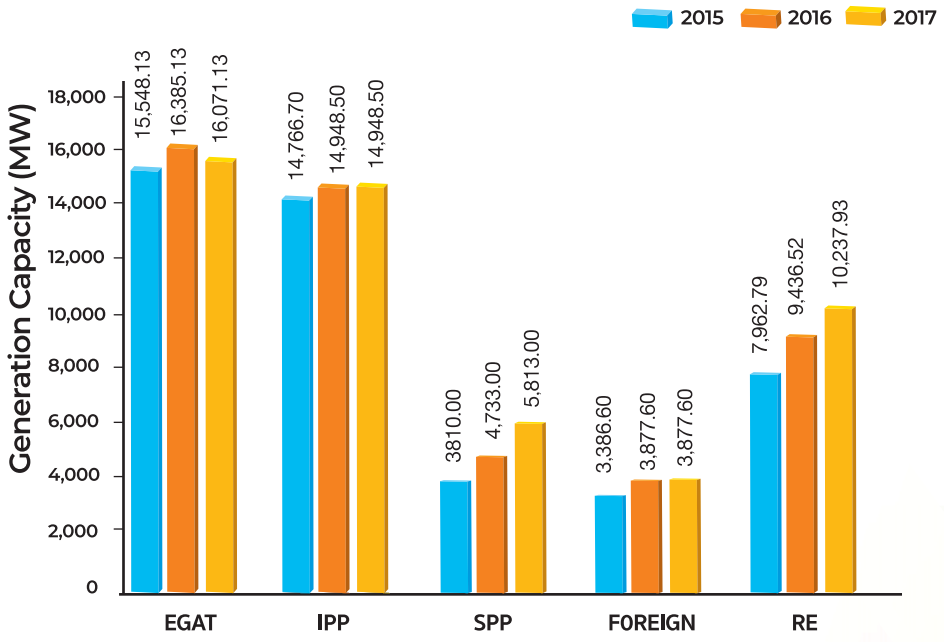
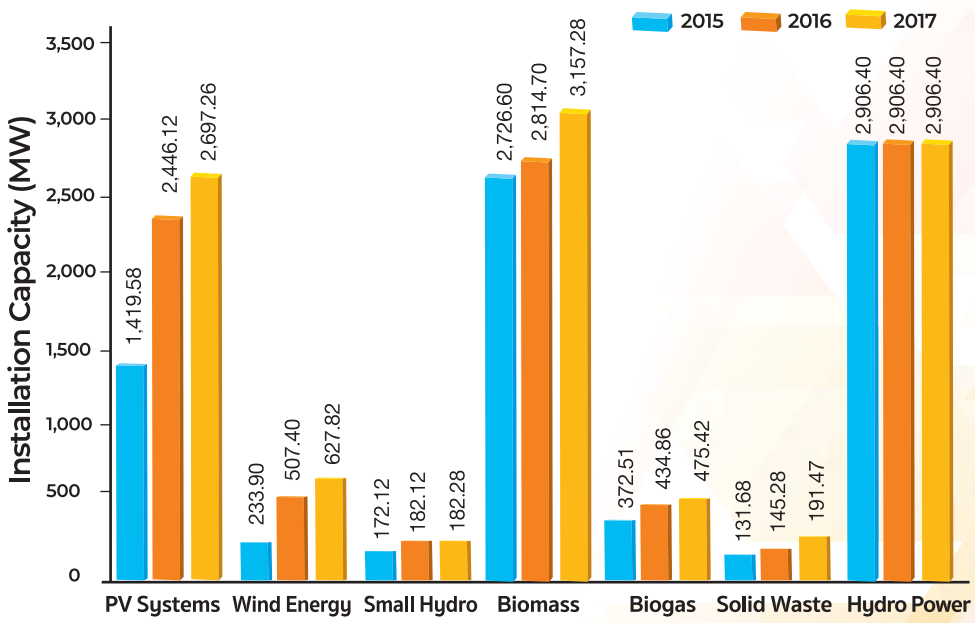


Fig. 5.2 : Renewable energy installation capacity in Thailand between 2015 and 2017



Source : DEDE

The situation of energy demand and energy supply in Thailand have changed, the single buyer model will be changed by the very small power producers and prosumers. In August 2017, act of plan and step for Energy Reform which 6 directions was announced. These are :

1. Energy Management
2. Electricity
3. Petroleum and Petrochemical
4. Renewable Energy
5. Energy Conservation and Efficiency
6. Technology Innovation and Infrastructure

For PV systems, the two directions of energy reform involve directly, namely electricity and renewable energy. The majority of energy reform of electricity consists of three issues. These are :

1. To improve the Power Development Plan (PDP) of Thailand
2. To support the electricity business competition and
3. To reform the structure of electricity power system.

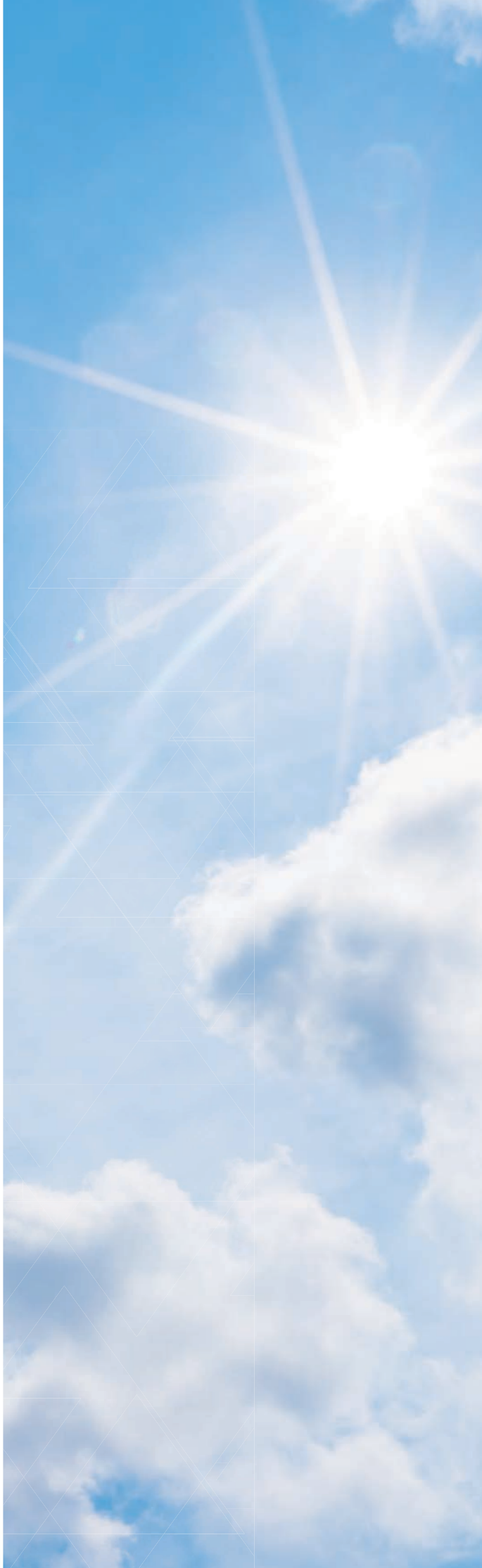
Power Development Plan (PDP) of Thailand for the latest draft version 2018 by MOE has been improved according to the large-scale power plants projects and transmission lines projects did not follow the plan. Moreover, the new PDP has to deal with the changing of electricity consumption behavior causing the daily peak demand shift from daytime to nighttime.

Energy reform of renewable energy consists of five issues. These are :

1. To manage the biomass fuel from fast-growing for biomass power plant.
2. To support and eliminate the obstacle of solid waste collection for power plant.
3. To support the liberalization of PV rooftop systems installation.
4. To restructure energy consumption in the transport sector.
5. To support the prosumers trend in term of regulation, infrastructure and energy conservation standard.

The liberalization of PV rooftop systems installation is one of the reforms of renewable energy to support the green community and city by using residential PV rooftop systems and to support the private electricity production and distribution.

The benefit of the liberalization of PV rooftop systems installation makes for new occupations and employment in the PV industry and business and to reduce the greenhouse gas emissions.



DEFINITIONS and ABBREVIATIONS

Adder

Adder is an incentive measure in purchasing of renewable energy such as wind, solar, small and micro hydro, biogas, biomass and municipal waste with the adder of existing electricity price for a certain period.

Biomass

Agricultural residues or wastes from production and agricultural products, lumber or wood from reforestation as fuel.

Capacity Factor (CF)

CF is a ratio of actual energy production in one year or over a period of time to the multiplication of installed capacity and number of hours in one year (8,760 hours) or over a period of time.

Feed-in Tariff (FiT)

FiT is an incentive measure in purchasing of renewable energy such as wind, solar, small and micro hydro, biogas, biomass and municipal waste with the fixed-rate electricity price for a certain period.

Kilowatt Peak (kWp) and Megawatt Peak (MWp)

The maximum power production of PV modules (or systems) under standard test condition (STC) for PV module testing according to the scale of the power output as kilowatt and megawatt, respectively.

Performance Ratio (PR)

PR is a ratio of actual energy production divided by installed capacity to the incident solar irradiation divided by the reference solar irradiance at STC (1,000 W/m^2).

Small Power Producer (SPP)

SPP is a private or state enterprise generating electricity using a cogeneration system (heat and power generation) or non-conventional energy sources with generation capacity from 10 to 90 megawatts.

(1) Non-conventional energy sources are such as wind, solar, and small hydro excluding oil, natural gas, coal and nuclear.

(2) SPP includes the electricity generating projects using following sources

- Agricultural residues or wastes from industry or agriculture
- Processed products from agricultural residues or wastes from industry or agriculture
- Garbage
- Wood from reforestation

Very Small Power Producer (VSPP)

VSPP is a private or state enterprise generating electricity with generation capacity less than 10 megawatts using the following non-conventional energy sources.

- Renewable energy sources such as wind, solar, small hydro, micro hydro and biogas
- Agricultural residues or wastes from industry or agriculture, processed products from agricultural residues or wastes from industry or agriculture, garbage, wood from reforestation

ACRONYMS

BOI	Board of Investment
BRU	Burriram Rajabhat University
CMRU	Chiang Mai Rajabhat University
CMU	Chiang Mai University
CU	Chulalongkorn University
DEDE	Department of Alternative Energy Development and Efficiency
EGAT	Electricity Generating Authority of Thailand
EPPO	Energy Policy and Planning Office
FiT	Feed-in Tariff
KU	Kasetsart University
KKU	Khon Kaen University
KMITL	King Mongkut's Institute of Technology Ladkrabang
KMUTT	King Mongkut's University of Technology Thonburi
MEA	Metropolitan Electricity Authority
MU	Mahidol University
NPU	Nakhon Phanom University
NRRU	Nakhon Ratchasima Rajabhat University
NU	Naresuan University
NIDA	National Institute of Development Administration
NSTDA	National Science and Technology Development Agency
PCRU	Phetchabun Rajabhat University
PEA	Provincial Electricity Authority
RMUTK	Rajamangala University of Technology Krungthep
RMUTSB	Rajamangala University of Technology Suvannabhumi
RMUTT	Rajamangala University of Technology Thanyaburi
SCOD	Scheduled Commercial Operation Date
SNRU	Sakon Nakhon Rajabhat University
SU	Silpakorn University
SWU	Srinakharinwirot University
SUT	Suranaree University of Technology
UBU	Ubon Ratchathani University
UBRU	Ubon Ratchathani Rajabhat University
UP	University of Phayao

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