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Critical review of the current status of solar energy in Thailand

Nares Chimres, Somchai Wongwises *

Fluid Mechanics, Thermal Engineering and Multiphase Flow Research Lab. (FUTURE), Department of Mechanical Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Bangmod, Bangkok 10140, Thailand

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ABSTRACT

At present, the global community is aware of the critical limit of the pollution of fossil fuels. Many countries including Thailand have explored alternative energy, one of which is solar energy. In particular, the use of solar for electricity generation is important to reduce imported energy because Thailand's primary commercial energy imports are 50%, approximately. The government has supported renewable energy through the long-term 22-yr alternative energy development plan 2015–2036 (AEDP 2015) which aims to boost the production of electricity using renewable energy, especially solar, to 6000 MW by the year 2036. They fund the price incentives of commercial power. The result is that the electricity authority of Thailand now has a production capacity of solar power-generation projects of 1558 MW, and 1261 MW of projects are under construction. This is 46.98% of the AEDP 2015 target. The major barriers of a solar system development are the high investment cost, the uncertain subsidy and lack of the thorough policy planning. Those obstructions are depended on the government strategy.

Contents

1. Introduction

Fossil fuel is the primary fuel used to generate energy, whether electricity, thermal energy, or energy for the transportation. However, it creates air pollution, and there is a limited quantity. Consequently, a study on renewable energy is necessary. Renewable energy is

* Corresponding author. Tel.: +662 470 9115; fax: +662 470 9111.
E-mail address: somchai.won@kmutt.ac.th (S. Wongwises).

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obtained from natural sources and can be used all the time. It can be continually used and includes wind, hydro, wave, geothermal heat, and solar energy. The distinctive features of solar energy are that it never runs out, no combustion or motion is needed in the energy converting process, there is no noise, and there are various energy capacities. Solar can be a stand-alone installation, so it can used in remote places like on an island and in the backcountry.

Thailand uses fossil fuel as the primary fuel for electricity generation, which mostly imported from overseas. The government realizes that the dependence on imported fossil energy is too high [1]. It will not only affect the energy stability of the country, but it also causes pollution through the emission of greenhouse gases. Therefore, the Ministry of Energy has investigated the potential of renewable energy and promotes electricity production by renewable energy for the substitution of fossil energy.

This paper provides information about the situation of solar energy for electricity production, especially in Thailand. We address the potential of solar energy, its status and the barriers of the solar system development in Thailand, including the potential and growth of electricity production with solar energy globally. The aims of the paper are the guide line information for the industry, investor and people sectors who attend and explore the alternative energy for replacing the fossil energy of their business, including the investment in electricity-generating by solar energy projects. Additionally, it is also benefit to the people who interest about the government policy and situation of the alternative energy for energy security, along with the researchers who need the overview information of the solar system in Thailand for their research of knowledge and policy.

2. Solar energy's growth around the world

The solar energy potential depends on solar irradiation. The Global Horizontal Irradiance (GHI) is the indicator of the irradiation level, and it is a necessary criterion for solar potential assessment. GHI is the direct normal irradiation (DNI) integrated with diffuse horizontal irradiation (DHI) [2]. GHI is dependent on the location and climate. Fig. 1 shows the yearly mean of GHI of Earth [3].

The average irradiation range in Fig. 1 is presented in 2 different ways: annual and daily values. The annual range starts from $< 700\ kW\ h/m^2$ to $> 2700\ W/m^2$. The irradiation quantity is identified by the color contour. The colors start with blue ($< 700\ kW\ h/m^2$) to red ($> 2700\ W/m^2$). The daily value is equal to the annual value divided by 365 days. Obviously, in many locations shown the red region, there is a high potential for solar energy. Northern and southern Africa, the Middle East of Asia, Australia, and South America are the high solar potential areas. The class of solar resource is classified by daily irradiation [4]. Each class will vary according to $0.5\ kW\ h/m^2$ of GHI daily rate. The range of the class of solar resources is 1–14. The top class countries are Kiribati, Chad, Niger, Saudi Arabia, and Botswana, which are in class 12–13 and whose irradiation is between 6 and $7\ kW\ h/m^2$. Although the irradiation per area of those countries is high, the total solar energy potential depends on the area. Therefore, the top three regions in terms of total solar energy potential are Russia, Antarctica, and China. The details are shown in Table 1.

Currently, many countries have increased the production of electricity using solar energy to replace fossil fuel. Solar irradiation is converted to electricity by the photovoltaic (PV). Fig. 2 shows the development of global PV's cumulative installed capacity since 2000–2014 [5] and [6]. This information consists of the cumulative installed capacity of the Middle East and Africa (MEA), China, the Americas, the Asia-Pacific (APAC) region, Europe, and the rest of the world (ROW). From 2000 to 2007, the global PV cumulative installed capacity slightly increased and then increased rapidly since 2008. This is despite the world economy being affected by the subprime mortgage crisis in 2007; during this time, the

Table 1
Top ten countries of total solar energy source [data from [4]].

Rank	Country	GW h/year
1	Russia	3.06×10^7
2	Antarctica	2.98×10^7
3	China	2.74×10^7
4	Australia	2.51×10^7
5	Brazil	2.50×10^7
6	United States	2.46×10^7
7	Canada	2.12×10^7
8	India	9.88×10^6
9	Sudan	8.70×10^6
10	Algeria	8.16×10^6

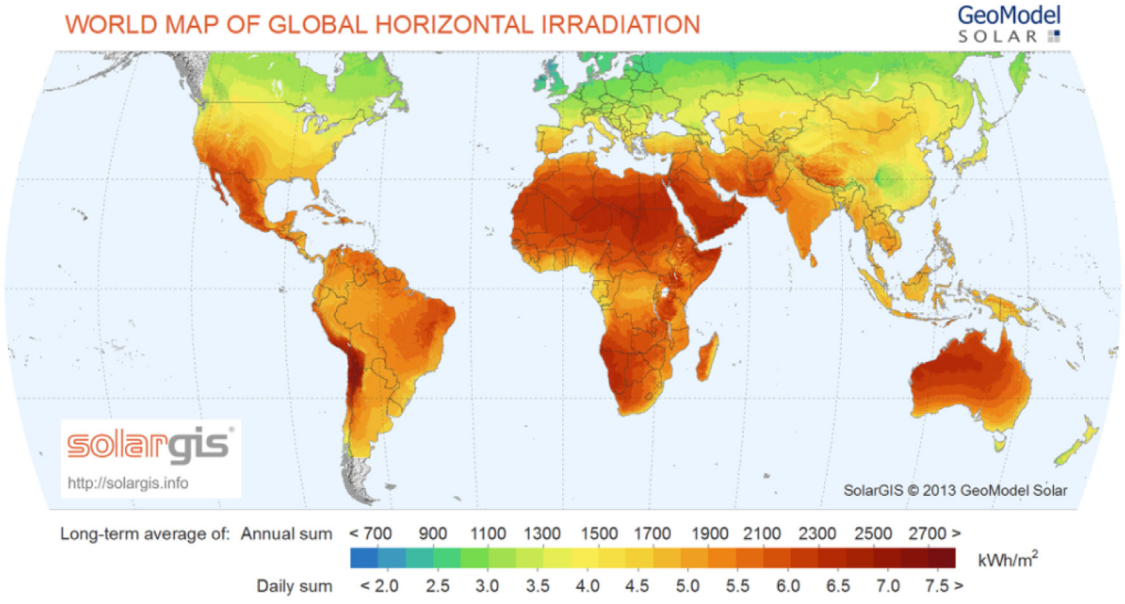
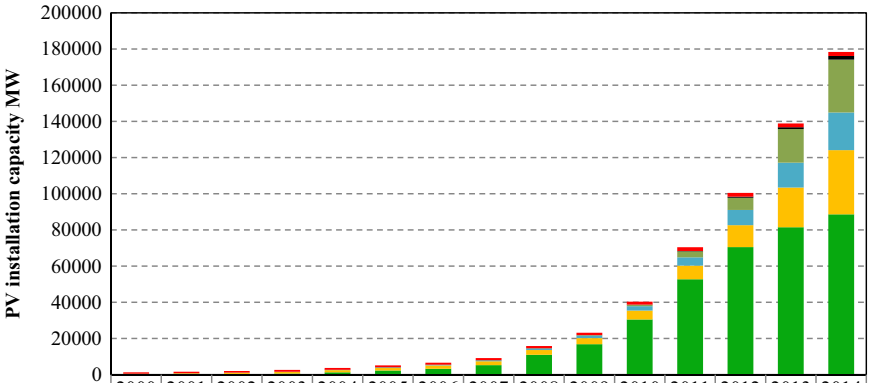


Fig. 1. Annual mean GHI of the earth (data and map from [3]).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
ROW	751	807	887	964	993	1003	1108	1150	1226	1306	1590	2098	2098	2098	2215
MEA	0	0	0	0	1	1	1	2	3	25	80	205	570	953	2043
China	19	24	42	52	62	70	80	100	140	300	800	3300	6800	1860	2920
Americas	21	24	54	102	163	246	355	522	828	1328	2410	4590	8365	1372	2082
APAC	368	496	686	916	1198	1502	1827	2098	2628	3373	4951	7513	1215	2199	3547
Europe	129	265	399	601	1306	2291	3289	5312	1102	1685	3050	5276	7051	8148	8863

Fig. 2. The development of global PV cumulative installed capacity since 2000–2014 [data from [5,6]].

growth of solar installations increased at a higher rate. At the end of 2009, cumulative PV capacity in the world was more than 23 GW and increased to 40.3 GW at the end of 2010. The cumulative PC capacity was over 100 GW at the end of 2012 and increased to 138.8 GW at the end of 2013. In 2014, the cumulative PC capacity moved forward to 178.3 GW or increasing 28.45% from 2013. It is very high opportunity to archive to 200 GW within few years.

Since 2004, Europe has been a leader in terms of cumulative installed capacity with 88.6 GW in 2014. This is approximate 49% of the total cumulative installed capacity. However, the Europe capacity ratio was down from 59% in 2013 and 70% in 2012. The ratio was disturbed by the growth of PV installed capacity in Asia-Pacific countries. Their growth rates were fast with 22 GW in 2013 and about 24 GW in 2014. Many regions outside of Europe featured the PV installation, which is evidenced by the amount of cumulative installed PV increase from 60 GW in 2013 to 90 GW in 2014.

In terms of development, the Asia region including China and APAC demonstrated the highest rate of annual installed capacity. In 2014, the PV installation of this region was 24.1 GW or 60.1% of global PV installation, while Europe has almost 11 GW or 18.0%. In third place is Americas with 17.9%. It is the same sequence in 2013. It means that the Asia region has become the leader of the PV installed capacity development. In the event of the country's development, Germany maintained the highest annual installation 7 times in the last 14 years. But in 2013, China became the top installer with 11.8 GW and 10.8 GW in 2014. Japan was in second place with 6.9 GW in 2013 and 9.7 GW in 2014, and next was the US with 4.8 GW in 2013 and 6.2 GW in 2014. They were followed by UK and the Germany. These countries were about 79.2% of global installation in 2014. Australia had a high growth rate in 2011 and 2012 with about 1 GW but reduced to 0.83 GW in 2013 and increased again to 0.9 GW in 2014. India installed 1 GW in 2013 and decreased the PV installation to 616 MW in 2014. Korea booted up the PV capacity with 900 MW and placed at the third place of the annul PV installation of Asia in 2014. Thailand and Taiwan also increased the PV installation to 475 MW and 400 MW in 2014, respectively. Malaysia installed the PV system 87 MW in 2014 or increasing 52.6% from 2013 and it was the third year for the Feed-in tariffs promotion of Malaysia. In the Americas, Canada installed 500 MW, and Mexico including Peru established several PV projects. Chile installed the PV system 400 MW, approximately. Although Brazil, Mexico and Peru have great potential, they do not have widespread PV installation but they applied the policy that suitable to PV development in few year. South Africa was the country which highly developed the PV capacity in 2014 with 800 MW. Israel was the leader in the Middle East region with 420 MW in 2013 and decreased in 2014 with 250 MW. Turkey has begun gradually with 40 MW in 2014.

The direction of PV installation in the future has changed in the last 3 years. The growth rates in China, Japan, and Southeast Asia are becoming more influential than Europe. The development of PV installation in China and Japan in 2014 affects the forecast of the future growth rate. These countries are likely to remain at the same level or even slightly increase. Especially in China, the annual installation will probably be above 10 GW for several years. In 2014, all regions indicated the development of the PV capacity, clearly. Globally, there are 19 countries have generated electricity by PV system over 1% of their electricity demand, including Thailand. Italy is leader with 7.92%, following with Greece and Germany, respectively. Many countries at the equator have more potential for PV installation because the support policies of each country and the cost reduction of PV system. Thus, the cumulative PV installed capacity could be 450 GW in 2019. Some countries will plan PV to be a main alternative energy source within the next 10 years.

3. Solar potential in Thailand

Thailand is located close to the equator and receives sunlight throughout the year. The Ministry of Energy initiated a project to evaluate and provide a solar potential map for Thailand in 1993 [7]. The project consists of a solar potential map and database of solar potential. The information was collected from both satellites and ground stations. The solar potential is not dependent only on irradiation but also on the northeast monsoon and southwest monsoon, which flow through the country. Therefore, the potential is different each month. Most of the country receives maximum solar irradiation during April and May with 20–24 MJ/m^2-day. The northeast of the country has the highest average solar potential in Thailand. It includes Nakhon Ratchasima, Buri Ram, Surin, Si Sa Ket, Roi Et, Yasothon, Ubon Ratchathani, and Udon

Thani provinces. The next highest average of solar potential is the Middle region, which consists of the Suphan Buri, Chainat, Ayutthaya, and Lop Buri provinces. The solar irradiation average is shown in Fig. 3 [8].

The solar irradiation average of Thailand is 18.2 MJ/m^2-day. It is class no. 11 in 14 of the class of solar potential [4]. Moreover, 14.3% of Thailand demonstrates 19–20 MJ/m^2-day and more than 50% of the area has 18–19 MJ/m^2-day. In addition, 0.5% of Thailand displays less than 16 MJ/m^2-day. Currently, the Department of Alternative Energy Development and Efficiency (DEDE) of the Energy Ministry has 37 stations with pyranometers. There are 5 stations in the middle of Thailand, 12 stations in the northern part of the Thailand, 9 stations in northeast Thailand, 3 stations in the western part of Thailand, and 9 stations in the southern part of Thailand [9].

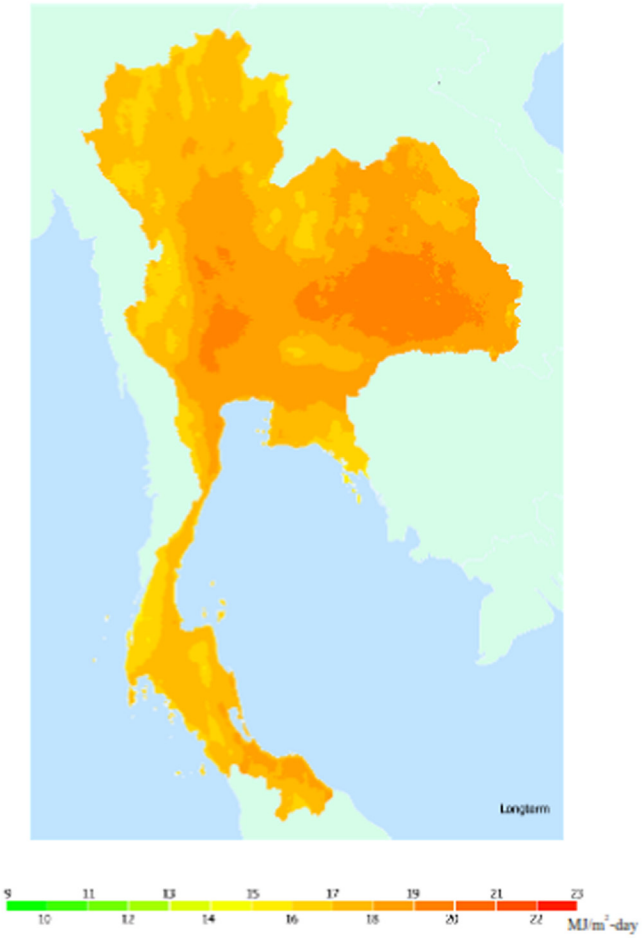


Fig. 3. The solar irradiation average map of Thailand [data from [8]].

The potential for developing solar energy to be the alternative energy resource is feasible high. Comparisons among Thailand and some other countries [8] is shown in Fig. 4. In fact, Thailand has greater potential than many regions in the world. Countries in Europe, for instance, have the lowest potential. Africa has the highest potential with 21.6 MJ/m^2-day. Hence, the government of Thailand has assigned DEDE to evaluate, monitor, encourage, and support the residents and private firms in using solar energy.

4. Strategy of solar energy in Thailand

The energy supply in Thailand is dependent on imported energy. In 2014, the primary commercial energy demand of Thailand was 136,832 ktoe but the domestic primary energy production just was 79,314 ktoe [10]. Obviously, Thailand needed to import the primary commercial energy 50.6% and 52.3% in 2013 [11]. These ratios affect to the nation energy security. Renewable energy development will seriously reduce its dependence on energy from imported energy. It also decreases the fuel supply to the electricity production of the country. By 2036, the final energy consumption is estimated increase to 131,000 ktoe [12] from the current 75,804 ktoe [10]. Thus, the Ministry of Energy plans to develop energy production to meet the total energy consumption in 22 years in the Power Development Plan 2015–2036: PDP 2015 [12]. Previously, Thailand had PDP 2010 rev.3 but the energy forecast deviation such as the target of the Alternative Energy Development Plan (AEDP) 2015–2036 is increased from 3000 MW in 2021 to 6000 MW in 2036 [12]. PDP consists of three main principles. There are Security, Economy and Enology. The Security is the security of the power supply to the country. The Economy is the electricity price modification to follow the actual cost of energy more properly and consider the efficient energy consumption for reducing the new power plant and imported power. The Enology is to reduce terrible effect to the environment and communities by developing the renewable energy to produce the electricity for reducing the carbon dioxide emission per unit of the electricity generation. The plan which concerns directly to the PV system in Thailand is the Alternative Energy Development Plan 2015–2036 (AEDP 2015). The AEDP aims to determine the scope and direction of the development of alternative energy in the country. In 2036, overall generated electricity by renewable energy capacity in Thailand will be 19,634.4 MW or 27.9% of the total electricity capacity in Thailand [12]. Solar energy is considered to be one of the alternative energy sources expected to be used in the

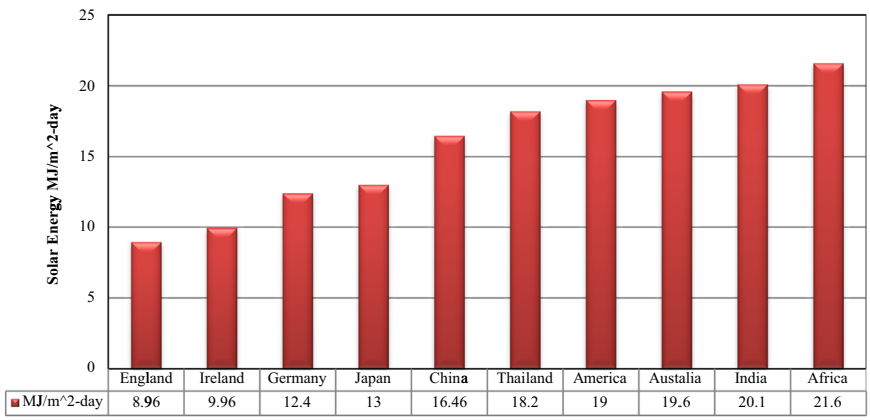


Fig. 4. The comparison among Thailand with the others countries [data from [8]].

production of electricity. If the solar energy technology cost decreases and is widely accepted, it will be developed to be the primary alternative energy to produce electricity for Thailand in the future. AEDP 2015's capacity target of electricity by solar energy is 6,000 MW or in 2036. The major strategies of the development framework for achieving the AEDP target are as follows.

4.1. Policies and incentives

The Ministry of Energy has provided the policies to encourage the production and use of electricity by renewable energy. There are the ESCO Fund and the Adder and Feed-in Tariff (FIT) measures. The details of the support are as follows.

4.1.1. ESCO Fund

Energy Service Companies (ESCOs) is a business that provides services in the fields of energy conservation and/or renewable energy. It is an integration service that is composed of project proposals, project management, engineering design, energy analysis, equipment installation and operations for energy conservation and/or renewable energy projects, including funding for the energy program. In 1999, the ESCO Pilot Project, which cooperates with the Electricity Generation Authority of Thailand (EGAT), the Ministry of Energy, and the World Bank, was established. The aim of the project is to promote ESCO to be accepted and spread widely in Thailand by favoring entrepreneurship both in industrial and commercial buildings, which require investments in energy projects and, thus, place confidence and trust in ESCO. The result is the continued development of ESCO to the present by the 46 ESCOs, which are registered with the Institute of Industrial Energy (IIE) of Thailand. DEDE has established the ESCO fund, which is intended to encourage investment in energy conservation and renewable energy by providing assistance to entrepreneurs who are potential investors in the project but who lack the necessary funds for investment. The Energy for Environment Foundation and the Foundation of Thailand Energy Conservation Center supervise the funds. The rules of participation are that a joint venture does not exceed 30% of the share capital but does not exceed 50 million baht per each, that the investment period is 5–7 years, and that the interest is a flat rate of 4%/year [13].

4.1.2. Adder and Feed-in Tariff (FIT) measures

Thailand is the first country in the ASEAN region that supports and promotes electricity with renewable energy due to its policy of adding the subsidy (Adder) in the regular electricity price [14]. The adder will be paid to the operator when electricity in the system is sold to the electricity authority. It was applied commercially in early 2007 after the National Energy Policy Committee (NEPC), chaired by the prime minister, approved the payment rate. In this measure, the subsidies rates are always reviewed and revised to ensure that it is a reasonable rate with the current renewable energy technology and private sector situation.

The subsidies rates of adder and the duration of support for each renewable technology [15] are shown in Table 2. The support duration length starts at the commercial operation date (COD). The subsidies rates of solar energy is higher than other energy rates due to greater investment rates. The grid-connected solar power systems, the solar power systems that are connected to the utility grid, have increased more than 6 times between 2007 and 2010. In 2010, due to the fact that the PV system cost dropped continually [16], the adder rate was reduced to 0.203 USD/kW h for any project that had not been approved before 28 June 2010 [15]. Furthermore, the National Energy Policy Commission (NEPC) found that the solar power plant which confirmed to connect to the system within 2010–2025 is 16% of the total alternative power plant. But the subsidies which be paid of the solar power plant is 9060 million USD or 72% of total subsidies for overall alternative power plant and it will affect to the electricity price in the next few years. Because the solar's adder rate is paid for every capacity and technology of the PV system. But in the actual investment, the capacity and technology of the PV system affect to the investment directly then the adder is not neutral subsidies. Consequently, NEPC changed the subsidies strategy, stopped the new participants of solar power plant and announced the plan of the adder measure's substitution with Feed-in Tariff (FIT) program in the same year [17]. The Energy Policy and Planning Office (EPPO) cooperated with the Energy Research Institute (EIR) of Chulalongkorn University to investigate the FIT program [18]. The FIT is evaluated by considering the initial investment, the return on investment, the debt-to-equity ratio, and the support duration of the project. Therefore, the FIT should be more reflective to the agreeable subsidies than the adder. The electricity cost structures by FIT and the adder program are different. The adder subsidy is the price added to the regular electricity price, while the FIT is the net price of the electricity purchase and is constant throughout the period of support. In 2013, the National Energy Policy Commission (NEPC) announced the FIT rate for its solar energy project. Two FITs' rate groups were used for the rooftop and ground-mounted solar system [19], and the NEPC revised them again in 2014 [20]. The aims of the rooftop and ground-mounted solar systems are to generate and use the electricity at the installation area. Because of the loss of transmission and the installation area are less than the solar power plants. Both of them are shown in Table 3. The FIT rates in 2014 expect to target 200 MW of the rooftop and 800 MW of ground-mounted solar system of the new project and the existing project, which is under the petition process. However, all of the projects must be operated commercially by December 2015. The support duration is 25 years from the COD. But in 2015 regarding to AEDP 2015, the new target of the solar system in Thailand is 6000 MW but the new incentive are holed at the FIT 2014.

Table 2
Thailand's Adder rates (Exchange rate: 1 US Dollars = 32 Thai Baht) 2007–2010 [data from [15]].

Renewable energy technology	2007–2008 (USD/kW h)	2009 (USD/kW h)	2010 (USD/kW h)	Special adder for diesel replacement (USD/kW h)	Special adder for three southernmost provinces (USD/kW h)	Support duration (year from COD)
1. Wind	0.109	0.141	0.141	0.047	0.047	10
– Installed capacity ≤ 50 kW	0.109	0.109	0.109	0.047	0.047	10
– Installed capacity > 50 kW						
2. Small/Microhydro	0.013	0.025	0.025	0.031	0.031	7
– Installed capacity 50 – ≤ 200 kW	0.025	0.047	0.047	0.031	0.031	7
– Installed capacity < 50 kW						
3. Solar	0.25	0.25	0.203	0.047	0.047	10

Table 3
The FIT rate of 2013 [data from [19]] and 2014 [data from [20]] (Exchange rate: 1 US Dollars = 32 Thai Baht).

FIT for rooftop solar		
Scale	2013 (USD/kW h)	2014 (USD/kW h)
0–10 kW	0.218	0.214
10–250 kW	0.205	0.200
250 kW–1 MW	0.190	0.189
FIT for Community ground mounted solar		
Year of COD	2013 (USD/kW h)	2014 (USD/kW h)
1–3	0.305	Fixed rate: 0.177
4–10	0.203	
11–25	0.141	

4.2. Standardization of the PV system [21]

The national standards authority of Thailand, under the Ministry of Industry, is the Thai Industrial Standard Institute (TISI). The TISI establishes the TIS standard for the country, as well as the PV system. In 2015, Thailand will be the single market the ASEAN Economic Community (AEC 2015). The Electronic Mutual Recognition Arrangement (ASEAN EE MRA) requires all electronic standards to be aligned to the International Electrotechnical Commission (IEC) standard. Hence, the TIS standards for PV systems are referred to IEC standards; examples of these standards include TIS 1843-2542 (IEC 1215:1993), TIS 1844-2542 (IEC 1277:1995), and TIS 2210-2548 (IEC 1646:1996). In 2011, TIS 1843-2553 (IEC 61215:2005) was declared in the government gazette. Recently, the technical committee has reviewed IEC/TC 82 and will be proposed in the future.

The power producers have be classified by the agreement of the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA). The MEA and PEA are 2 distribution network utilities in the country. The 2 groups of power producers are divided into small power producers (SPPs) with larger than 10 MW and very small power producers (VSPPs) with lower than 10 MW. The power purchase agreements (PPAs) of those producers are different. VSPPs have to be co-signed with the MEA or PEA, but SPPs need to be co-signed with the Electricity Generation Authority of Thailand (EGAT). All procedures need to be certified in deference with the standard of the IEC 61727:2004 and IEC 62116:2008 or IEEE 1547 and UL 1741 or others accepted by electricity authority.

Next, the standards for solar home systems are provided by the department of local administration under the ministry of interior and the engineering institute of Thailand (EIT), under His Majesty the King's Patronage.

4.3. Qualification service of PV system

The government has arranged the testing service in universities and government agencies as follows.

4.3.1. The CES (Clean Energy System) Group Solar Cells Testing Center (CSSC)

The CSSC was organized in 2005 and placed at the King Mongkut's University of Technology Thonburi (KMUTT) under the investment advocate by the DEDE and Energy Conservation Fund. The capability service consists of 3 groups. For PV modules up to 2 m × 2 m in size, the service aligns to IEC 61215:2005 and IEC 61646:2008. For inverters up to 30 kW, the service accords to the IEC 61727:2004 and IEC62116:2008. For batteries up to 3000 A h at 100 h, the rate is consistent to IEC 61427:1999 and IEC 60896-11:2002. The website of CSSC is http://www.ces.kmutt.ac.th/ [22].

4.3.2. The Electrical and Electronic Products Testing Center (PTEC)

The National Science and Technology Development Agency (NSTDA) created a cooperation agreement with King Mongkut's Institute of Technology Lardkrabang (KMITL) and established the Electrical and Electronic Products Testing Center (PTEC) in 1998. PTEC provide the PV standard testing and PV on site testing service. The PTEC website is http://www.ptec.or.th/english/ [23].

4.3.3. The Electrical and Electronic Institute (EEI)

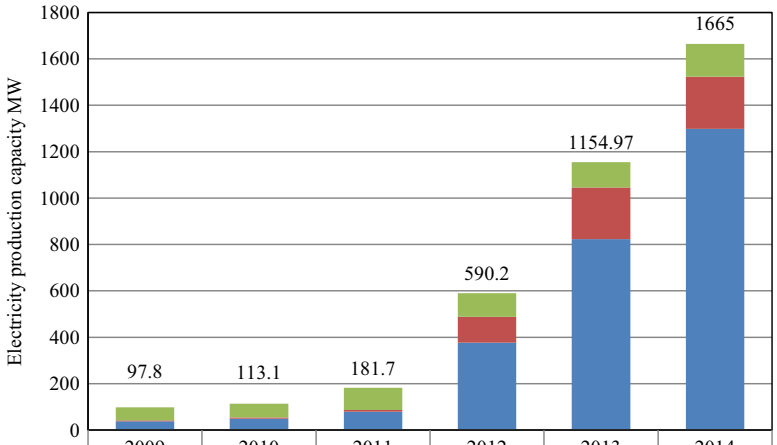
The Electrical and Electronic Institute (EEI) was formed in 1998. It is an institute supervised by the Ministry of Industry for focusing in the industry. The balance of systems (BOS), such as the charge controller and the inverter, according to TIS 1293-2538 and PEA's requirements, are the main test services of the IEE. The EEI's website is http://www.thaieei.com [24].

5. Solar energy situation in Thailand

Regarding AEDP, renewable energy has been fully supported by the Ministry of Energy. Therefore, the renewable energy production is increasing continually [25,26], as shown in Fig. 5. It shows the cumulative electricity production as a renewable energy since 2009–2014. The renewable energy technologies in the figure are solar energy, wind energy, and small hydro power. The growth rates have increased rapidly, especially for solar energy. The solar energy capacity of 2014 was increased 57.7% from 2013. Individually, the cumulative electricity production by solar energy since 1983–2014 [21] and [25,26] is shown in Fig. 6. The PV system installation in Thailand began in 1983 with the off-grid systems, and the PV systems are not connected to a power utility. Initially, the PV systems were installed in non-electrified areas, which are rural or remote locations. Primary applications were infrastructure, which consists of lighting and telecommunication equipment. Then, they were applied to water pumping, and they supported the electricity devices in schools or learning centers and healthcare clinics of the community. In addition, they were used in military and police bases in the border area in the Royal Agricultural Project. The installations of these PV systems were supported by the budget of the government and performed by the Ministry of Energy. In 2005, the installations of off-grid systems increased dramatically because the government had imposed a solar home program (SHP) and implemented the installation of PV by PEA. The accumulated power-generation capacity of off-grid systems that were installed in 2005 is 22.11 MW, up from the existing capacity of 9.07 MW at the end of 2004. However, due to the relatively high cost of investment, the installation of off-grid systems decreased until the year 2011 with a capacity of 29.652 MW [21]. The groups of off-grid systems are composed of 28.19 MW for electricity to schools, centers for health services, and households in remote areas; 1.142 MW for telecommunication; and 0.320 MW for pumping systems in rural areas.

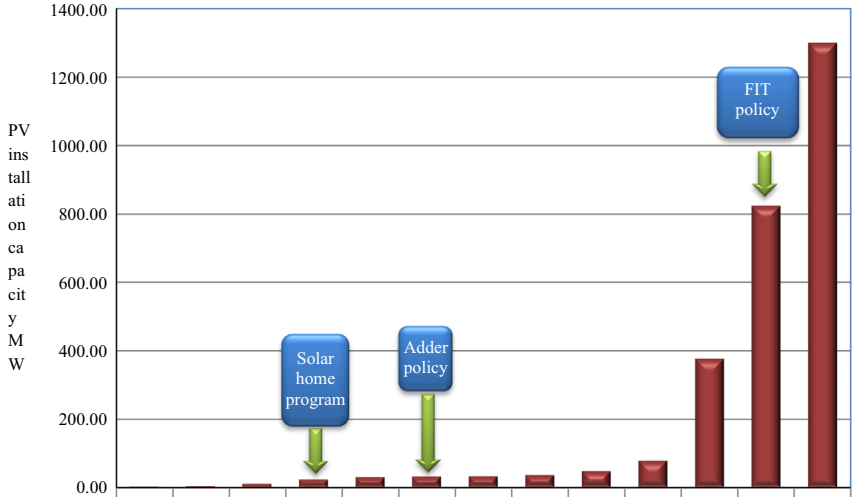
In 2004, the large on-grid or grid-connected systems were installed in the country. EGAT invested the first large on-grid system with a capacity of 500 kW at the Mae Hong Son province in northern Thailand. In addition, the Tesco Lotus department store installed the first large rooftop PV system in Bangkok downtown with 460 kW in the same year. In 2007, the on-grid systems were widely installed. The growth rate corresponds with the government's policy to promote the commercial electricity production with renewable energy by adder measures. After the launch of the Adder scheme, as shown in Fig. 6, the PV systems were motivated and grew at a superb growth rate. Table 4 shows the information of the solar farm under Adder scheme in Thailand [21,27–32].

Most of the solar farms' capacities in Thailand are less than 10 kW, but 4 mega projects are larger. There are the Natural



	2009	2010	2011	2012	2013	2014
Total	97.8	113.1	181.7	590.2	1154.97	1665
Small hydro power	55.7	58.9	95.7	101.8	108.8	142
Wind	5.1	5.6	7.3	111.7	222.71	224.5
Solar	37	48.6	78.7	376.7	823.46	1298.5

Fig. 5. The cumulative of electricity production by renewable energy of 2009–2014 [data from [25,26].



	1983-2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PV installation capacity MW	2.89	4.22	10.83	23.88	30.52	32.51	33.39	37.00	48.60	78.70	376.70	823.46	1298.5

Fig. 6. The cumulative of electricity production by solar energy of 1983–2014 [data from [21 and [25,26]].

Energy Development Company (NED), the Bangchak Group (Bangchak Petroleum Public Company Limited), the Solar Power Company (SPC) and the Energy Absolute Public Company Limited (EA). The NED is a joint venture among the CLP Thailand Renewable Limited, the Diamond Generating Asia Limited, and the Electricity Generating Public Company (EGCO) by equal sharing. It started the commercial operation in May 2013 at the Lopburi province with a capacity of 63 MW [27].

The second mega project, the Sunny Bangchak project, was organized by Bangchak groups [28] and [30,31]. This project is under the Clean Development Mechanism (CDM) [33]. The project has been certified as achieving the Crown standard of the Thailand Greenhouse Gas Management Organization (TGO), which is certificated by the Verified Carbon Standard (VCS) [34,35]. The project has investments of 406 million USD for electricity-generating projects from solar power with a production capacity of 118 MW. The project is split into 3 phases. The first phase is the solar farm at the Bang Pa-In District in the Phra Nakorn Sri Ayutthaya province with a capacity of 58 MW and delivered to PEA at 38 MW. The second phase is in the Bamnet Narong District, the Chaiyaphum province and the Bang Pahan district, and the Ayutthaya province with a total capacity of 32 MW. The last phase is in the northeast region of Thailand with 48 MW. Currently in phase 1, the project was implemented into commercial production in June 2012. In April 2013, Bangchak launched the commercial operation of its solar farm project in phase 2 with a capacity of 32 MW, comprising the solar farms at the Bamnet Narong district in the Chaiyaphum province and the Bang Pahan district in the Ayutthaya province with 16 MW each. Phase 3 consists of 5 locations. The largest solar farm is located in the Kabin Buri district in the Prachinburi province with a capacity of 16 kW. The rest are 4 solar farms with capacities of 8 MW. There are 2 solar farms in the Dankhunthod district and the Nong Khai district in Nakhon Ratchasima, the Prakhon Chai district in Buriram, and the Bamnet

Table 4
The information of the solar farm in Thailand [data from [21,27–32]].

No.	Location	Company	Capacity (MW)	COD
1	Mae Hong Son	EGAT	0.504	Apr 2004
2	Chachoengsao	BSP*	1.495	Oct 2007
3	Udonthani	BSP	0.282	Jul 2008
4	Petchaburi	BSP	2.144	Feb 2009
5	Angthong	BSP	1.136	Feb 2009
6	Udonthani	BSP	1.563	Apr 2009
7	Nakon Sawan	BSP	0.547	Nov 2009
8	Nakon Ratchasima	Solar Power	6.0	Apr 2010
9	Lopburi	BSP	2.225	May 2010
10	Udonthani	EGAT	1.012	Dec 2010
11	Nakon Rachasima	BSP	1.114	Jan 2011
12	Prajuabkirikan	BSP	1.949	Feb 2011
13	Sakonakon	Solar Power	6.0	Feb 2011
14	Nakon Phanom	Solar Power	6.0	Apr 2011
15	Nakon Ratchasima	Solar Power	6.0	Aug 2011
16	Loei	Solar Power	6.0	Aug 2011
17	Nakon Ratchasima	Solar Power	6.0	Jan 2012
18	Khon Kaen	Solar Power	6.0	Feb 2012
19	Ayutthaya	Bangchak	38	Jun 2012
20	Lopburi	EA	8	Oct 2012
21	Chayaphum	Bangchak	16	Apr 2013
22	Ayutthaya	Bangchak	16	Apr 2013
23	Lopburi	NED	63	May 2013
24	Nakhonsawan	EA	90	Dec 2013
25	Lampang	EA	90	Feb 2015
26	Phisanulok	EA	90	Dec 2015

*BSP = Bangkok Solar Power Company Limited.

Narong district in the Chaiyaphum province. Those projects started construction in October 2013 and plan to deliver the electricity to PEA in the second quarter of 2014. The entire capacity of the Sunny Bangchak project is approximately 118 MW.

The third project, SPC, is a subsidiary of SPCG Public Company Limited (SPCG) [29]. SPC invested in the 34 projects featuring solar farms and has already commercially launched 7 projects. The locations of the launched projects were at the Wang Saphung District in the Loei Province, the Sawang Daen Din District in the Sakon Nakorn Province, the Pla Pak District in the Nakhon Phanom Province, and the Mueang District in the Khon Kaen Province, and 3 of the projects were in the Non Sung District in the Nakhon Ratchasima Province. Each capacity of the launched projects is 6 MW.

The forth project is EA [32]. They concentrated on the solar power plant in earnest. There are one of 8 MW solar power plant which operated commercially on 17 October 2012 at Phatthananikom District, Lopburi Province and three of 90 MW solar power plants. The first 90 MW solar power plant is in Takhi District, Nakhonsawan Province and operated commercially on 23 December 2013. The second plant is in Muang District, Lampang Province and operated commercially on 17 Febuary 2013. The third plant is in Prompiram District, Phisanulok Province and planned to operate commercially on 1 December 2015.

But in 2010, NEPC requested EGAT shut down to sign the contact with the investor of solar power plant, regarding to the subsidies modification following mention as above. After the FIT has established since 2010, the new mega power plant almost disappeared. After the FIT is implemented, the rooftop and ground-mounted solar systems have induced the solar power capacity in Thailand. Although the rooftop and ground-mounted solar systems are the low generated electricity capacity but these systems allow the people or the community can invest and participate widely in the PV system. And they also enhance the widespread use of solar power and reduce the loss of transmission for supplying the electricity from solar power plant. In Fig. 6, the increment of the generated electricity capacity since 2010 has been affected from adder scheme. The success of FIT needs to be monitored and evaluated in next few years.

At present (August 2015), the information about the capacity and status of the PV installation project is evident in the newest resolution of NEPC on 14 May 2015. The electricity authority has the total capacity of PV projects at 2819 MW. They contain the commercially produced project with 1558 MW, the projects that under construction is 1261 MW [36].

Even though Thailand have the high potential of solar energy and the growth rate of solar power is increased continually, but there are many barriers of the solar power development which be found by the Thailand's Solar PV Roadmap Initiative (TSPR) [37]. TSPR is the cooperation between DEDE and EIR. TSPR is the first platform of the key associates-government department, utilities, academy, civil society and investor – to discuss and design the future of Thailand's solar power development. After TSPR did the seminars and workshops between 2013 and 2014, the barriers of the solar system development are following:

(1) The initial investment of solar system is too high. Despite the solar cost is reduced continually but it is still high for the people and communities to invest in the rooftop and ground-mounted solar systems. The solution of this issue can be divided to be two sections. The first is to generate the funding support to the people or communities, specially. The second is to develop the domestic solar system manufacture and enhance R&D of solar system technology and productivity in Thailand. It does not only reduce the cost of the solar system investment in Thailand but it also develops Thailand to be the hub of the solar system in ASEAN. Because of Thailand is the lead solar system capacity in ASEAN and Thailand location locates at the center of ASEAN, so it is the continence logistic to supply the product to ASEAN. So it is very high opportunity for Thailand to be the solar system hub of ASEAN in case Thailand has high solar system technology.
(2) The subsidy does not certain. The Adder scheme had been announced in 2007 but it was canceled in 2010. Since 2010, the solar power project must be stopped 3 years for wait for the new subsidies. It resulted in investor anxiety and lack of confidence for investment. The subsidy is the major policy which impacts directly to the PV system growth rate in Thailand as shown in Fig. 6. Therefore, it is necessary to be carefully considered and should be assigned the exact duration of each subsidy scheme and long enough for ensuring the investors.
(3) Lack of the thorough policy planning. The best sample of this topic is the solar rooftop scheme. Although the solar rooftop regulation has released by the Energy Regulatory Commission (ERC). But there are many obstructive laws outside the Ministry of Energy blocking the solar rooftop participants to apply to this scheme. For example, the Energy Industry Act 2007 defines the solar system capacity over than 3.7 kW must align to the Factory Act 1992, the Building Control 1979 and the Energy Production and Development Act 1992. Additionally, the rooftop program always opened for applying in short period and less quota, including the complexity of the permitting process by the multiple stages. By these issue, the government assigned the Committee of Energy Reform under the Nation Reform Council had investigated the Solar PV rooftops for Residential and General Buildings project and proposed to the Nation Reform Council in 29 December 2014. The major proposal of the Solar PV rooftops for Residential and General Buildings project consists of the unlimited of quota for solar PV rooftops, the exemption from registration as a factory for Solar Roof and the reduction of the permitting process or “One stop service”. Currently, the Ministry of

Industry allow the solar roof not need to the factory registration and the ERC announced the One Stop Service for support the participants of the solar rooftop, including the NEPC expanded the quota of the solar rooftop capacity to 300 MW. The expected target of the solar system by the Committee Energy Reform are 5000 MW of residential scale and 5000 MW of general build scale within 20 years.

All obstruction as mention above is the main barriers in Thailand. The government needs to concern all barrier because in many countries cannot success by focus on just incentive or to provide the funds for the solar system [38]. Those issues can be solved in policy level. But the smart policies would be released by the sincerity and resolution government with the participation of all stakeholders of the solar system development. The TSPR is the good start to balance the requirement of all stakeholders together. TSPR did the seminars, workshop and collecting the information with all stakeholder. Then TSPR will propose to the government organization for providing the strategy and policy to support the solar system development to achieve the AEDP 2015 target. Consequently, the direction of solar system development needs to be monitor, closely.

6. Conclusion

The last decade is the excellent period of the world's PV system development with 35 times the growth rate from 2004 to the present. Thailand is one of the potential countries with class no. 11 of the solar potential's class. Thailand is also the first country in ASEAN who announced the incentive (Adder scheme) for the generated electricity by solar system. Although the solar system petition was stopped by the over incentive issue and the incentive was reduced in 2013 and 2014 (FIT) respectively but Thailand continues to demonstrate an exceptional growth rate of 80 times the rate during the same period with the effect of the Adder scheme. Therefore Thailand is the first place of the solar system capacity in ASEAN. Regarding to the attention of the Ministry of Energy for effective developing the solar system capacity, TSPR has been generated and worked for collecting the necessary information of all stakeholders of the solar system development. Then, TSPR will propose to the government organization for providing the suitable policy or promotion for solar system development. At present, the total solar system capacity in Thailand is 2819 MW. It is 46.98% of the AEDP 2015 target. The major barriers of solar system development are the high investment cost, the uncertain subsidy and lack of the thorough policy planning.. Those issues can be solved by the effective policy. Additionally, in case Thailand has the high technology of solar system, it is very high opportunity of Thailand to be the solar system hub in ASEAN regarding highest capacity in ASEAN and the convenience logistic to ASEAN members. Consequently, the solar system is not only the alternative energy for reduce the fossil energy but it is also the chance for increasing the exported solar system revenue. But it is depended on the strategy of government.

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