Department of Alternative
Energy Development and Efficiency
MINISTRY OF ENERGY

SUSTAINABLE DEVELOPMENT GOALS

THAILAND PV STATUS REPORT 2020

Forward

Statistics from the past year have shown a promising trend. In addition to government support and promotion, we have seen substantial installation by the private sector for their own use, including sharing and distributing within the sector, independent of the grid (Independent Power Supply – IPS). This has resulted in an overall increase in installation and the indications are that this trend will continue into the foreseeable future.

Thus the time is right for the relevant government agencies to take note of these developments and to pursue a policy that actively supports them. This includes how to maintain the stability of the grid network and, in turn, energy security. In addition, the industrial standards for PV modules, inverters and batteries, as well as installation standards of the Engineering Institute of Thailand, need to be revised and upgraded where necessary, ensuring the regulation of electricity supply.

Department of Alternative
Energy Development and Efficiency
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Executive Summary

1.1 Installation of PV Systems

In 2020 PV systems installation added 143.6 MWp, resulting in the total PV installation capacity reaching 3,939.8 MWp. Most are the ground mounted PV system projects with power purchase agreements under the Alternative Energy Development Plan (AEDP) of Thailand. Meanwhile, PV systems for self-consumption and projects for which there are private sector power purchase agreements, are increasing continuously. There are 3,076.5 MWp of ground mounted PV systems, 842.4 MWp of rooftop systems and 14.8 MWp of floating systems. Off-grid PV systems have an installed capacity 6.1 MWp.

1.2 PV Industry

In 2020, the number of PV manufacturers remains the same with 15 manufacturers, while the cumulative installed capacity has doubled compared to 2018. There is 918 MW of capacity for 8 Thai manufacturers and about 8,000 MW for 7 international manufacturers. Most of the international manufacturers aim to export.

Due to the growth of the PV market, the manufacture of PV EVA production has been taken up by Thai businesses and most of these EVA are exported. Other equipment such as balance of systems manufactures and EV and ESS battery manufacture to support the electric vehicle and energy storage systems are also promoted in accordance with national policy.

In 2020, the cost of PV module of kW-scale production and of MW-scale production were lower than in 2018. These were 13-19 THB per watt (11.1%), and 8-11 THB per watt (36.7%) respectively. Cost of PV systems were around 35-45 THB per watt for residential, 25-30 THB per watt for commercial and 20-25 THB per watt for PV power plant systems.

1.3 Supporting Measures

There are two supporting measures contained within the Thailand Integrated Energy Blueprint (TIEB) which directly involves renewable energy development, The Thailand Power Development Plan (PDP) in 2018-2037, or PDP2018, and the Alternative Energy Development Plan (AEDP). In PDP2018 revision 1, by 2037 the target of 2,725 MW for the floating PV systems integrated with hydro-power generation was set. In addition, AEDP2018 targets 18,696 MW of renewable energy by 2037, 12,139 MWp of Solar Energy target, resulting to renewable energy per demand of electricity being 34.23%. During 2020, the government continued support through the solar rooftop PV systems for Thai People Project, as well as introducing the pilot project of solar systems for schools, hospitals and solar pumping systems for agriculture.

Movable PV system at Phu Lean Kha National Park, Chaiyaphum province

1.4 PV systems in the energy transition context

The continued growth of PV system installation in Thailand occurred due to both government policy support and the private sector's market drive. This can be attributed to the cost of PV module reduction and global climate change policy. The national power development plan has set the renewable energy target with 2,725 MW of floating PV systems installed in major dams by 2037. This electricity energy will play an important role in the digital era with the infrastructure preparation of smart grid ongoing, including the Thai people project of rooftop PV systems.

There has been increased consumer interest in PV systems installation to produce electricity for self-consumption and for private sector consumption as prosumer. This is largely due to increased awareness of the effects of climate change which has seen a surge in rooftop systems. This has been actively promoted through bodies such as the Thailand Carbon Neutral Network, Thailand RE100 Club and Carbon Market Club.

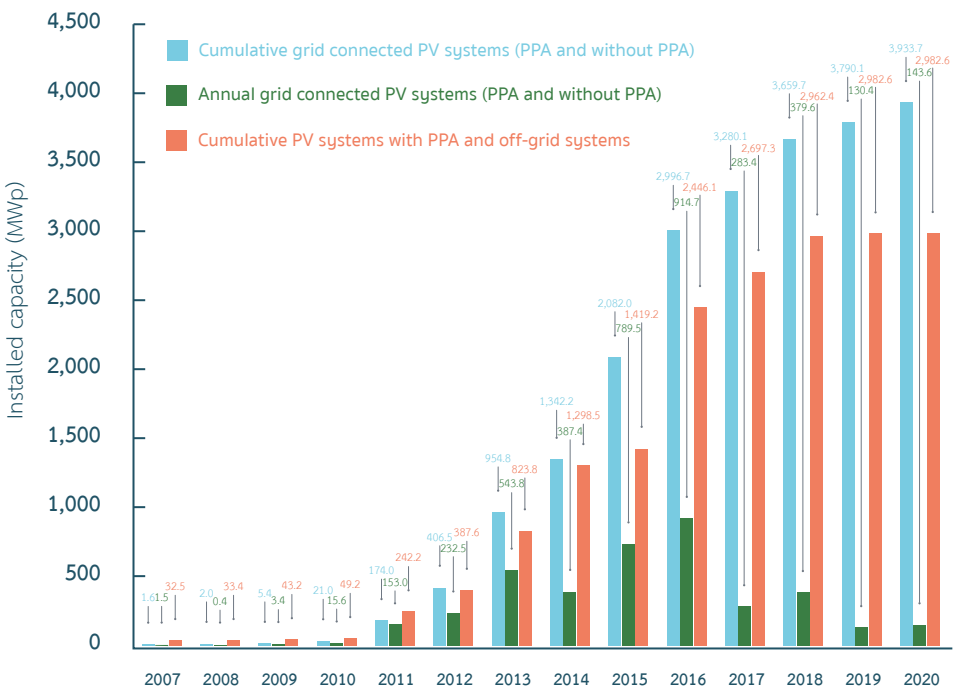
2

Implementation of PV Systems

2.1 Installation Capacity of PV Systems

PV systems production in Thailand has been steadily increasing under the Alternative Energy Development Plan (AEDP) beginning from 2011. The private sector has received power production licenses to produce the RE electricity and sell to the grid, called Power Purchase Agreement or PPA. PV systems installation has been continuously growing from 2011 until the present due to the decrease of the PV module price from PV module industry in China. In 2020, the cumulative installed grid connected PV systems capacity in Thailand reached 3,933.7 MWp, including the adder program, offering 10 years purchase of electricity, the feed in tariff program (FiT) for 25 years supporting the purchase of electricity at a fixed rate and PV systems without PPA. Total installation of PV systems in Thailand in 2020 stood at 3,939.8 MWp including the off-grid PV systems.

In 2017-2020, grid connected PV systems with PPA increased 4.7%, meanwhile the total of grid connected PV systems (with PPA and without PPA) increased 6.5%.



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

Figure 2.1 Cumulative PV systems installation in Thailand from 2007-2020

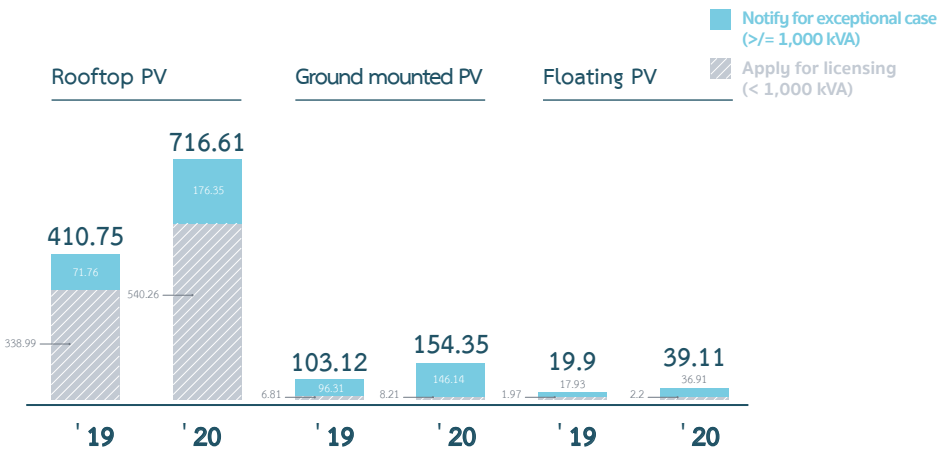
Table 2.1 Installed capacity of PV systems from 2007-2020

Year	Cumulative grid connected systems (PPA and without PPA) (MWp)	Annual grid connected systems (PPA and without PPA) (MWp)	Cumulative PV systems with PPA and off-grid systems (MWp)
2007	1.6	1.6	32.5
2008	2.0	0.3	33.4
2009	5.4	3.4	43.2
2010	21.0	15.6	49.2
2011	174.0	153.0	242.4
2012	406.5	232.5	387.6
2013	954.8	548.3	823.8
2014	1,342.2	387.5	1,298.5
2015	2,082.0	739.7	1,419.2
2016	2,996.7	914.7	2,446.1
2017	3,280.1	283.5	2,697.3
2018	3,659.7	379.5	2,962.4
2019	3,790.2	130.5	2,982.6
2020	3,933.7	143.6	2,982.6

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

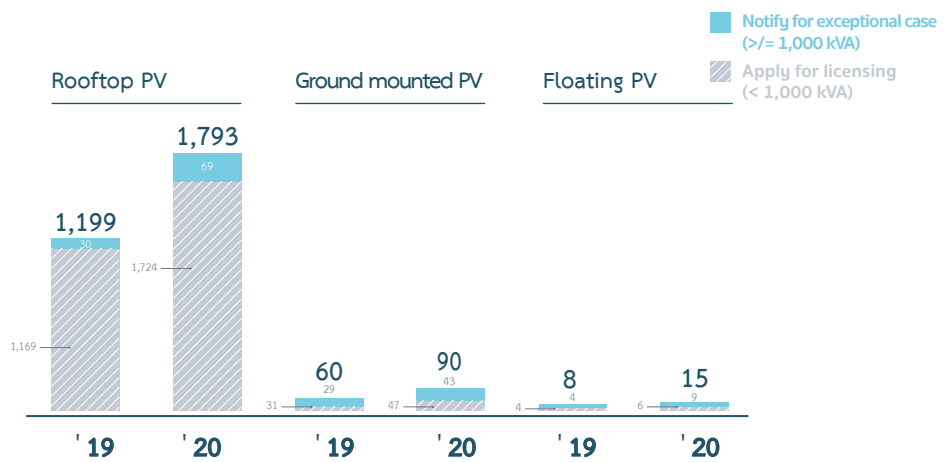
PV systems installation continuously increased from 2007 until 2018, which was the year that the power purchase program by the government ended. In contrast, PV systems production for self-consumption or private sector purchase has grown as Independent Power Supply (IPS). Figure 2.2 illustrates cumulative PV systems of licensing and non-registered with exceptional cases during 2019-2020.

In 2020 installed PV systems was the licensed power producers without PPA and not licensed but registered with exceptional cases, totaling 910.06 MWp of 1,898 projects. While most of PV systems was the rooftop PV systems 716.61 MWp of 1,793 projects, the others were ground-mounted PV systems 154.35 MWp for 90 projects and floating PV system 39.11 of 15 projects, as illustrated in Figure 2.2 and detailed in Table 2.2. The trend of rooftop solar PV and floating PV systems are expected to rise continuously due to the available space for installation with enabling investment.



Source: This data was provided by OREC.

(a) the cumulative installed capacity in 2019-2020 (Unit: MWp)



Source: This data was provided by OREC.

(b) the number of projects in 2019-2020 (Unit: project)

Figure 2.2 Cumulative installed PV systems of licensing and non-registered with exceptional cases during 2019-2020

Table 2.2 Cumulative installed PV systems of licensing and non-registered with exceptional cases during 2019-2020.

Type of installation	2019		2020	
	Installed Capacity (MWp)	Number of projects	Installed Capacity (MWp)	Number of projects
Rooftop PV system	**410.75**	**1,199**	**716.61**	**1,793**
- Notify to exception	338.99	1,169	540.26	1,724
- Apply for Licensing	71.76	30	176.35	69
Ground mounted PV systems	**103.12**	**60**	**134.33**	**90**
- Notify to exception	6.81	31	8.21	47
- Apply for Licensing	96.31	29	146.14	43
Floating PV systems	**19.9**	**8**	**39.11**	**15**
- Notify to exception	1.97	4	2.2	6
- Apply for Licensing	17.93	4	36.91	9
Total	533.77	1,267	910.06	1,898

Source: This data was provided by OREC.

Note: The electricity system that more than or equal to 1,000 kVA of capacity has to register to license while the electricity system that less than 1,000 kVA of capacity need to notify for exceptional case.

2.2 Grid-connected PV Systems

Most of PV systems installation in Thailand are grid connected systems, known as Small Power Producers (SPPs) for system capacity of more than 10 MW but not exceeding 90 MW, connected with Electricity Generating Authority of Thailand (EGAT) system. However, there is also the Very Small Power Producers (VSPPs) with system capacity less than 10 MW which are connected with MEA for Bangkok, Nonthaburi, and Samut Prakarn provinces and with PEA for other locations.

The cumulative installed PV systems for SPP reached 588.47 MWp of 7 projects as in Table 2.4. The first and last projects had COD on December 2011 and April 2016, respectively. All projects are ground-mounted systems which are mainly located in the central and northern region of Thailand. Details for the VSPP PV systems are as follows:

(1) The cumulative ground-mounted PV systems installation has reached 2,479.4 MWp for 587 projects such as the adder incentive program for 10 years which was introduced in 2005. After that the incentive program was changed to be feed in tariff (FiT) beginning in 2016, for previous adder applicants who were accepted to change the contract. The ground-mounted systems for agricultural cooperatives program phase I of 2016 and phase II were also included.

(2) Solar PV Rooftop projects which applied FiT phase I of 2013 and phase II of 2015, the cumulative installation was 130 MWp with 6,135 projects.

(3) Residential rooftop PV projects for Thai people in 2019, the cumulative installation was 2.61 MWp with 480 projects.

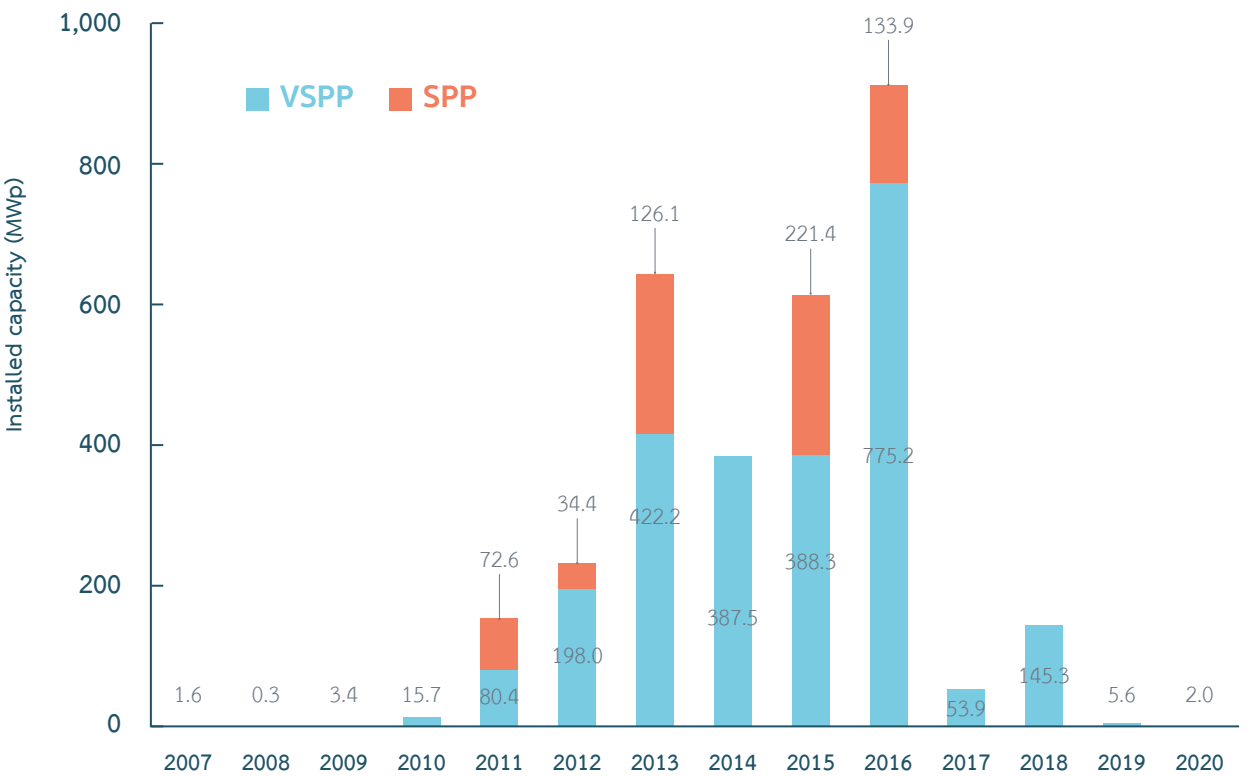
From 2008 to 2020, cumulative PV system capacity with PPA was 3,200.5 MWp of 7,209 projects.

2.2.1 PV systems installation under the government policies

There are three types of PV systems installation which are firstly ground-mounted system with more than 1 MW to 10 MW due to the limitation of feeders in distribution system, whereas the higher system connected to EGAT system. Secondly, rooftop PV system has most of the installation lower than 1 MW which consisted of residences that have a capacity less than 10 kW, commercial building more than 10–250 kW and large commercial building including factory with more than 250–1000 kW. Finally, floating PV system scale relates with specific areas that its capacity less than 10 MW.

Ground-mounted PV systems

The number of ground-mounted PV systems installation between 2007 and 2020, especially with PPA registration, has increased until 2019, reaching a peak in 2016 of 909.1 MW for 142 projects due to the change of supporting scheme from Adder to be Feed in Tariff. After that, from 2017 to 2019, there was the ground-mounted PV system program for government agencies and agricultural cooperatives program phase I and II, in 2017, totaling 3,067.9 MWp of 562 projects as shown in Figure 2.3.



Source: This data was provided by OERC.

Figure 2.3 Yearly installation capacity with registered PPA between 2007 and 2020

Table 2.3 Ground-mounted PV systems in Thailand from 2007 to 2020

Year	VSPP (MWp)	SPP (MWp)	Total installed capacity (MWp)
2007	1.6	-	1.6
2008	0.3	-	0.3
2009	3.4	-	3.4
2010	15.7	-	15.7
2011	80.4	72.6	153.0
2012	198.0	34.4	232.4
2013	422.2	126.1	548.3
2014	387.5	-	387.5
2015	388.3	221.4	609.7
2016	775.2	133.9	909.1
2017	53.9	-	53.9
2018	145.3	-	145.3
2019	5.6	-	5.6
2020	2.0	-	2.0
	Total		**3,067.9**

Source: This data was provided by OERC.

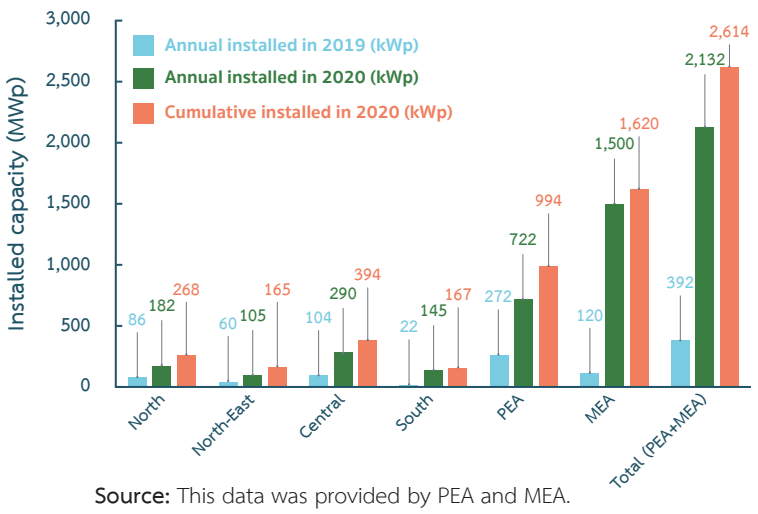
Table 2.4 SPP power plants of PV systems in Thailand in 2020

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

Source: OERC and PV Power Plant owners

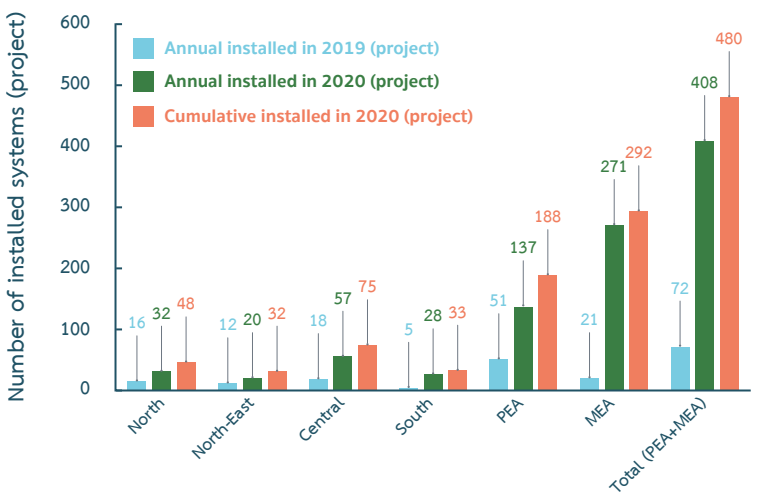
Rooftop PV systems

Self-consumption PV systems installation has been continuously increasing since 2019 from solar PV rooftop projects with FiT incentive program phases I in 2013 and phase II in 2015. It appears that most of rooftop PV systems installed capacity was between 500 and 1,000 kWp which could be further run by market mechanism whilst residential installation had lower installed capacity. As a result, in 2019, the government has launched the residential rooftop PV systems program for Thai people at less than 10 kWp of capacity that the cumulative installation in 2020 was 2.61 MWp of 480 projects. Moreover, the ratio of cumulative installed capacity accounted for 61.97% of MEA, 1.62 MWp of 292 projects and 38.03% of PEA, 0.994 MWp of 188 projects.



Source: This data was provided by PEA and MEA.

Figure 2.4 Installed capacity of rooftop PV systems for Thai people projects in 2019-2020



Source: This data was provided by PEA and MEA.

Figure 2.5 Number of rooftop PV systems project for Thai people projects in 2019-2020

Floating PV systems

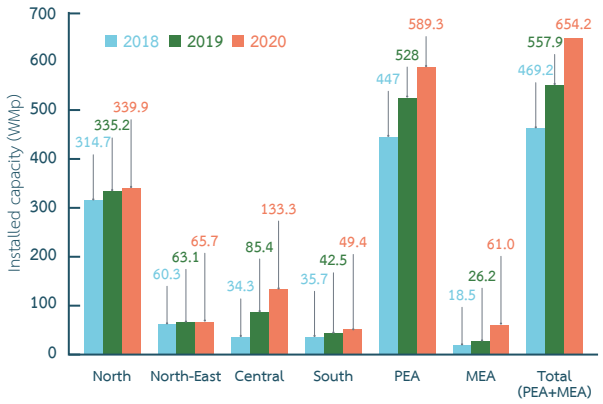
The application of floating PV systems (FPV) in Thailand was initiated by EGAT, who also have responsibility for managing hydro-power. The first FPV system of EGAT was the 249.6 kWp system at Sirindhorn Dam, Ubon Ratchathani Province. After that, Thailand Power Development Plan (2018-2037) Revision 1, target's FPV system with hydro-power to be 2,725 MW. In 2020, the FPV has been already installed for 45 MW at the Sirindhorn Dam, which expected for COD by 2021. This is the biggest FPV system with hydro-power plant in the world which has a total area of around 720,000 m^2, using double glass PV module technology and HDPE (High Density Polyethylene) buoys. This project can reduce the CO_2 emission by 47,000 tons/year.

FPV system of EGAT (45 MW) at Sirindhorn dam, Ubon Ratchathani province

2.2.2 Self-consumption PV systems and activity in private sector

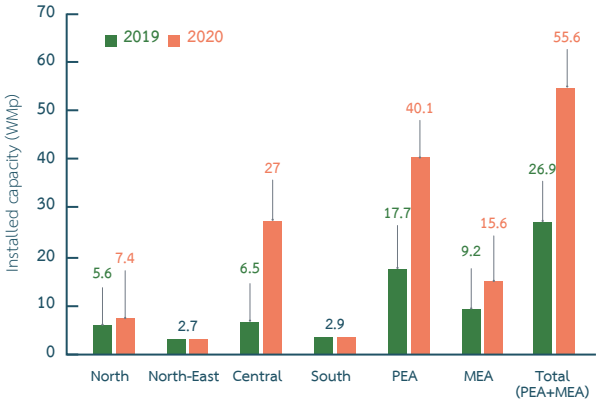
In 2018–2020, self-consumption rooftop PV systems without PPA saw continuous growth. Because the PV module price has significantly dropped by market mechanism that leads more rooftop PV systems installation to reduce the electricity bill. This increases the number of self-consumption PV systems installation and extends the trade of electricity between private sectors.

In 2020 the cumulative self-consumption rooftop PV systems reached 733 MWp for 1,974 projects, including pilot projects for liberalizing rooftop PV systems installation 5.63 MWp of 180 projects, and private sector distribution consisting of rooftop PV systems 55.6 MWp of 83 projects, floating PV systems 14.6 MWp of 5 projects and ground-mounted PV system 8.6 MWp of 3 projects. Figure 2.6 illustrates the self-consumption PV systems and the PV systems in the private sector's distributed generation as same as the data shown in Table 2.5.



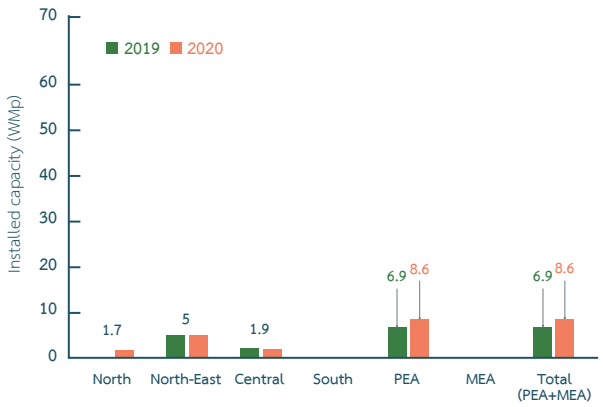
Source: This data was provided by PEA and MEA.

(a) Seft-consumption rooftop system



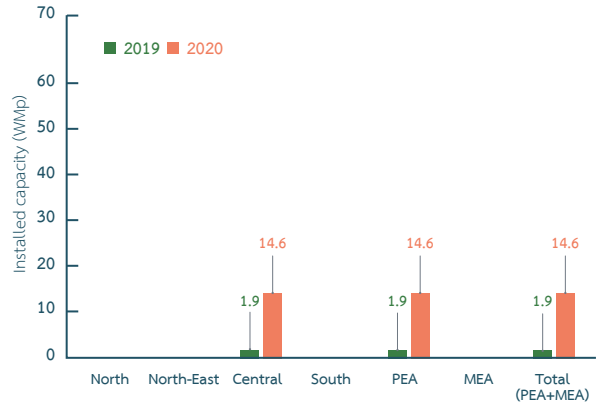
Source: This data was provided by PEA and MEA.

(b) Private sector's distributed PV system



Source: This data was provided by PEA and MEA.

(c) Seft-consumption ground mounted system



Source: This data was provided by PEA and MEA.

(d) Private sector's distributed floating system

Figure 2.6 Self-consumption PV systems and PV systems of private sector's distributed generation by 2018-2020.

Table 2.5 Data of Self-consumption PV systems and PV systems of private sector's distributed generation by 2018-2020.

Type of installation		North	North-East	Central	South	PEA	MEA	Total installed capacity (MWp)
Rooftop PV system (self-consumption)	Installed capacity (MWp)	339.9	65.5	132.9	49.2	589.2*	65	**654.2**
	Number of projects (project)	474	243	292	182	1,218*	665	**1,883**
Rooftop PV system (Private sector's distribution)	Installed capacity (MWp)	7.4	2.7	27	2.9	40.1	15.6	**55.6**
	Number of projects (project)	12	4	22	4	42	41	**83**
Ground-mounted PV system (self-consumption)	Installed capacity (MWp)	1.7	5	1.9	-	8.6	-	**8.6**
	Number of projects (project)	1	1	1	-	3	-	**3**
Floating PV system (Private sector's distribution)	Installed capacity (MWp)	-	-	14.6	-	14.6	-	**14.6**
	Number of projects (project)	-	-	5	-	5	-	**5**
Total	Installed capacity (MWp)	**349**	**73.2**	**176.8**	**52.1**	**652.6**	**80.6**	**733**
	Number of projects (project)	**487**	**248**	**320**	**186**	**1,268**	**706**	**1,974**

Source: This data was provided by PEA and MEA.

Note: *Rooftop PV systems for self-consumption include the pilot project in 2016, consist of 1.69 MWp of 27 projects for PEA and 3.93 MWp of 153 projects for MEA.

2.3 Off-grid PV Systems

Off-grid PV systems installation initiative in Thailand for supporting the remote areas which have the limitations for electricity generation and distribution. Table 2.6 shows the cumulative off-grid PV system installation capacity in 2020 totaling a capacity 6,109.1 kWp for 3,625 systems (not including the Solar Home Project year 2005). Off-grid PV systems increased 6.2% from 2018.

Table 2.7 shows off-grid PV systems applications by DEDE that have been in continuous operation. In 2020, cumulative off-grid installation reached 3,974.7 kWp of 2,589 projects and has been transferred to the local owner 912.2 kWp of 622 projects.

Table 2.6 Off-grid PV systems applications in 2020.

Organization	2018		2020	
	Number of projects (project)	Cumulative installed systems (kWp)	Number of projects (project)	Cumulative installed systems (kWp)
Solar Energy Research and Training Center, SERT, Naresuan University	4	3.6	Changed to on-grid PV system	
TOT Public Company Limited	1	6	1	6
King Mongkut's University of Technology Thonburi	5	52.4	6[1]	67.4[1]
National Science and Technology Development Agency	5	142.8	25[2]	207.8[2]
Defence Energy Department	167	641	382	941
Department of Alternative Energy Development and Efficiency	2,633	4,084.9	2,589	3,974.7
System transfer from Department of Alternative Energy Development and Efficiency	572	801.7	622	912.2
Solar Home project in 2005	203,100*	24,388*	-	-
Total	**206,487**	**30,120.4**	**3,625**	**6,109.1**

Source: Owner and DEDE

Note: This data does not include PV devices for lighting.

1 Mobile hybrid system including 15 kW of PV, 1 kW of wind turbine 60 kWh of lithium-ion battery and 26 kW of diesel generator.

2 In 2019 total installed capacity is 65 kW for 20 systems, consisting of 1.5 kWp each for 10 PV systems and hybrid systems of 5 kWp PV system with diesel generator.

* Solar Home project in 2005 was implemented by PEA then transfer of these systems to the local administration organization.

Table 2.7 Off-grid PV systems application by DEDE in 2020

Applications	Year	Cumulative installed systems (kWp) (Number of projects)	Decommissioned systems (kWp) (Number of projects)	Systems transfer from DEDE (kWp) (Number of projects)	DEDE remaining systems (kWp) (Number of projects)
The royal development projects	1999-2019	516.19 (1,068)	10 (19)	9.8 (10)	496.3 (1,039)
Rural schools	2002-2017	1,642.5 (423)	15 (4)	241.2 (58)	1,386 (361)
Mae Fah Luang the Tribal Community learning center	2004-2017	384 (256)	-	303 (202)	81 (54)
Sub-district health promoting hospitals	2003-2016	238 (111)	-	58 (30)	180 (81)
National parks and forests	2006-2016	298 (92)	-	9 (3)	289 (89)
Solar pumping systems	2003-2015	200 (100)	4 (2)	74 (37)	122 (61)
Battery charging stations	1993-2004	1,309.2 (387)	60 (3)	114 (34)	1,135.2 (350)
Military operations base and border protection base	2002-2014	388.38 (802)	-	103.1 (248)	285.2 (554)
Total		**4,976.26 (3,239)**	**89 (28)**	**912.2 (622)**	**3,974.7 (2,589)**

Source: This data was provided by DEDE.

The distributed off-grid PV systems can be transformed to the centralized off-grid PV system to develop solar pump systems for communities such as the microgrid with PV systems using existing 132.6 kW of PV system, 128 kWh of battery system and 100 kW of diesel generator, operated by King Mongkut's University of Technology Thonburi.

There was also the collection of used PV modules from other projects namely

(1) 102 kWp from Internal Security Operations Command (ISOC) project

(2) 4.8 kWp from Ban Bang Kloy-Pong Luk Royal Folk Arts and Crafts Center

(3) 8.1 kWp from the border police school

(4) 5.6 kWp from Department of Groundwater Resources for village water supply

(5) 15.3 kWp from Royal Irrigation Department (Ban Pong Luek) pumping for agriculture

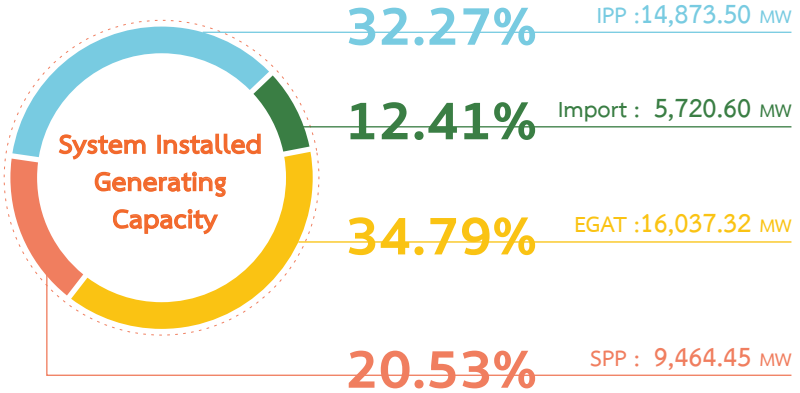
(6) 15.3 kWp from Royal Irrigation Department (Ban Bang Kloi) pumping for agriculture

(7) 16.5 kWp from other systems.

The benefit of solar pumping project for community is to provide the water supply for agricultural areas as 969,600 m^2 and 144 homes gaining the advantages from consumable water.

2.4 Electricity Production

Thailand has power generation of 46,095.87 MW (as of 31 May 2021), comprised of 34.79% of EGAT, 32.27% of IPP, 20.53% of SPP, 12.41% of imported and others from RE VSPP of EGAT.



Source: EGAT

- Total capacity: 46,095.87 MW
- Renewable Energy of EGAT: 3,057.92 MW

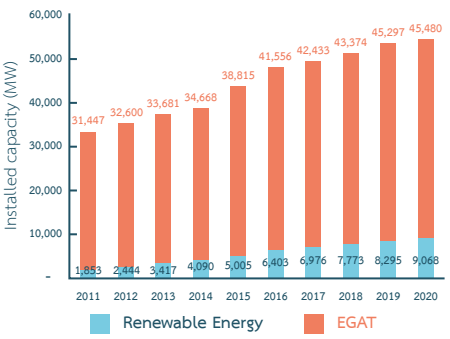
as of May 31, 2021

Figure 2.7 Power generation in system by type of power plants

Power generation and energy consumption by year

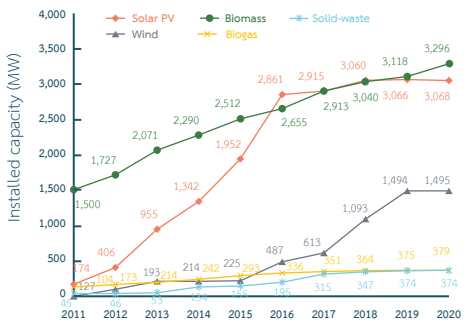
In 2011-2020, power generation has increased according to the national economic development plan that significantly rose 10% in 2015, while increasing average value at 3.2% in previous years. In 2016-2020 the average value of power generation growth is about 3.7% as shown in Figure 2.8 (a).

For renewable energy generation in 2011-2020 has raised around 15.8% on average that PV systems installed capacity has also increased continuously the capacity and reached the top capacity installation with biomass energy. This demonstrates PV power system has the main effect for renewable energy production of Thailand in Figure 2.8 (b).



Source : EPPO

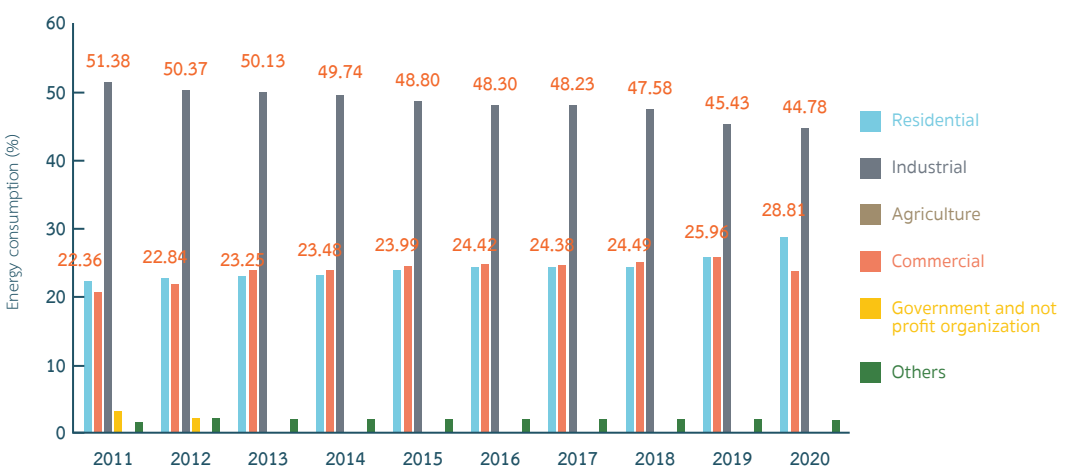
(a) System installed power generation capacity and renewable energy generation



Source : OERC

(b) Renewable energy generations by type of fuels

Figure 2.8 Power generation capacity and renewable energy generation in 2011-2020



Source : EPPO

Figure 2.9 Energy consumption by applications in 2011-2020

Figure 2.9 illustrates the energy consumption in different sections that the majority is appeared to be industrial that is decreasing energy consumption. Because the self-consumption PV system installation of industry has continued to increase. The same as commercial has slightly decreased due to self-consumption PV system installation. On the other hand, residential has increasing energy consumption due to more activity when many residents stay at home during Covid-19 pandemic. In 2019-2020 the rooftop PV system installation for residences was few increasing that need to support from government by the re-regulation.

3

PV Industry and Growth

3.1 PV Technology in the Market

3.1.1 PV module efficiency

During the first half of 2020 there were 9 technologies under development and 4 of these showed continuous improvement in efficiencies over a 5-year period. Silicon PV modules with 2 technologies demonstrated module efficiency of 20.4-24.4%, while 2 thin-film technologies reached module efficiencies of around 19%. In the case of emerging technology, perovskite modules have also been developed that reached an efficiency of around 17.9%, however, the stability of this technology was still under development.

Table 3.1 PV module efficiency for various technologies (from solar cell efficiency tables version 57)

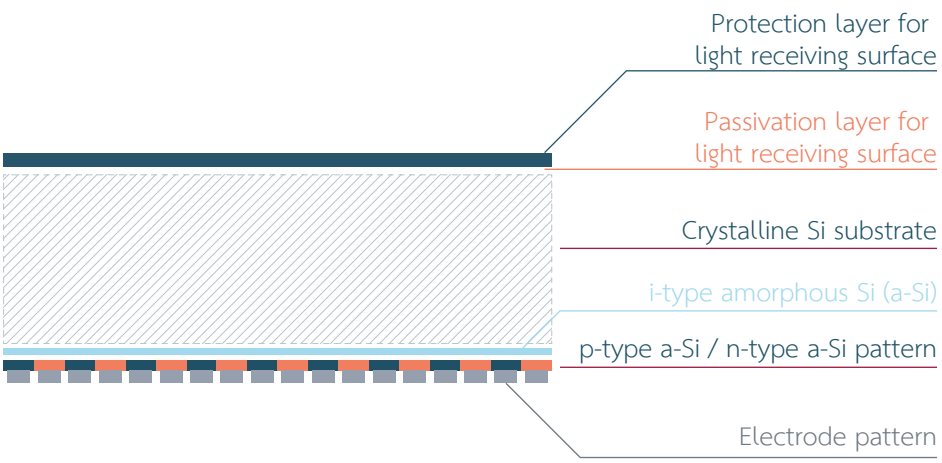
Technology		Efficiency (%)	Area (cm^2)	Open circuit voltage, Voc (V)	Short circuit current, Isc (A)	Fill Factor, FF (%)
Crystalline Silicon	Mono crystalline Si	24.4	13,177 (da)	79.5	5.04	80.1
	Poly crystalline Si	20.4	14,818 (ap)	39.9	9.83	77.2
Thin film	GaAs	25.1	866.45 (ap)	11.08	2.3	85.3
	CIGS (Cd-free)	19.2	841 (ap)	48	0.45	73.7
	CdTe	19	23,573 (da)	227.8	2.56	76.6
	a-Si/nc-Si (tandem)	12.3	14,322 (t)	280.1	0.9	69.9
	Perovskite	17.9	804 (da)	58.7	0.32	76.1
	Organic	8.7	802 (da)	17.47	0.56	70.4
Multi-junction	InGaP/GaAs/InGaAs	31.2	968 (da)	23.95	1.5	83.6

Source: Progress in photovoltaics, Vol. 29, Issue 1, pp. 3-15, Jan. 2021.
Note: t (Total area) means module areas including frame.
ap (Aperture area) means the cell areas, busbars, fingers, and electrical connection points inside the module without frame.
da (Designated illumination area) means the area of cells excluding busbars outside the calls.

Crystalline silicon technology

1. Heterojunction Back Contact (HJBC)

Heterojunction technology has n-type crystalline Si substrate and p-type amorphous Si. The maximum efficiency is 24.4% because of the electrode development, being on the back of cell, gaining an advantage on light receiving. Additionally, interdigitated design between n-type and p-type reduce the electrical resistance on connection points (ohmic contact).

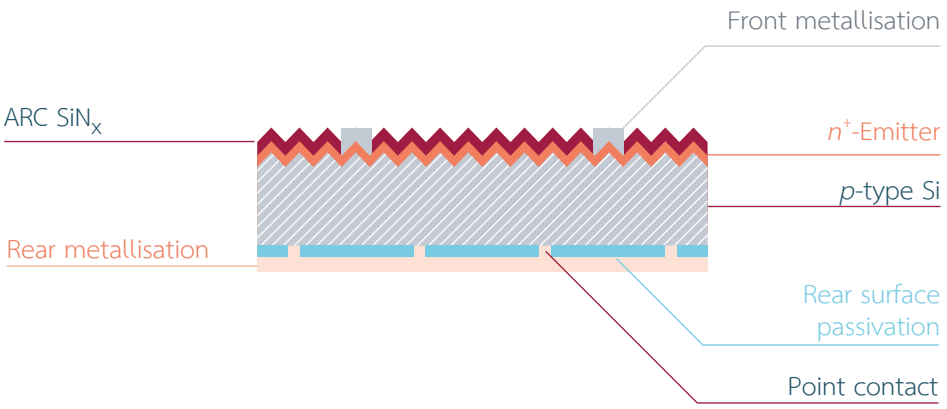


Source: https://www.nedo.go.jp/english/news/AA5en_100109.html

Figure 3.1 Heterojunction Back Contact structure

2. Passivated Emitter Rear Cell (PERC)

Passivated Emitter Rear Cell (PERC) technology is made from multicrystalline Si that has efficiency of 20.4%. Passivation layers were developed by using dielectric film at the back side of p-type layer to combine fixed charges under the insulation layer. This causes magnetic field on the surface to reduce recombination between electron and hole and contact area between semiconductor materials and electrodes to reduce the electrical losses.



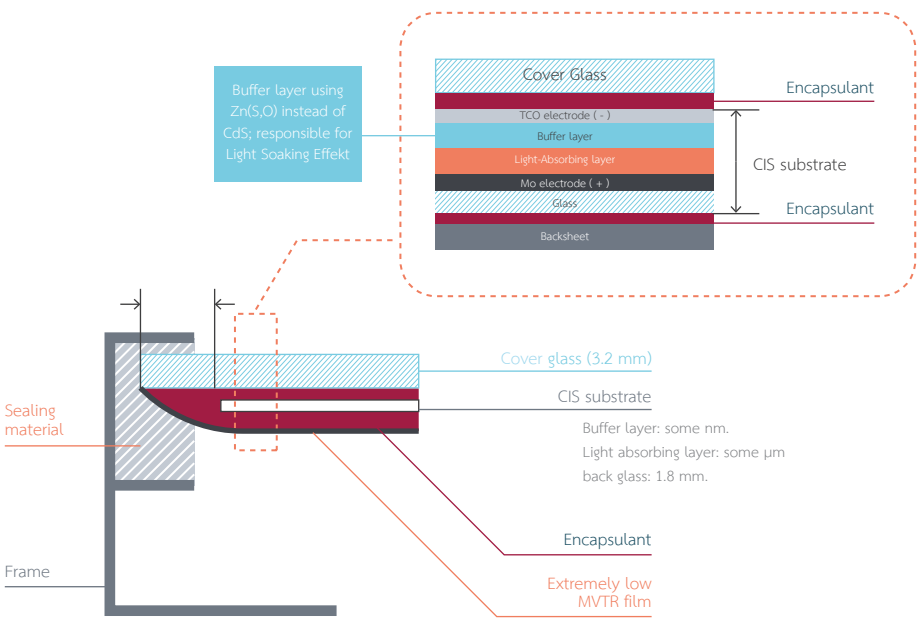
Source: B. Kl¨oter, et. Al., "Current status of high-efficiency Q.ANTUM technology at Hanwha Q CELLS", IEEE PVSC, June 2013

Figure 3.2 Passivated Emitter Rear Cell (PERC) structure

Thin-film technology

1. CIGS

Thin-film PV modules, CIGS or Copper Indium Gallium di-Selenide (CuIn1-xGaxSe2) have maximum efficiency of 19.2% with absorber and buffer layers being developed, including the development of cell integration by using monolithic integration technique to reduce series resistance.

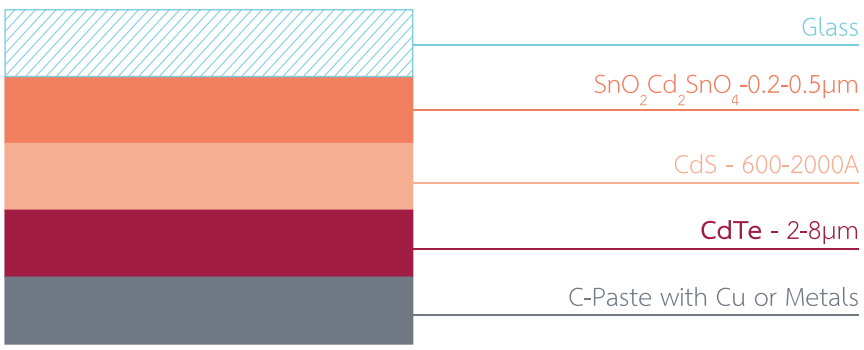


Source: https://docplayer.net/4582872-Solar-frontier-cis-modules.html

Figure 3.3 CIGS (Cd free) PV module structure

2. CdTe

CdTe PV module technology has reached 19.0% of maximum efficiency due to wide diversity in development including replacement of copper by group 5 elements as antimony or arsenic. The increase of Voc by $CdCl_2$ (cadmium chloride), the increase of phosphorus atoms in lattice of Te (tellurium) and the improvement of material layer junction were also developed. These developments affect the conductive value of CdTe and carrier lifetime by several times.



Cadmium Telluride (CdTe)

Source: https://www.nrel.gov/pv/cadmium-telluride-solar-cells.html

Figure 3.4 CdTe PV module structure

3.1.2 Commercial PV module efficiency

Table 3.2 shows the commercial PV module efficiency by technology. There are 3 groups of average module efficiency such as (1) 17% by average (2) 18.4% by average and (3) 20.5% by average. The first group are p-Si and m-Si, the second group are PERC p-Si and PERC m-Si and the third group are n-type m-Si, HJT n-type m-Si and IBC n-type m-Si.

Table 3.2 Commercial PV module efficiency by technology

Technology	Efficiency (%)
Polycrystalline	15 - 18
Monocrystalline	16.5 - 19
Polycrystalline PERC	17 - 19.5
Monocrystalline PERC	17.5 - 20
Monocrystalline n-type	19 - 20.5
Monocrystalline n-type HJT	19 - 21.7
Monocrystalline n-type IBC	20 - 22.6

Source: Cleanenergyreviews.info, March 2021

3.2 Development of PV Module Production and Balance of Systems

In Thailand PV manufacture development can be divided into two major periods that are (1) the production period between 2005 and 2014, mostly in support of government programs and (2) the international manufacturers becoming involved, since 2015, PV cell and module manufacturers have invested in Thailand to primarily produce for export.

Table 3.3 shows PV cell and module manufacturers in Thailand in 2020 with 7 manufacturers having around 8,000 MW of production capacity. Meanwhile Table 3.4 shows 8 PV module manufactures that have 918 MW of production capacity and 269 MW of production per year. Additionally, there has also been production of ethylene vinyl acetate (EVA) in Thailand by TPI Polene (Public) Co., Ltd. using the existing EVA for forming specific solar EVA, which has supplied approximately 10% to Thailand market and another 90% for exporting to Europe, USA and the Middle East.

Table 3.3 PV cell and module manufacturers in Thailand in 2020

No.	Manufacturer	Investor	Production Capacity: Module (MW)	PV module production (MW/year)
1	Canadian Solar Manufacturing (Thailand) Co., Ltd	Singapore, China	3,600 (1,000 MW, 2018)	2,000 (Mono Si / Poly Si)
2	Gintech (Thailand) Limited	Taiwan	n/a (1,000 MW, 2018)	1,600 (Mono Si / Poly Si) Half cut
3	Jetion Solar (Thailand) Co., Ltd.	China, Thai	200 (250 MW, 2018)	200
4	Solartron Public Co., Ltd.	Thai	700 (200 MW, 2018)	100
5	Trina Solar Science & Technology (Thailand) Co., Ltd.	Singapore	n/a (500 MW, 2018)	n/a
6	Talesun Technology (Thailand) Co., Ltd.	China	1,500 - 2,000 (800 MW, 2018)	n/a
7	Yingli Green Energy Holding Co., Ltd.	China	500 (300 MW, 2018)	n/a
	Estimated total*		**8,000 MW**	-

Source: Manufacturers and company's website
Note: * This estimated total used some data of 2018.

Table 3.4 PV module manufacturers in Thailand in 2020

No.	Manufacturer	Investor	Production Capacity: Module (MW)	PV module production (MW/year)
1	G.K.Assembly Co., Ltd.	Thai	n/a (90 MW, 2018)	81 (Poly Si) (2018)
2	Schetten Solar (Thailand) Co., Ltd.	China, Thai	500 (30 MW, 2018)	10 (Mono Si / Poly Si)
3	Solar PPM Co., Ltd.	China, Thai	n/a (250 MW, 2018)	150 (Poly Si)
4	Solar Power Technology Co., Ltd.	Thai	7.5 (25 MW, 2018)	5 (Mono Si / Poly Si)
5	Pornjaroen Tempered Safety Glass Co., Ltd.	Thai	2.5 (30 MW, 2018)	2.5 (Mono Si / Poly Si)
6	Full Solar Co., Ltd.	Thai	50 (the same as 2018)	10 (Mono Si / Poly Si)
7	Irradiance Solar Co., Ltd.	Thai	3 (6 MW, 2018)	1.5 (Poly Si)
8	Ekarat Solar Co., Ltd.	Thai	15 (50 MW, 2018)	9 (Poly Si)
	Estimated total*		**918**	**269**

Source: Manufacturers
Note: * This estimated total used some data of 2018.

Inverter manufacture

Most of the inverter usage in Thailand is from imports due to the low cost. However, in the case of higher cost, some users opt for reliability and after sales service. There are now 6 Thai inverter manufacturers, (increasing from the previous 2 namely Leonics Co., Ltd. and Thai Tabuchi Electric Co., Ltd.). Now there are 4 more manufacturers established which are Chuphotic Co., Ltd., Delta Electronics (Thailand) Public Company Limited, Daddee Power Group Co., Ltd., and A.P.Y Engineering Co., Ltd., as shown in Table 3.5.

Table 3.5 Inverter manufacturers in Thailand

No.	Manufacturer	Investor	Technology					
			Solar Pump Inverter	Stand-Alone Inverter	Grid Connected Inverter	Grid Interactive Inverter	Hybrid Inverter	Charge Controller
1	A.P.Y. Engineering Co., Ltd.	China	●		●			
2	Chuphotic Co., Ltd.	Thai	●	●	●		●	●
3	Daddee Power Group Co., Ltd.	Thai	●					
4	Delta Electronics (Thailand) Public Co., Ltd.	China			●		●	
5	Leonics Co., Ltd.	Thai	●	●	●	●	●	●
6	Thai Tabuchi Electric Co., Ltd.	Japan		●	●			

Source: Manufacturers

Battery manufacture

Previously, battery manufacture in Thailand was based on lead–acid battery (Starting Lighting Ignition: SLI). However, there has been research and developed on the deep-cycle stationary battery for supporting PV systems which, in 2003-2009, supplied only off-grid PV systems. In addition, there has been imports of stationary batteries with capacities in excess of 12 and 24 volts. Following this, the PV systems and batteries can mutually operate with allied government policy using EV which leads to the high-capacity battery manufacturer as shown in Table 3.6 showing EV and ESS manufacturers in Thailand as of 2020 for 3 manufacturers. Thailand has set a target to be the centre of battery technology manufacture in Southeast Asia.

Table 3.6 EV and ESS manufacturers in Thailand

No.	Manufacturer	Location	Production Capacity (GWh)	Production per year
1	Amita Technology (Thailand) Co., Ltd. (ATT) and Energy Absolute Public Co. Ltd. (EA)	Bangpakong, Chachoengsao	50 GWh	Lithium-ion Polymer (Taiwan) /1 GWh
2	Global Power Synergy Public Company Limited (GPSC) PTT Group's	Map Ta Phut, Rayong	1 GWh	semi solid lithium ion (24M Technologies Co , US) /30 MWh
3	Rojana Industrial Park Public Co., Ltd. and EVLOMO (US) Co., Ltd.	EEC Nong Yai, Chonburi	8 GWh	Lithium ion (Korea) /1 GWh

Source: Manufacturers

Note: EEC stands for Eastern Economic Corridor, EV stands for Electric vehicle, ESS stands for Energy Storage System.

Batteries are applied as Energy Storage Systems, or ESS, for diverse applications that must be appropriately designed to the application. EV battery used in kWh requires the rapid charge within minutes to hour periods. However, ESS used in kWh-MWh requires the charge period as hours.

3.3 PV Module and System Pricing

Table 3.7 indicates the change of PV module pricing in Thailand between 1997 and 2020. This shows that PV module prices for kW-scale installation capacity during 2019-2020 has dropped from year 2018 by 11.1%. There is a similar trend with installed capacity of MW-scale, which has gone down around 36.7% whilst the global price dropped 25%. In comparison, the 5-year average decreased ratio, there is around 16.3% per year for the kW-scale of installed capacity, followed by 14.7% per year for MW-scale installed capacity. At the same time, the global PV module price has dropped to be around 19.2% per year on average which has a similar trend with global silicon price going down around 14.2% per year due to the oversupply with demand side.

Table 3.7 Typical module prices for a number of years (Unit: THB/Wp)

Year	1997 - 1998	1999 - 2000	2002 - 2003	2011	2012	2013	2014	2015	2016	2017	2018	2019 - 2020
Typical module price, kW-scale (THB/Wp)	180-200				70-80	50-60	35-50	25-40	16-22	16-20	16-20	13-19
Best module price, MW-scale (THB/Wp)	-	-	-	110*	50-60	35-45	20-25	20-25	15-20	15-17	14-16	8-11

Source: Manufacturers and investors

Note: * for installed system more than 30 MW

Table 3.8 Trend of system prices for different application from 1997 to 2020 (Unit: THB/Wp)

Year	1997 - 1998	1999 - 2000	2002 - 2003	2011	2012	2013	2014	2015	2016	2017	2018	2019 - 2020
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	50-55	35-45
Commercial / Factories (>10 – 1,000 kWp,THB/Wp)	-	-	-	n/a	n/a	90-150	60-65	50-55	43-57	45-54	35-45	25-30
Ground mounted PV systems (> 1,000kWp, THB/Wp)	-	-	-	110*	110*	60-100	40-60	30-50	42-57	41-48	30-40	20-25

Source: Manufacturers and investors

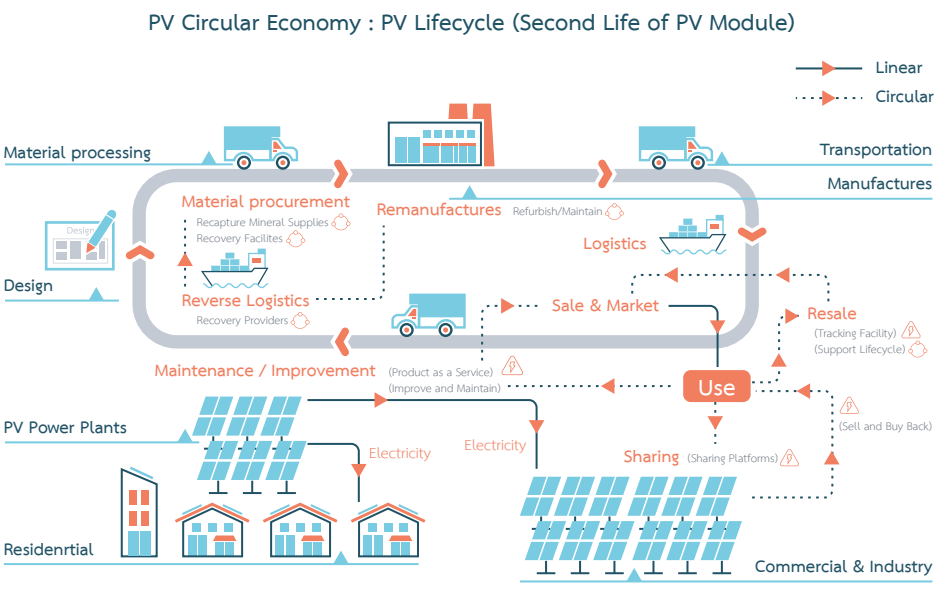
Note: *for installed system more than 30 MW

As shown in Table 3.8, the PV system prices (THB/Wp) of installed capacity of more than 1,000 kWp is lower than the PV systems of commercial/factories and residential systems because of the higher amount of PV modules used for the system leading to lower cost. In addition, commercial and residential PV systems primarily require additional safety measures to protect residents that must be aligned to safety regulation of PV systems installation. In addition, the trend of system prices for residential, commercial and PV power plants has declined in the past 5 years as 5.9%, 17.8% and 13% per year respectively. In contrast, during 2016 there was an increase in system prices of PV power plants due to high demand of more than 1 MWp system of ground mounted PV systems for government agencies and agricultural cooperatives programs.

3.4 PV and the Circular Economy

PV business is currently running under environmentally friendly practices for all processes including module manufacture, PV electricity generation, re-use of PV modules and reducing greenhouse gases in carbon market.

The example of PV electricity generation business is the electricity generation for selling to the private sector via trading platform. This has sparked the awareness of PV systems maintenance to achieve high performance of electricity generation which drives the operation and maintenance services and cleaning business. Furthermore, there can be additional value of damaged or expired PV modules by reusing arrangement. This has led to cooperation for expired PV modules management by researching the possibility of building a recycle factory and the efficient mechanism of PV module waste collection. For example, the Department of Alternative Energy Development and Efficiency (DEDE), the National Science and Technology Development Agency (NSTDA) and Chulalongkorn University have supported the PV recycle research in Thailand. Additionally, EGAT in cooperation with the Department of Industrial Works are preparing to build a PV recycle factory which in 2020 was in the first phase, studying for building a pilot plant to recycle the expired PV module and battery. It is expected to take 2 years to complete this study. The predicted PV module waste that would occur in 2022 is 112 tons.



Source: KMUTT

Figure 3.5 Typical of PV circular economy

Carbon Markets

Due to the global warming situation, the increased awareness of the need to care for the environment, especially in the energy sector, has led to the promotion of the 100% Renewable Energy (RE100) campaign in Thailand. RE100 Thailand Club is the key organization for running the campaign by setting up the renewable energy industry club, the federation of Thai industries and partners. In addition, EGAT has the main role for credit trading services from renewable energy electricity generation (Renewable Energy Certificate: REC) including the support of REC certifier that they only have the rights in Thailand from the International REC Standard (I-REC) of the Netherlands. This results in the growth of green energy and prepares for further support to RE100 members investing in Thailand.

Carbon trading is one of the mechanisms to reduce the greenhouse gas emissions and is operated by the Thailand Greenhouse Gas Management Organization (Public Organization) or TGO. Carbon credit is accepted as product which can be traded to replace the amount of greenhouse gas emission released by the buyer who intends to reduce the gas emission. (carbonmarket.tgo.or.th/)

Currently, there are two carbon markets globally operating as follows:

1. Mandatory carbon market is the carbon trading market which can trade the carbon credits and the rights for releasing the greenhouse gas emission, replacing the gas emission. This is to achieve the target of greenhouse gas emission reduction by the compulsory laws (legally binding target) or the mutual agreement between the countries.

2. Voluntary carbon market is the carbon market created without compulsory laws. This is the volunteer cooperation within the private sector aiming to reduce the environmental issues. This targets the amount of greenhouse gas emission reduction from the members (voluntary cap-and-trade) and operates the carbon credits and rights for trading.

4

Framework for Deployment

4.1 Renewable Energy Development

The energy development in Thailand has been carried out in parallel with economic and social development, which is growing sequentially. The development of modern power generation systems had started with thermal power plants using lignite as fuel and Bhumibol dam hydropower plant at Sam Ngao District, Tak Province, to generate electricity, which was the main driver for the country's economic development. However, with the rapid increase in energy demand, more power generation plants using coal, oil, and natural gas as fuels have been established to meet the rapid increase in power demand by both residential and industrial sectors.

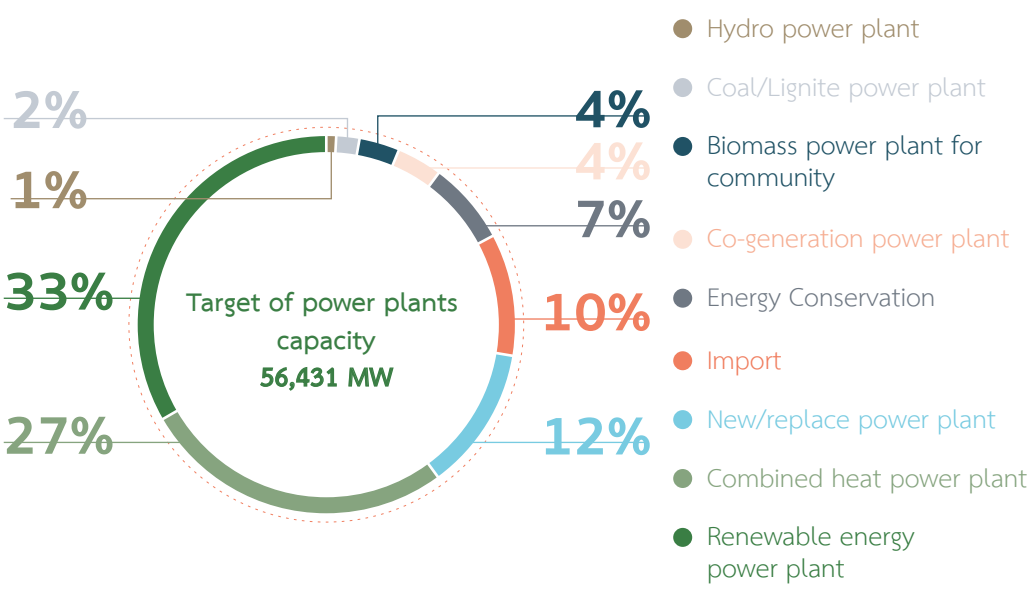
The two global oil crises, in 1973 and 1978, resulted in the development of alternative and renewable energy technologies and this is now the promising player in the market that was supported by the government for quite a long time.

4.1.1 Thailand Power Development Plan 2018 – 2037 Revision 1 (PDP 2018 Rev.1)

Development of electrical energy in Thailand has followed the current framework of the Thailand Power Development Plan as called PDP2018 Rev.1 covering the period 2018–2037 and was approved by the cabinet on 20 October 2020.

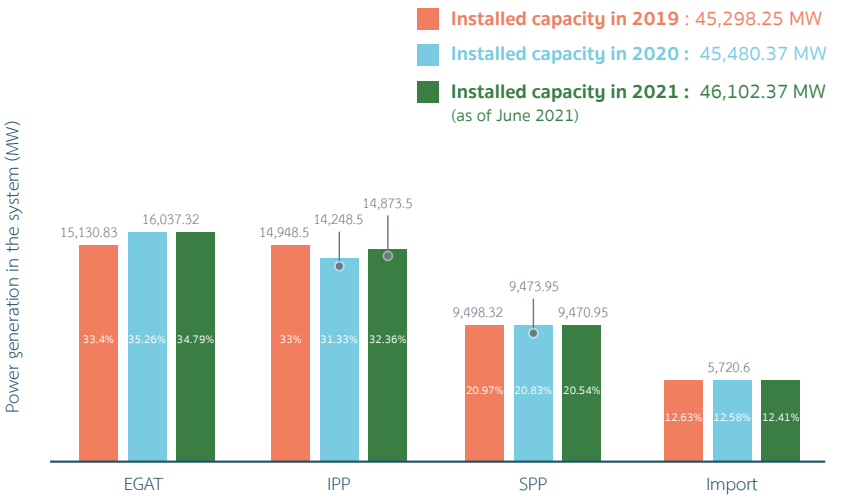
The main focus of this plan is to support renewable energy, while at the same time decentralizing the power generation to different provinces in Thailand and bringing power sustainability to the areas with efficient renewable energy usage.

The overall target of the plan is to achieve total power production from the three major electricity authorities at 77,211 MW within 2037, including 56,431 and 25,310 MW from new power plants and expired power plants shutdown respectively. Figure 4.1 shows the ratio of new power production by different fuels in PDP2018 Revision 1 that there is around 37% of new power plants from renewable energy and community power plants.



Source: PDP2018 Revision 1

Figure 4.1 Target of power production by different fuels in PDP2018 Revision 1



Source: EGAT

Figure 4.2 Power production of the power plants between 2019 and 2021

Figure 4.2 shows power production in the system between 2019 and 2021 (June) which, 2020 and first half of 2021, have the increase of power generation by 0.4% and 1.38% respectively due to the development of infrastructure preparing for economic improvement. As per PDP2018 Revision 1, there is a target for renewable energy development, especially for floating PV system combined with hydroelectric power plants reaching 2,725.25 MW (AC) within 2037 as shown in Table 4.1.

Table 4.1. Floating PV system and hydroelectric power plant projects following PDP2018 Revision 1

Project	Installation, MW (Year)			Accumulative Installation (MW)
Floating PV system at Sirindhorn Dam	0.25 (2018)	45 (2020*)		45.25
Floating PV system combined with hydroelectric power plant at Ubonrat Dam	24 (2023)			24
Floating PV system combined with hydroelectric power plant at Bhumibol Dam	158 (2026)	300 (2030)	320 (2033)	778
Floating PV system combined with hydroelectric power plant at Srinakarin Dam	140 (2026)	280 (2029)	300 (2032)	720
Floating PV system combined with hydroelectric power plant at Wachiralongkorn Dam	50 (2027)	250 (2031)		300
Floating PV system combined with hydroelectric power plant at Chulabhorn Dam	40 (2033)			40
Floating PV system combined with hydroelectric power plant at Bang Lang Dam	78 (2033)			78
Floating PV system combined with hydroelectric power plant at Ratchaprapha Dam	140 (2034)	100 (2036)		240
Floating PV system combined with hydroelectric power plant at Sirikit Dam	325 (2035)	175 (2037)		500
Total				**2,725.25**

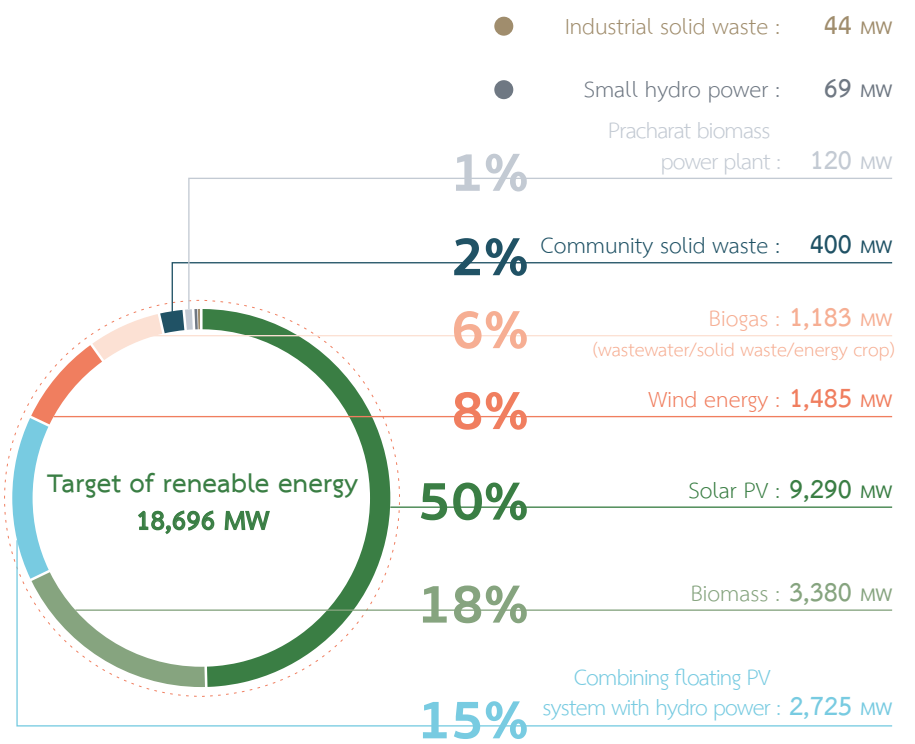
Source: PDP2018 Revision 1

Noted: *postponed to 2021 duo to the Covid-19 situation.

4.1.2 Alternative Energy Development Plan (AEDP2018)

AEDP2018 aims to support existing renewable energy in the country by developing the production processes and using appropriate energy technology to achieve a better quality of life and environment. This plan is related to and integrated with other national plans namely the Power Development Plan (PDP), the Energy Efficiency Plan (EEP), Gas plan and Oil plan for supporting the energy sustainable development in Thailand.

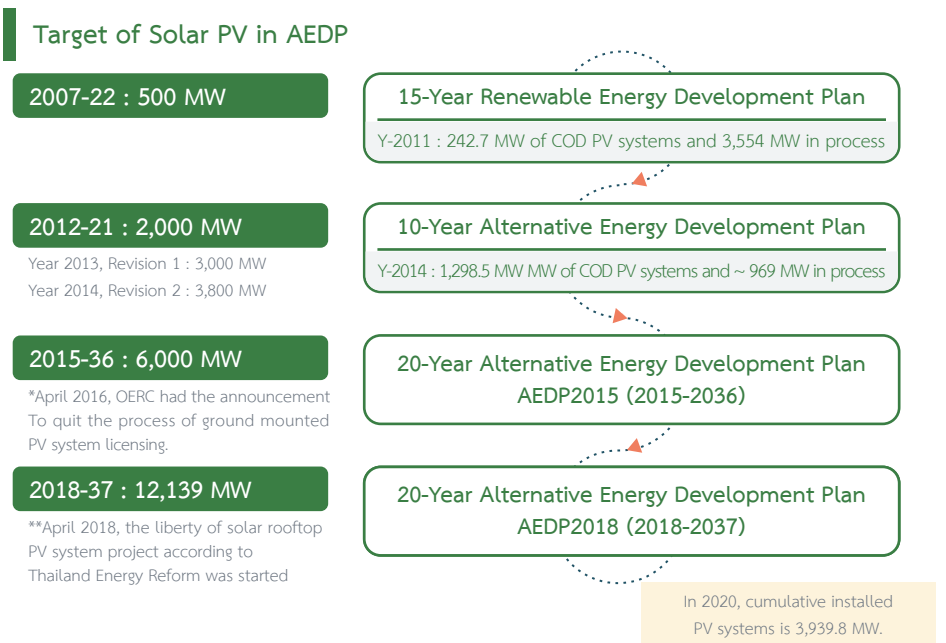
In addition, AEDP2018 has increased the percentage of renewable energy consumption to be 30% by 2037, including electrical energy, heat, and biofuel, of which new electricity production from renewable energy would be 18,696 MW, accounting for 34.23% of national demand. Most of the production dominates from solar energy 9,290 MW, accounting for 50% of ratio. If the floating PV systems are included, this would be 2,725.25 MW, or around 15% of ratio, forming the total production as 12,015 MW as 65%.



Source: AEDP2018

Figure 4.3 The target of AEPD2018 between 2018 and 2037

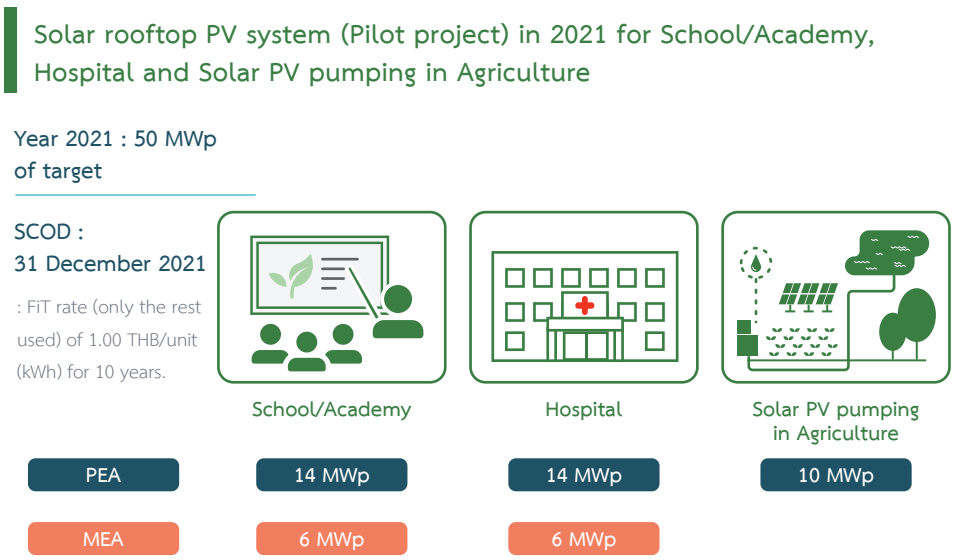
Thailand power development has slightly increased the renewable energy portion. Figure 4.4 shows the evaluation of Alternative Energy Development Plan of Thailand. Total power production from solar energy is 12,139 MW, according to AEDP2007-2022 and AEDP2018-2037. In addition, during 2019-2020, there has been increased support for rooftop PV systems installation following the energy development plans. In addition, industry has been producing electricity from rooftop PV systems in order to reduce the costs of production. This has led to an increase of PV systems installation expanding from purchasing by government to private sector purchasing for self-consumption and trading.



Source: This data was provided by DEDE.

Figure 4.4 Achievements of Alternative Energy Development Plan of Thailand

These developments have been continuously supported by the government which in 2021 launched the rooftop PV systems for schools, academies, hospitals and water pumping for agriculture (pilot project) in 2021, following a government resolution dated 25 December 2020. Furthermore, there has been the introduction of guidelines for rooftop PV system supplied by VSPP with capacity between 10 kW and 200 kW as a non-firm contract. There has been around 50 MW of power purchase with electricity price selling to the grid of 1 THB per unit (kWh) for 10 years, expecting SCOD on 31 December 2021.



Source: This data was provided by OERC.

Figure 4.5 Rooftop PV systems pilot projects in 2021

4.1.3 Rooftop PV systems for Thai people project

As per NEPC (National Energy Policy Committee) resolution on 24th January 2021, there approved on electricity generation for people which, after that, ERC announced the policy of electricity generation providing by VSPP especially from rooftop PV systems for Thai people, not exceeding 10 kWp/house for 100 MWp. This is mainly self-consumption which remains can be sold to the grid as 1.68 THB/unit (kWh) for 10 years. In addition, between 2019 and 2020, the power production reached 2.6 MWp, MEA 1.6 MWp or 64% and PEA 1 MWp or 36%, and the trend seems to be increased continuously.

Rooftop PV systems installation has the advantage on changing the roof to be the power generation source. To support this the government has changed the electricity price rate exchange to be 2.20 THB/unit (kWh) for 10 years, beginning on 1st January 2021, following the announcement of ERC on 3rd February 2021, which targets 50 MWp of solar for Thai people program per year, 15 and 35 MWp for MEA and PEA, respectively.

4.2 Investment Promotion for PV Industry (BOI)

BOI has supported investment in PV system industries which can be divided into 3 groups namely

1) machine and equipment manufacture for electricity generation from PV systems such as PV module, solar cell raw materials and parts or equipment used in PV systems,

2) electricity generation by PV systems,

3) energy efficiency improvement for renewable energy by PV systems, installation with existing projects for self-consumption.

The data of investment and promotion support between 2019 and 2020 (statistics of requested investment and promotion) and policy for PV industries

1. 1. Solar cells and related raw materials activities

	2019 (Apply for promotion support)	2020 (Apply for promotion support)
Number of systems (Project)	-	2
Installed capacity (MW)	-	Solar Cell: 1,200 MW
Investment (MTHB)	-	351

2. PV module manufacturers and electronic parts involved in solar modules such as battery and inverter

2.1 PV module manufacture

	2019 (Apply for promotion support)	2020 (Apply for promotion support)
Number of systems (Project)	-	3
Installed capacity (MW)	-	1,858
Investment (MTHB)	-	1,814.8

2.2 Battery for energy storage (including EV battery)

	2019 (Apply for promotion support)	2020 (Apply for promotion support)
Number of systems (Project)	1	-
Installed capacity (piece/year)	Lithium-ion battery 50,000 piece/year (EV battery)	-
Investment (MTHB)	510	-

2.3 Inverter and power conditioning system

	2019 (apply for promotion support)	2020 (apply for promotion support)
Number of systems (Project)	1	1
Installed capacity (MW) (set/year or piece/year)	Power Conditioning System* 30 set/year	PV inverter 22,080 piece/year
Investment (MTHB)	77.46	155

Source: This data was provided by BOI.

Noted: *Power Conditioning System (PCS) is a received low dc voltage equipment from solar module and adjust the current to be stable.

3. Solar Power Plant (not include energy efficiency improvement for PV system installation item 7.1.1.2)

	2019 (Apply for promotion support)	2020 (Apply for promotion support)
(a) Solar farm		
Number of projects (Project)	11	15
Installed capacity (MWp)	60.56	321.42
Investment (MTHB)	2,293.6	11,508.9
Cumulative installed capacity* (MWp)	64.32	324.65
Total projects* (project)	12	17
(b) Solar floating systems		
Number of projects (Project)	17	5
Installed capacity (MWp)	55.36	15.36
Investment (MTHB)	1,875.6	426.7
Cumulative installed capacity* (MWp)	57.32	15.46
Total projects* (project)	20	6
(c) Solar rooftop systems		
Number of projects (Project)	179	222
Installed capacity (MWp)	162.22	243.23
Investment (MTHB)	4,455	5,860.30
Cumulative installed capacity* (MWp)	167.41	244.83
Total projects* (project)	178	225
(d) Solar farm/ Solar floating/ Solar rooftop systems**		
Number of projects (Project)	3	3
Installed capacity (MWp)	10.91	4.93
Investment** (MTHB)	290.9	124.7

Source: This data was provided by BOI.

Noted: * including installed capacity and number of projects from (D) by separating by type of installation
** Unable to separate the investment cost of each project duo to total investment plan

In addition, in 2019 and 2020 PV systems applying for support by BOI only the electricity production from renewable energy (solar, wind, biomass and biogas) excepting solid waste. This data did not include the energy efficiency improvement measures.

4.3 Standards, Codes and Regulations

PV modules, inverters and batteries are the quality controlled components, as well as safety regarding industrial standards, by Thai Industrial Standards Institute (TISI).

PV module's standard

Two Thai Industrial Standards regarding PV modules were issued in 2020.

Firstly, TIS 2580-1-2562 safety qualification of PV module 1st volume is the codes to replace TIS 2580-1-2555 which has been announced and published on 4th February 2020. This standard defines the qualification of materials of PV module in both crystalline silicon and thin films to be electrical and mechanical safety such as protection against electrical shock and danger from the fire. The detail of this standard follows the standard of IEC 61730-1:2016 Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction.

Secondly, TIS 2580-2-2562 safety qualification of PV module for testing codes to replace TIS 2580-2-2555 to define PV module testing order regarding the safety which is mutually applied to TIS 2580-1. The detail of this standard follows the standard of IEC 61730-2:2016 Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing.

Standard overview of PV systems at present are shown in Table 4.2. In 2021, IEC announced the new series of IEC 61215:2021 Edition 2 standard for 6 volumes which has been edited from the series of IEC 61215:2021 Edition 1.0 standard and TISI will prepare for further edition of standard series for TIS 61215-2561.

Table 4.2 PV system standards: PV module, inverter and battery

Product	Thai Industrial Standard (TIS)	Harmonization Standard
PV Module	TIS 2580-1-2562	IEC 61730-1:2016 Ed.2.0
	TIS 2580-2-2562	IEC 61730-2:2016 Ed.2.0
	TIS 61215-1-2561	IEC 61215-1:2016 Ed.1.0
	TIS 61215-1(1)-2561	IEC 61215-1-1:2016 Ed.1.0
	TIS 61215-1(2)-2561	IEC 61215-1-2:2016 Ed.1.0
	TIS 61215-1(3)-2561	IEC 61215-1-3:2016 Ed.1.0
	TIS 61215-1(4)-2561	IEC 61215-1-4:2016 Ed.1.0
	TIS 61215-2-2561	IEC 61215-2:2016 Ed.1.0
Grid-connected Inverter	TIS 2603-1-2556	IEC62109-1 Ed.1.0 2010-04: Part 1
	TIS 2603-2-2556	IEC62109-1 Ed.1.0 2010-04: Part 2
	TIS 2606-2557	IEC61727 Ed.2.0 2004-12
	TIS 2607-2557	IEC62116 Ed.1.0 2008-09
Battery	TIS 2218-2548	IEC 61960:2003
	TIS 718-2530	-
Solar PV systems	TIS 2572-2555	IEC 60364-7-712

Source: TISI

Table 4.3 Regulations of grid-connected PV systems

Product	Regulations	Harmonization Standard
Grid-connected Inverter	MEA regulation of grid connection 2015	IEEE1547.1-2005, IEC62116-2008, IEC61000-3-3, IEC61000-3-5, IEC61000-3-11
	PEA regulation of grid connection 2016	IEEE1547.1, IEC62116, IEC61000-3-3, IEC61000-3-5, IEC61000-3-11, IEC TS 62910
Solar PV systems	The Engineering Institute of Thailand Under H.M. The King's Patronage (EIT), especially rooftop PV systems (EE 022013-59)	

Source: PEA, MEA, and EIT

Inverter standards

The announcement of industrial standards, codes and regulations from the electricity authority for inverters is as follows:

(1) IEC62109-1 Ed.1 2010-04 Safety of power converters for use in photovoltaic power systems - Part 1: General requirements TIS 2603-1-2556 safety of inverter for PV systems 1st volume, general qualification has been similarly used as IEC62109-1 Ed.1 2010-04 Safety of power converters for use in photovoltaic power systems - Part 1: General requirements.

(2) IEC62109-1 Ed.1 2010-04 Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters TIS 2603-2-2556 safety of inverters for PV systems 2nd volume specific qualification required for inverters have been similarly used as IEC62109-1 Ed.1 2010-04 Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters.

(3) IEC61727 Ed.2 2004-12 Photovoltaic (PV) systems - Characteristics of the utility interface TIS 2606-2557 PV systems – gird connection has been similarly used as IEC61727 Ed.2 2004-12 Photovoltaic (PV) systems - Characteristics of the utility interface.

(4) IEC62116 Ed.1 2008-09 Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters TIS 2607-2557 test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters when no voltage has been similarly used as IEC62116 Ed.1 2008-09 Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters.

(5) MEA regulation of grid codes 2015, registered inverters can be connected with MEA grid without approval required by cases.

(6) PEA regulation of grid codes 2016, registered inverters can be connected with PEA grid without approval required by cases.

In conclusion, Thai Industrial Standards relating to inverter/conversion equipment used with PV systems are not compulsory and can be similarly used as IEC standards that TISI accepts the test results and certification following IEC.

Furthermore, PV systems with utility-interconnection, grid-connected inverter must follow the grid codes of electricity authorities (not related to safety standards). MEA and PEA are considering announcing the new regulation of grid codes to be related to PV systems supporting programs.

Battery standards

For battery standards in Thailand, TISI has set standards for 4 types which are

(1) lead-acid starter battery: TIS 6-1-2559 referencing as IEC60095-1 (2006-11),

(2) secondary cells and batteries, containing alkaline or other electrolytes which have no acid for portability: TIS 2217-2548 and portable storage battery as TIS 2879-2560,

(3) secondary cells and batteries, containing alkaline or other electrolytes which have no acid-cells and secondary lithium battery for portability: TIS 2218-2548,

(4) regular use lead-acid battery: TIS 718-2530.

However, type (2) battery is only set to be compulsory standards. In addition, international standards involving PV systems will be considered as follows:

1) IEC 61427-1 edition 1 2013-04: Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 1: Photovoltaic off-grid application,

2) IEC 61427-2 edition 1 2015-08: Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 2: On-grid application.

Installation and maintenance standards

Installation and maintenance standard for PV systems in Thailand is TIS 2572-2555 electrical installation – PV systems distribution, announced in 2013, referencing IEC 60364-7-712:2002 Low voltage electrical installations - Part 7-712: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems, mainly focused for electrical installation. However, the current IEC standard has been improved and announced as IEC 60364-7-712:2017, now covering the structure installation.

Another standard is rooftop PV systems installation standard which is set up by standards subcommittee of electrical installation of Thailand, the Engineering Institute of Thailand under H.M. the King's Patronage (EIT) as coding EE 022013-59. This is the guideline for design, installation, commissioning and maintenance of rooftop PV systems for small, medium and large-scale with focusing mainly on electrical installation as referencing AS/NZS 5033 Installation and safety requirements for photovoltaic (PV) arrays 2014 from Australia and IEC 62548 Photovoltaic (PV) arrays - Design requirements 2013.

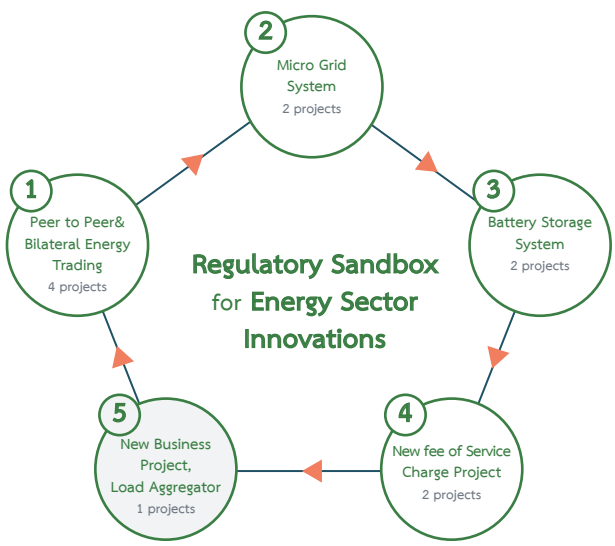
4.4 Energy Regulatory and Digitalized Transformation

Increasing competitiveness for electric and gas business following the Power Development Plan of Thailand improves the request procedure for doing energy business and time spent on the processes, including the revoking of power plants from being an industrial plant (Industrial Act) by OERC, continuously operating during 2020 and on the processes. Moreover, there is now a licensing scheme for new power plants, the improvement of license for electric and natural gas business. However, safety standards, environment standards and sewage management or unused materials of power plants will set up a Memorandum of Understanding (MOU) with the Ministry of Natural Resources and Environment including guidelines and request procedures for building permission and other activities for running energy business with Ministry of Interior.

However, there is a further trend of energy development, called 4D1E, which covers Decarbonization: low carbon energy by reducing carbon dioxide emission from energy sector and Digitalization: digital access system by using digital technology for energy management. Furthermore, there are Decentralization: energy generation and fundamental structure spreading and Deregulation: the regulation improvement for supporting new generation energy policy and Electrification: transformation energy usage to electric power. These encourage Thailand to be prepared for an effective transformation with proper performance.

Consequently, OERC has operated the ERC Sandbox for testing business innovation and managing new electric systems. In addition, they have set the codes for grid connection to third-party (TPA Framework) for ERC Sandbox operation and guidelines of service charges for utility-interconnection (Wheeling Charge) for supporting electricity treading from the private sector (Peer-to-Peer).

The projects are divided into 5 groups as shown in Figure 4.6 which are 2 years operation including (1) Peer to Peer & Bilateral Energy Trading for 4 projects, (2) Micro Grid System for 2 projects, (3) Battery Storage System for 2 projects (4) new service charge project for 2 projects (5) new business project, Load Aggregator, 1 project.



Source: OERC

Figure 4.6 ERC Sandbox projects

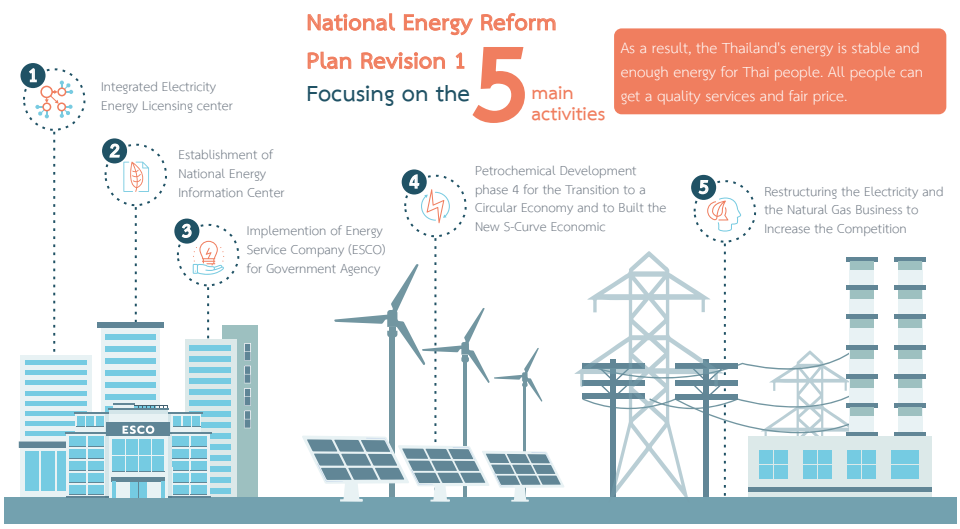
5

Highlights and Prospects

5.1 Energy Reform Revision 1

National Reform Plans, issued on 6th April 2018, have been developed under the national strategy and master plan, approved by the national strategy board and cabinet for revised edition, dated 8th December 2020. This latest revision compliments and improves the previous national reform plans, dated April 2018.

National Energy Reform Plans (revised edition) proposes the proper competition in energy business, using clean energy that is environmentally friendly, as well as the dissemination of analyzed energy information to support the planning and prepare for national infrastructure and improvement of renewable energy by continually building appropriate understanding with the community.



Source: Government Gazette, issue 138, 44, February 25, 2021

Figure 5.1 National Energy Reform Plan Revision 1

The Power Development Plan 2018–2037 Revision 1 aiming to provide prospective energy relating to master plans and national reform plans, is comprised of 3 aspects, namely

(1) the stability covering generation, transmission and distribution of power and adequacy of electricity demand in the areas,

(2) supporting low-cost electricity generation,

(3) reduction of environmental issues.

In 2020, electricity production by PV systems has increased in both main national power generation and industrial generation, including the residential sector.

5.2 Combining Floating PV System and Hydroelectric Generation

This combination combines electricity generation between floating PV systems and hydroelectric power plants. EGAT has to date developed an effective project for Sirindhorn Dam, that has 36 MW and 45 MW (AC) or 58.8 MWp for hydroelectric power and floating PV system respectively. This has been combined with an Energy Management System, operating since July 2021, that has the potential to increase the power production.

This floating PV system is a prospective model for power plants using a combination of technologies aimed at carbon-free energy usage. Additionally, there are the advantages such as environmental sustainability from renewable energy production and economic development through eco-tourism.

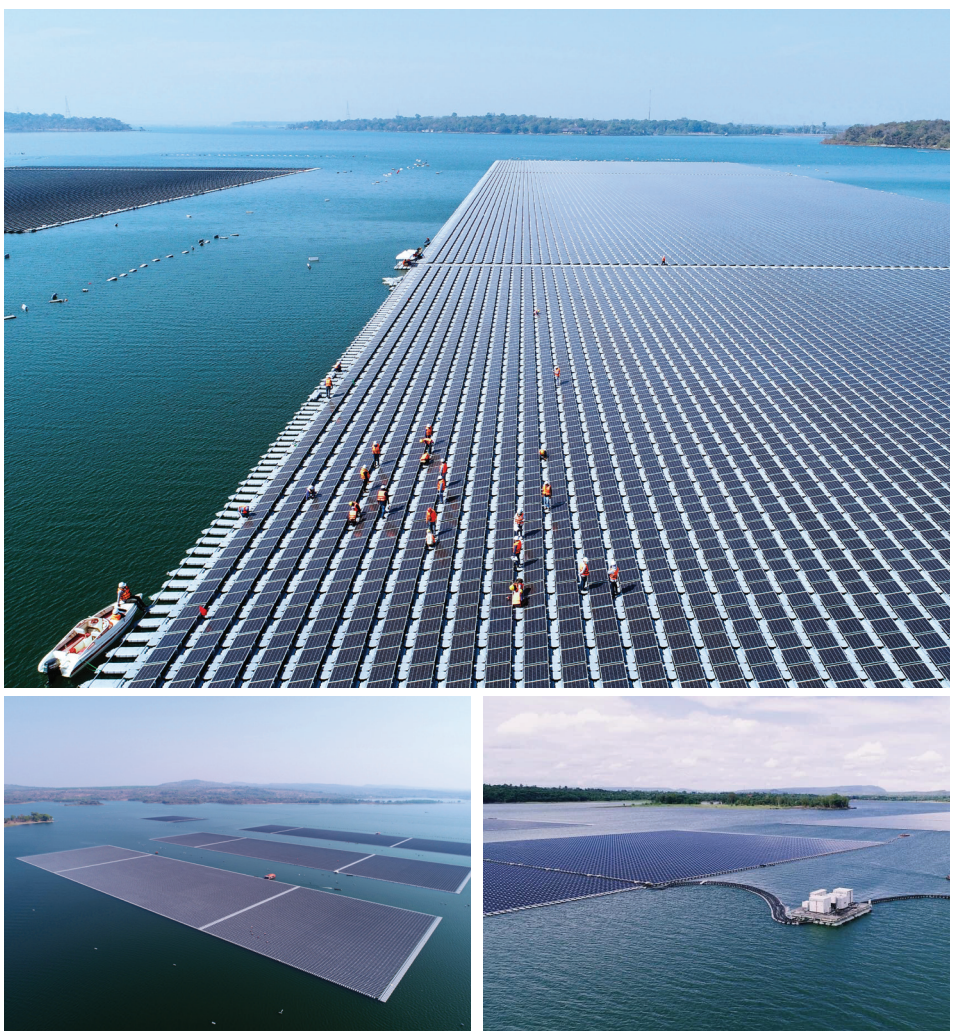


Figure 5.2 The first and largest floating PV system project, 45 MW (AC) and hydroelectric power plant at Sirindhorn dam, Ubonratchathani province

5.3 Rooftop PV Systems and Smart Microgrid

Thailand Energy Reform has also focused on technological and innovative energy improvements that are environmentally friendly, as well stressing the urgency for rapid infrastructural energy development.

Renewable energy has become more of a choice to increase power generation in 2020. In 2019, the rooftop PV system for Thai people project, was implemented but saw minimal development. However, in 2020 the installed capacity of this project was significantly increased. Following this, the tariff rate was increased from 1.68 to 2.20 THB/kWh, effective on 1st January 2021 to stimulate the implementation for residential applications. Furthermore, the previous project participants would also receive the new adjusted rate.

Rooftop PV system for Thai people project

Interested people are able to apply under the project at electricity authorities, MEA for Bangkok, Samut Prakarn and Nonthaburi and PEA for other service areas.

MEA: Users can submit an application form to connect to the electric grid system of MEA at https://myenergy.mea.or.th/ social media platforms such as:

- Facebook : METROPOLITAN ELECTRICITY AUTHORITY (MEA)
- Line : @meathailand
- Twitter : @mea_news
- Instagram : meafanclub

and MEA Call Center 1130 for 24 hours.

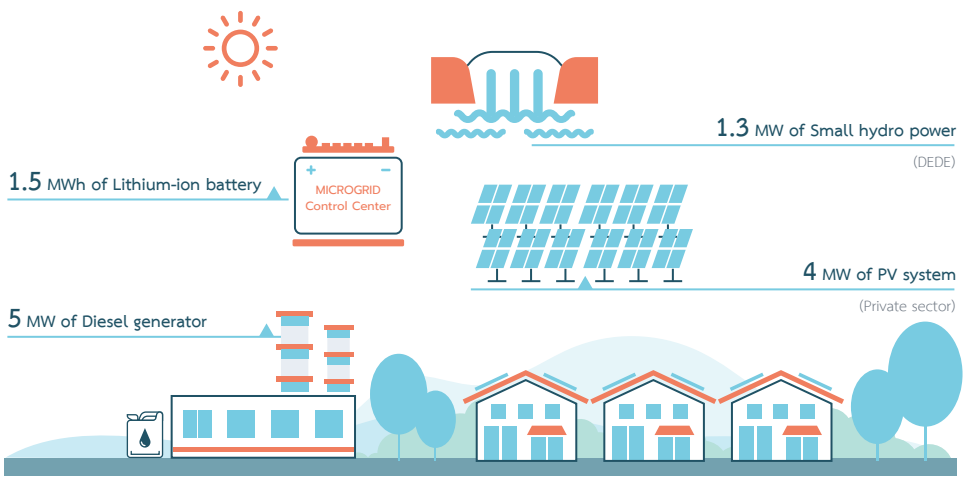
PEA: User can submit an application for installing the rooftop PV systems project at Energy Management and Digital Services Division, call 1129 at PEA Contact Center. There are installation and requesting permission services, for more details.

Smart microgrid project by PEA

Microgrid technology and energy storage were used for stability and quality of electric system improvement including reduction of distribution losses. This would result in the development of infrastructure preparation of smart grid system that will be beneficial for people that followed government policy of power development for stability and sustainability.

Smart grid and energy storage system are one of activities to drive Thailand's smart grid development plan. The pilot projects, initiated by EGAT, PEA and MEA, consist of the development of business models for microgrid systems and very small power distribution networks. The projects have been implemented in Betong district, Yala province that is part of the Indonesia-Malaysia-Thailand Growth Triangle project (IMT-GT), and in Mae Sariang district, Mae Hong Son province, to enhance power system security for the areas.

The microgrid network at Mae Sariang, Mae Hong Son province has installed the energy storage system, lithium-ion battery as 3 MW / 1.5 MWh (maximum capacity 3 MW for half an hour), equally supplying electricity for half of Mae Sariang area. This can independently supply without connecting to electrical network that uses local power generation such as 4 MW PV systems, REC small hydroelectric power plant for 1.3 MW and 5 MW diesel power generation (1 MW for 5 generators). In addition, PEA has microgrid plans for 2 projects that are Betong, Yala province and Ko Samui, Surat Thani province.

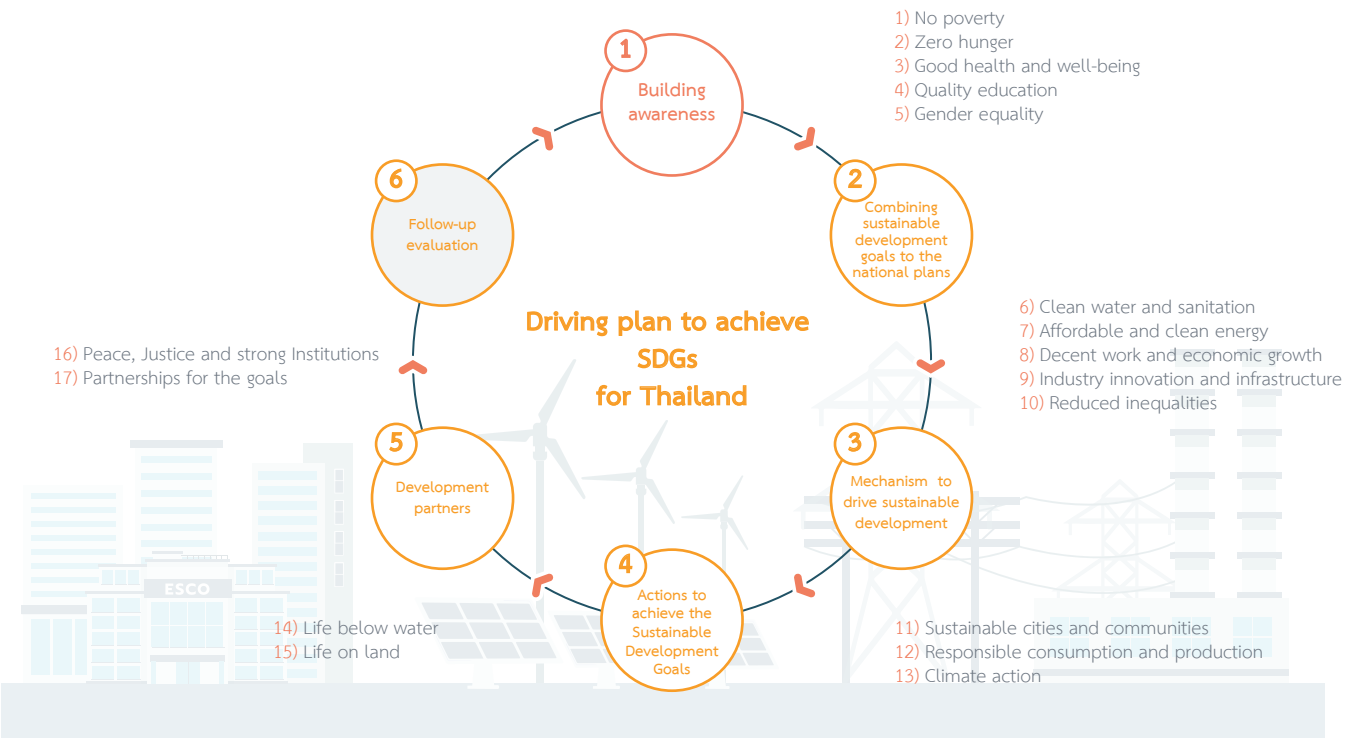


Source: PEA

Figure 5.3 PEA microgrid project development, building electrical stability at Mae Sariang, Mae Hong Son province.

5.4 Other Factors Driving Renewable Energy Consumption

Sustainable Development Goals, SDGs, are an important agenda to drive the global development between 2016 and 2030 that have 17 targets from United Nations. The main direction of sustainable development in Thailand has 6 strategies that are related to 17 targets of SDGs, having SDGs of Thailand as the main working group. The development of SDGs of Thailand, especially for government responsibility, is handled by the Office of the National Economic and Social Development Council.



Source: Office of the National Economics and Social Development Council

Figure 5.4 Sustainable Development Goals Driving Plan for Thailand

There is the connection between PV systems production and indicators of SDGs target that are 7) accessible renewable energy, 9) industry, innovation, and infrastructure and 13) climate change management especially for reducing carbon dioxide emission in production sector and power production by renewable energy of industrial sector. This is the strategy for working with the Thailand Carbon Neutral Network (TCNN) that has main aspect to build the carbon price mechanism, explicit and proper competition for gaining mutual advantages to economy, society and environment, leading to reducing the cost of Thailand greenhouse gas to be lowest.

Thailand Carbon Credit Exchange Platform is developed by Thailand Greenhouse Gas Management Organization (Public Organization) and Federation of Thai Industries. In addition, there is an established Thailand RE 100 club that has mutually operated in both demand and supply side of industry, including other organizations who are able to join the platform for exchanging carbon credit and renewable energy. This is to sustainably run the business and demonstrate responsibility for society and environment that lead the national business, small until massive, sustainably growing.

Additionally, leading national organizations focus on greenhouse gas emission reduction by running business through carbon credit exchange or Carbon Markets Club via online to be ready for new challenges such as

Bangchak Corporation Public Company Limited (BCP),

Electricity Generating Authority of Thailand (EGAT),

BCPG Public Company Limited,

BBGI Public Company Limited,

Charoen Pokphand Company Limited,

Shell Company of Thailand Company Limited,

Kasikornbank Public Company Limited,

Bank of Ayudhya Public Company Limited,

Tetra Pak (Thailand) Company Limited,

Bangkok Industrial Gas Company Limited,

BTS Group Holdings Public Company Limited

and the member of RE100 Thailand Club, including more than

500 companies/organization as of 21st July 2021.

6
Definitions

Definitions

Grid-connected PV systems	The PV systems that connected to the PEA and/or MEA distribution network and has the grant from PEA and/or MEA with pass the grid-connecting test according to regulation of PEA and/or MEA.
Self-consumption PV system producer	The producer of PV systems for electricity production for using in their own activity without connect to the utility grid of EGAT, PEA and MEA.
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 MW. (1) Non-conventional energy sources 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, not more than 10 MW 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.
Micro-grid	The power production from renewable energy sources such as hydro, biomass, wind, that are integrated to the grid with battery energy storage systems. The system shell provides the electricity when the grid line is not operated.
Energy Storage System (EES)	The device in the PV systems use to storage the energy from renewable energy production projects such as SPP Hybrid Firm project. In the other way, its used in the electrical vehicles (EV).
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 to existing electricity price for a certain period.

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.
Installed capacity (kWp or MWp)	The size of installation of PV systems that have 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 peak (kWp) and megawatt peak (MWp), respectively.

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Energy Policy and Planning Office	Mr. Channarong Rungruang Dr. Nitima Nakthong
Office of Thailand Board of Investment	Mr. Parkpoom Buranabun Mr. Nattapan Neelapaijit Mr. Tachas Kongsukkanjana
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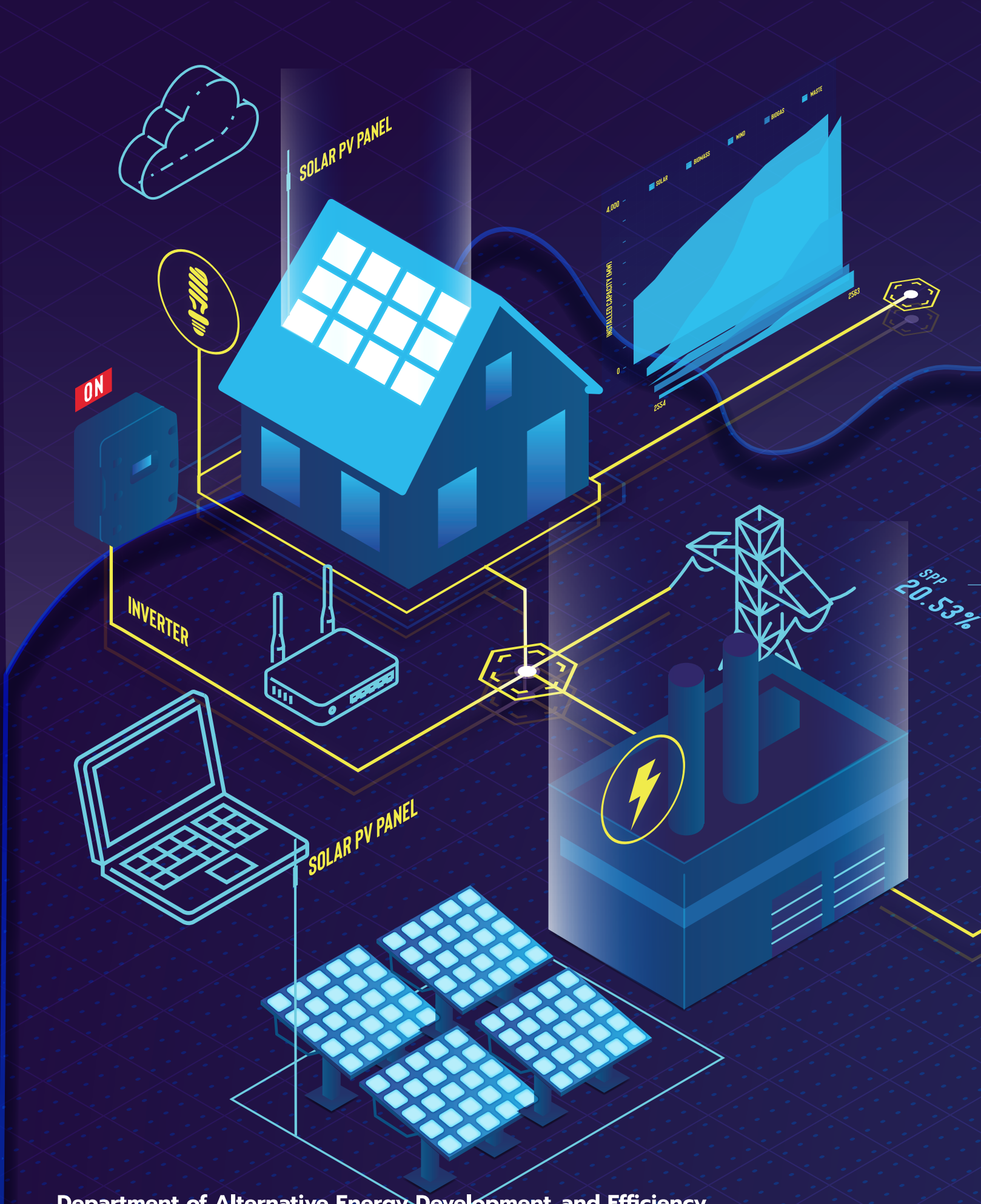
News update

Various PV-related activities carried out in 2020 and onwards have led to a significant increase in the use of renewable energy in 2021. In this regard, battery-store renewable energy that can later be managed for maximum benefit. In Thailand, a semi-solid battery manufacturing plant has been set up, which combines lithium-ion battery technology with solid-state battery technology to allow batteries to store more energy, charge and discharge faster and lighter in weight. These will meet the demands of electric vehicles and energy storage for renewable energy systems.

As for the Ministry of Energy, who are responsible for setting the energy sector policy guidelines, the goal is now to support Thailand towards to use the renewable energy with the aim to reduce carbon emissions to zero (Carbon Neutrality) in 2065-2070. However, this will depend on technological change factors and financial support.

In addition, the prototype factory to dispose of solar panels and batteries in Thailand will be set up under the auspices of EGAT. Progress involves continuous cooperation with the Department of Industrial Works is considering technological innovation potential area and the management guidelines that are appropriate for Thailand.



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