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Analysis of Distributed Energy Systems and Implications for Electrification: The Case of ASEAN Member States*

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Abstract: *The study of distributed energy systems (DES) in the Association of Southeast Asian Nations (ASEAN) highlights the potential role of DES to enhance electricity access and provide energy solutions as a modern energy system in response to increasing energy demand. This study grasps the overall status and policies of DES in selected ASEAN member states through literature survey and information exchanges from meetings and conferences within the region. The study also attempts to estimate the DES-related renewable energy capacity and investment needed for 2013–2040. At the ASEAN level, the estimates of DES-related renewable capacity and needed investment for combined renewable energy such as wind, solar photovoltaic (PV), geothermal, hydropower, and biomass will increase significantly from the investment opportunity of US$34 billion in the business-as-usual (BAU) scenario to US$56 billion in the alternative policy scenario (APS). At the same time, the application of DES-related renewable energy also implies reduced CO_2 emissions of 46.1 million metric tonnes for BAU and 64.6 million metric tonnes for APS. Thailand's case study of DES in the form of small power producers (SPPs) and very small power producers (VSPPs) demonstrated the likelihood of DES expansion in ASEAN member states in the future. Finally, the study suggests that the DES-related investment opportunity is large, and will provide jobs and business opportunities to the community. DES is a modern generation system and its deployment will also help address the electricity supply shortage in ASEAN member states.*

Keywords: distributed energy system (DES), electricity access, investment opportunity, energy demand, energy security

JEL Classification: Q40, Q41, Q47, Q48

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1. Introduction

The recent economic growth in the East Asia Summit (EAS) participating countries, especially emerging countries, has driven the rapid increase in energy demand. Although the countries have been introducing energy supply infrastructures such as power plants, some are still faced with instability and high cost of energy supply as well as high emissions of greenhouse gases (GHGs). For example, islands, mountainous, and other remote off-grid areas mainly rely on diesel power and other energy sources, where high energy costs and reduction of GHGs are the big challenge. In emerging countries of ASEAN, industrial and commercial zones, which contribute to economic growth, are sometimes faced with unstable energy supply, which is likely to prevent companies from investing and providing goods and services. Distributed energy systems (DES) are a potential solution to these tasks as they allow increasing the availability of small power generation and intelligent grid technologies. It is necessary to examine what kind of role the systems can play so that the ASEAN member states can utilise them. The DES study was welcomed by the 9th EAS Energy Ministers Meeting (EMM) as they realised that DES could play a role to enhance electricity access and provide energy solutions to enhance the well-being of both investors and consumers.

The concept of DES is not new and it was traditionally used at the early start of power generation in the late 18th century when Thomas Edison built the first power plant to provide electrical and mechanical power at or near the point of use (Owens, 2014). DES and its application has come back in the 21st century, and it has been widely deployed to respond to the increasing energy demand. The flexibility of DES at multiple locations makes it economically and technically viable, attracting many industrial, commercial, and residential units. Micro-grids in remote areas such as mountainous, island, and also economic zones are the most widely installed type of DES because of their scale and flexibility.

The driving force for DES has gained popularity globally to provide better energy in terms of secure, reliable, and affordable energy to customers. The wave of decentralised energy systems through DES applications is gaining market share because its lower capital cost can offer affordable prices to many part of the world.

The technological development of small and distributed generators of all types of energy sources (diesel, gas, coal slurry, wind, solar, geothermal, and mini-hydropower) has become more effective and less costly today than they were just a decade ago. DES creates a decentralised power system within which distributed generators meet local power demand. The advantage of DES is that they are small and have lower capital requirements that can be built and become operational faster with less risk than large power plants.

The ASEAN primary energy supply is projected to increase almost threefold from 592 million tonnes of oil equivalent (Mtoe) in 2013 to 1,697 Mtoe in 2040 (Kimura and Han, 2016). This pattern of increasing energy demand posts threats to energy security, especially the need to provide energy access, affordable price, and stable energy supply sources. The idea of transboundary grids is being promoted in the ASEAN Power Grid (APG). The APG is expected to contribute significantly to maximise ASEAN's benefit from avoiding cost of power generation; however, these grids are expensive and it may take years to realise the connectivity. In contrast, DES has the ability to overcome cost constraints that typically inhibit the development of large capital projects and transmission and distribution (T&D) lines. Thus, this study discusses the opportunities for DES in the ASEAN region, to support and foster the convergence of the ASEAN Economic Community and sustainable economic growth by providing affordable, reliable, and better energy sources with less GHG emissions through application of DES.

1.1. Scope and Definition of a Distributed Energy System

The DES is considered a decentralised power system in which electric power is produced and consumed locally at or near the point of use. DES involves distributed power technologies which can be stationary (typical of electrical applications) or mobile (as in marine and locomotive applications). There is no universal consensus or standard definition of DES; they in contrast to central power stations that supply electricity from a centralised location, often far from users. Electricity from central power stations is transmitted via transmission and distribution lines to end-users.

Central power systems do not supply mechanical power and are always stationary and land-based.

However, this study considered DES as a flexible energy system, small in size, yet effective to respond to the needs of growing energy demand. It should be noted that DES can offer an off-grid energy system for economic zones and isolated areas such as mountainous, island, and rural areas. For urban areas, DES could offer a smart energy system that can be integrated into the national grid system.

Generally, DES refers to two classes of technologies. First, it refers to renewable energy sources, which include biomass, solar, and hydro, with generating capacities scaled from a few kilowatts to as much as 10 megawatts (MW.) Renewable energy technologies can either be integrated into local distribution grids or as ‘stand-alone’ systems in areas where extension of transmission lines is not economically viable. Second, it refers to on-site generation, usually refers to industrial cogeneration or combined heat and power (CHP) systems that are gas-fired or coal slurry-fired. Cogeneration allows consumers to save much of the fuel and cost of generating electricity and heat by using one facility instead of a power plant to make electricity and boilers to make heat.

To define DES, this study also considers the installed capacity of distributed generation by type of fuels as follows:

- Solar farm, solar photovoltaic (PV), or small hydro is the development of solar and hydroelectric power on a scale serving a small community or industrial plant. The definition of a solar farm or small hydro project varies, but a generating capacity of 1–10 megawatts (MW) is generally accepted as the standard, which aligns with the concept of distributed generation.
- Small and mini thermal power plants, however, are generally observed in the form of small and very small power producers in ASEAN member states. Coal, gas, nuclear, geothermal, solar thermal electric, waste incineration plants, and biomass-fuelled thermal power plants are generally considered DES if they have capacities of less than 100 MW.

1.2. Research Hypotheses and Methodology

This study grasps the overall status and policies of DES in select ASEAN member states through literature survey and information exchange with relevant parties, taking opportunities such as the ASEAN Renewable Energy Sub-Sector Network meeting, ERIA Energy Research Institute Network (ERIN) meeting, Japan–ASEAN Capacity Building Programme, and other conferences. The study focusses, among others, on the following key questions:

- Current status of introduction of the systems:
  - What kind of distributed energy systems have been introduced?
  - How much energy have they supplied?

- Existing policies to promote the introduction of the systems:
  - Strategies, master plans, and roadmaps
  - Incentives/subsidies for renewables through the introduction of various policy instruments
  - Government-led model projects
  - Small power producer programmes

- Analysis of the outcomes of the policies:
  - What kind of distributed energy systems have the policies promoted?
  - How much energy have they supplied?
  - What kind of impacts has the introduction had on stable supply of energy, electricity tariff, the environment, and so on in the country as well as the community?

Questionnaires developed to address the above hypotheses are critical to understand the current status, policies, and the future potential of DES in the ASEAN region. Since DES information in each ASEAN member state is difficult to capture, this study also relies on various information from the national power development plan or any energy master plan of the countries studies. Taking advantage of current data from the Energy Outlook and Energy Saving Potential in East Asia (Kimura and Han, 2016), the generation output by ASEAN region was estimated by DES-related energy sources, particularly the renewable sources such as solar, wind, biomass, hydropower, and geothermal.

2. Key Drivers of Distributed Energy System

2.1. Energy Access

The ASEAN region has seen spectacular growth over the past two decades, and its growth has lifted hundreds of millions of people out of poverty. Energy demand has grown 2.5 times since 1990 and is expected to triple by 2035. Yet, about 130 million people in ASEAN member states still lack access to electricity and therefore have yet to enjoy the health, social, and economic benefits (ACE, 2013). As the ASEAN Economic Community declared by the end of 2015, the lack of power and energy access could threaten the region's economic growth and also economic transition. Energy is largely linked with economic opportunity. It is also noted that the expansion of energy infrastructure projects is slow, and it further affects the potential of industrial development and growth. In ASEAN member states, small power producers (SPPs) and very small power producers (VSSPs) play a significant role in filling the electricity supply gap and meeting growing electricity demand. However, there are also a growing number of so-called economic zones in an attempt to promote economic growth in ASEAN member states. As often, the electricity supply in the economic zones is in the form of DES as auto-electricity producers. In some case, the auto-electricity producers also supply surplus electricity to the grid or nearby areas. In rural areas of developing countries, schools and clinics operate with little to no power at all. Therefore, DES has gained a new recognition as a decentralised electricity system to meet end-use demand more effectively and to serve areas whereby grid expansion is not economically viable. This situation is practically observed in Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, and some remote islands of Indonesia.

Table 1 shows electricity access in ASEAN and East Asia. It also provides information on the progress of the access to electricity in urban versus rural areas from 1990 to 2012. While tremendous progress of almost 100 percent of energy access has been observed in Malaysia, Singapore, Thailand, Viet Nam, China, the Republic of Korea, Japan, Australia, and New Zealand, some countries in Southeast Asia have struggled to improve the energy access to their population.

Table 1. Access to Electricity (%)

	1990			2000			2012		
	Rural	*Urban*	*National*	*Rural*	*Urban*	*National*	*Rural*	*Urban*	*National*
Cambodia	5.0	36.6	19.2	9.0	49.9	16.6	18.8	91.3	31.1
Myanmar	.	.	.	.	.	.	.	.	32*
Lao PDR	39.7	100.0	51.5	40.0	68.7	46.3	54.8	97.9	70.0
Brunei Darussalam	56.4	70.5	65.7	61.2	72.7	69.4	67.1	79.0	76.2
Indonesia	.	.	66.9	.	.	.	.	.	74**
Viet Nam	84.5	100.0	87.9	86.6	96.9	89.1	97.7	100.0	99.0
Philippines	46.4	85.5	65.4	51.9	92.3	71.3	81.5	93.7	87.5
Malaysia	89.2	97.3	93.2	93.0	98.5	96.4	100.0	100.0	100.0
Singapore	99.0	100.0	100.0	99.0	100.0	100.0	99.0	100.0	100.0
Thailand	82.0	75.2	80.0	87.0	72.6	82.5	99.8	100.0	100.0

* The number was taken from the presentation of Khin Seint Wint (2014), Renewable Energy Association of Myanmar.
** The number was taken from ACE (2013).
Source: World Bank (2014), *World Development Indicators*. Washington, DC. http://data.worldbank.org/data-catalog/world-development-indicators

Cambodia and Myanmar still have very low access to electricity in rural areas (see Table 1). Only about 31 percent of the population in Cambodia and 32 percent in Myanmar have electricity access. While this rate is higher for the major cities, large parts of rural Cambodia and Myanmar have very low or almost no electricity at all. India also has a large population without access to electricity.

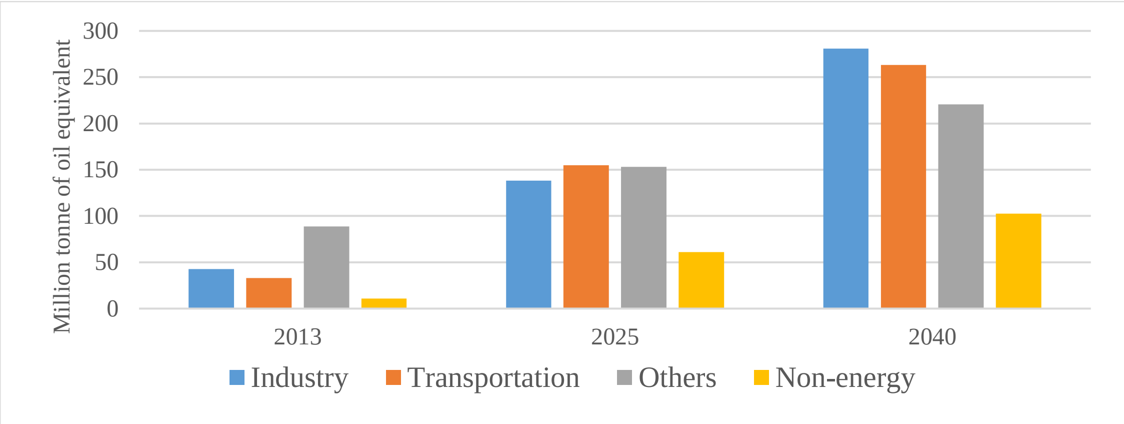
Promoting energy access requires investment for both energy infrastructure of grid expansion as well as off-grid electricity system. Regardless of on-grid or off-grid, DES can be well utilised depending on the context and the development of the energy market in the country as well as the region.

2.2. Increasing Energy Demand

Key drivers influencing the energy consumption in the EAS region are the population, gross domestic product (GDP), growth of the transportation sector as result of improved per capita GDP, and policy affecting the universal coverage of electricity access. The predicted primary energy supply and final energy demand almost double from 2013 to 2040 (see Figures 1 and 2).

Increase in final energy consumption**:** The final energy consumption is projected to increase from 431 Mtoe in 2013 to 1,191 Mtoe in 2040. By sector, Industry and transport energy demand is projected to grow most rapidly, increasing by 4.9 percent and 4.1 percent per year, respectively, as a result of industry expansion and motorisation driven by increasing disposable income in ASEAN member states. Demand of the commercial and residential ('Others') sectors will grow 2.5 percent per year. Figure 1 shows final energy consumption by sector under the business-as-usual (BAU) scenario in ASEAN from 2013 to 2040.

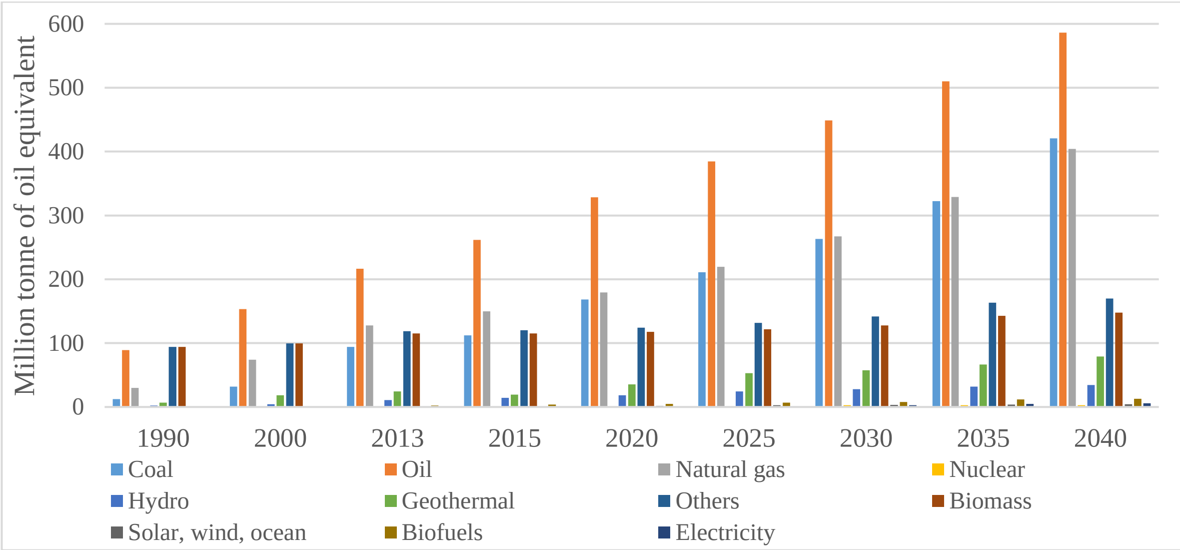
Figure 1. Final Energy Demand by Sector (2013–2040), BAU



BAU = business as usual.
Source: Authors' calculations (2016).

Increase in primary energy supply**:** The above drivers have influenced the increase in the estimated energy supply to meet the final energy consumption by 2040. The ASEAN primary energy supply is projected to increase from 592 Mtoe in 2013 to 1,697 Mtoe in 2040 (Figure 2). Oil will remain the largest share of primary energy supply, but its share drops to 34.5 percent in 2040 from 36.6 percent in 2013. Coal is predicted to have the fastest growth rate at 5.7 percent per year during the 2013–2040 period, and its share will increase from 16 percent to 25 percent during the same period. Coal will have the second-largest share after oil. Natural gas is predicted grow at 4.4 percent per year during the 2013–2040 period. Its share will increase from 21.5 percent in 2013 to 23.8 percent in 2040. Hydropower, geothermal, wind, and solar will see some increase in their shares as well, albeit small.

Figure 2. Primary Energy Supply in East Asia (2013–2040), BAU



BAU = business as usual.
Source: Authors' calculations (2016).

Among fossil sources of energy, natural gas is projected to have the fastest growth between 2013 and 2040, increasing at an annual average rate of 3.7 percent. Its share in the total will consequently increase from 9.1 percent (equivalent to 499 Mtoe) in 2013 to 12.7 percent (equivalent to 1,339 Mtoe) in 2035. Nuclear energy is also projected to increase at a rapid rate of 6.4 percent per year on average and its share will improve from 1.5 percent in 2013 to 4.3 percent in 2040. This is due to the assumed resumption of nuclear power generation in Japan, the expansion of power generation capacity in China and India, and the introduction of this energy source in Viet Nam.

3. Estimates of Energy Supply, Needed Investment, and CO_2 Emissions Reduction from the Application of Distributed Energy Systems

3.1. Estimates of Energy Supply

DES makes use of renewable energy sources such as biomass, wind power, small hydro, solar power, biogas, geothermal power, and other thermal plants with small capacity. However, the estimates of DES here is just for renewables. DES plays an important role in the electric power distribution system. The shift in preference towards green energy is one of the major factors that are encouraging the demand for DES across the globe. Moreover, the opportunity in developing nations and development of eco-friendly systems are the key opportunities for the growth of the DES market.

The global DES market is categorised into off-grid and on-grid segments. It is estimated that the market will increase owing to the adoption of financial incentive schemes worldwide for the promotion of clean energy as emphasised at the 2015 United Nations Climate Change Conference (COP21) and the intended nationally determined contribution (INDC) commitments. The EAS region is also predicted to significantly raise the application of DES to meet energy demand (see Table 2). All countries in the EAS region are expected to have increased solar and wind. However, hydropower and geothermal are also expected to increase their output in countries with resource potentials.

Table 2. Estimated Off-grid Distributed Energy System Generation Output (GWh) in ASEAN

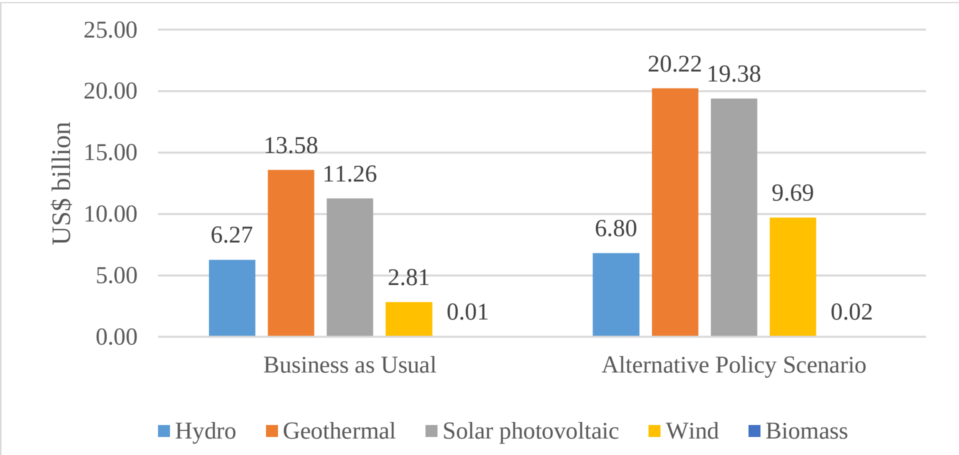
ASEAN Region	BAU vs. APS	Generation Output, 2013			Generation Output, 2040		
		Solar, wind, biomass	Hydropower	Geothermal	Solar, wind, biomass	Hydropower	Geothermal
Cambodia	BAU	1.4	50	0	11.6	1,650	0
	APS				25.6	1,197	0
Myanmar	BAU	0	443	0	918	2,137	350
	APS				2,363	1,497	350
Lao PDR	BAU	0	775	0	0	2,528	0
	APS				0	2,397	0
Brunei Darussalam	BAU	0.34	0	0	9	0	0
	APS				175	1.45	0
Indonesia	BAU	54	846	1,882	12,890	4,380	15,295
	APS				13,905	5,475	18,921
Viet Nam	BAU	26.4	2,847	0	160.8	6,231	0
	APS				12,353	6,550	0
Philippines	BAU	59.8	500	1,921	1,033	738	3,028
	APS				1,952	1,575	6,668
Malaysia	BAU	150	529	0	839	1,600	0
	APS				2,967	1,695	0
Singapore	BAU	274	0	0	1,292	0	0
	APS				1,710	0	0
Thailand	BAU	1,671	287	0	9,773	740	0
	APS				9,277	792	0
TOTAL	**BAU**	**2,240**	**6,281**	**3,804**	**26,927**	**20,008**	**18,673**
	APS				**44,731**	**21,182**	**25,941**

APS = alternative policy scenario, ASEAN = Association of Southeast Asian Nations, BAU = business as usual, GWh = gigawatt-hour, Lao PDR = Lao People's Democratic Republic.
Note: Various assumptions were made to calculate the future potential off-grid for solar, wind, biomass, hydro, and geothermal.
Source: Authors' calculations (2016).

3.2. Estimates of Needed Investment

The increase I DES energy supply in the ASEAN region also implies an opportunity for DES-related renewable investment. Figure 3 shows that investment opportunities by 2040 in BAU for combined solar, wind, biomass, hydropower, and geothermal are about US$34 billion and in the alternative policy scenario (APS) about US$56 billion. Among the DES-related renewable investment, investment in solar and geothermal power is expected to double from BAU to APS. Wind will have a large increase of more than threefold in terms of investment required to meet the expected generation output by 2040.

Figure 3. Estimated Off-grid Distributed Energy System-Related Renewable Investment Opportunities by 2040



Note: Various assumptions were made to calculate the estimated DES-related renewable investment opportunities.
Source: Authors' calculations.

3.3. Estimates of CO_2 Emissions Reduction

The increase of DES-related renewable energy supply in the ASEAN region will have great implications for carbon dioxide (CO_2) emissions reduction in the region. The estimates show that CO_2 emissions reduction from the application of solar, wind, biomass, geothermal, and hydropower is about 46.1 million metric tonnes in BAU and

64.6 million metric tonnes in APS (see Table 3). The CO_2 emissions reduction calculation method refers to the Greenhouse Gas Equivalencies using an emissions factor of 7.03×10^{-4} metric tonnes of CO_2/kWh (EPA, 2016).

Table 3. Estimated CO_2 Emissions Reduction from Off-grid Distributed Energy System Application in ASEAN

	Generation Output, 2040 (GWh)				CO_2 Emissions Reduction* (million metric tonne)
	Solar, wind, biomass	Hydropower	Geothermal	**Total**	
Business as Usual	26,927	20,008	18,673	65,608	46.1
Alternative Policy Scenario	44,731	21,182	25,941	91,854	64.6

*The Greenhouse Gas Equivalencies Calculator uses the Emissions & Generation Resource Integrated Database (eGRID) US annual non-baseload CO_2 output emissions rate to convert reductions of kilowatt-hours into avoided units of CO_2 emissions.
Source: Authors' calculations.

4. Potential System Cost of Electricity Generation and Enabling Policy Framework to Promote Distributed Energy Systems in ASEAN

4.1. Potential System Cost of Electricity Generation

The potential reduction of total system levelized cost of electricity (LCOE) for various generation plant technologies provides hope for the uptake of DES-related renewable technology. The study by the US Energy Information Administration (2016) on the Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2016 showed that LCOE from all renewable resources have high potential of lowering total system LCOE. The potential LCOE ranged from 4.1 to 5.1 cent/kWh for geothermal, 8.1 to 11.5 cent/kWh for biomass, 4.3 to 7.8 cent/kWh for wind, and 6.5 to 12.6 cent/kWh for solar PV. The LCOE of these renewable resources look competitive to their fossil fuel-generating plants

(Table 4). However, all the estimates of technology development are for the technology entering the market in 2022 in the United States (EIA, 2016).

Table 4. Estimates of System Levelized Cost of Electricity (LCOE) for Various Generation Plants in 2022

Plant Type	Range for Total System Levelized Costs (2015 $/MWh)	
	Minimum	Maximum
Advanced coal with CCS	129.9	162.3
Conventional combined cycle	53.4	67.4
Advanced combined cycle	52.4	65.5
Advanced CC with CCS	78.0	93.9
Conventional combustion turbine	103.5	122.8
Advanced combustion turbine	87.7	105.8
Advanced nuclear	99.5	108.3
Geothermal	41.1	51.8
Biomass	81.5	115.6
Wind	43.0	78.5
Wind – Offshore	137.1	213.9
Solar PV	65.6	126.2
Solar thermal	172.3	363.4
Hydroelectric	59.6	78.1

CCS = carbon capture and storage, MWh = megawatt-hour.
Source: US Energy Information Administration (2016).

4.2. Need for Enabling Policy Framework

Although DES is mainly known as a decentralised energy resources system, often the policy framework for promoting DES is related to renewable energy policies, and it has always remained the most important driver of DES deployment. An enabling policy framework provides a long-term government commitment and credible targets. The framework involves policy, fiscal, and financial attractiveness for the investment in DES as well as renewable energy. The enabling policy framework that has been employed so far includes the following:

- **National policy design** aims to provide a trajectory for the future energy mix. This includes renewable energy targets; renewable energy law or strategy; biomass and biofuels law or programme; and solar heating, solar power, wind, and geothermal law or programme.
- **Fiscal incentives** aim to reduce the upfront cost by introducing fiscal policy instruments such as exemptions of value-added tax (VAT), fuel tax, income tax, import and export tax, and local taxes; introduction of a carbon tax; and accelerated depreciation.
- **Grid access** aims to provide confidence to project developers through grid access priority and transmission discount policy if the production of electricity is from renewables.
- **Regulatory instruments** aim to provide incentives for investing in renewables through the implementation of energy policy such as feed-in tariffs, feed-in premiums, auctions, net metering, and quota.
- **Finance** aims to reduce the risk for investors through the implementation of currency hedging, dedicated fund, eligible fund, or guarantees.
- Other policies aim to help and target the energy access in remote areas through the promotion of renewable energy in social housing, renewable energy in rural access programmes, renewable energy cook stove programme, and other energy access activities done by non-governmental organisations, and communities.

The above policy framework needs to be reinforced and applied to suit the context in each country if DES and renewable energy are to be promoted as the future energy mix. In the ASEAN context, various policy instruments can be observed as being promoted. At the regional level, ASEAN has targeted a 23 percent share of renewable energy in the primary energy supply by 2025. The ASEAN member states have also set up renewable energy targets in each country and various instruments are being considered and developed to promote the renewable energy (Table 5).

Table 5. Renewable Energy Targets in ASEAN Member States

Country	Renewable Energy Target	Policy Instruments
Brunei Darussalam	10% RE share in power generation by 2035*	Need to be developed
Cambodia	More than 2 GW of hydropower by 2020	Permits and tax incentives are in place
Indonesia	23% NRE share in energy mix in 2025	Feed-in tariff
Lao PDR	30% RE share of total energy consumptions by 2025*	Permits and tax incentives are in place
Malaysia	4 GW RE installed capacity by 2030*	Feed-in tariff and capital subsidies
Myanmar	15%–20% RE share in installed capacity by 2030*	Need to be developed
Philippines	15 GW installed capacity in 2030	Feed-in tariff, capital subsidies, tax incentives, and RPS
Singapore	350 MW installed capacity of solar by 2020	Feed-in tariff, permits, and tax incentives
Thailand	30% AE share in total energy consumption by 2036*	Feed-in tariff, permits, and tax incentives
Viet Nam	27 GW RE installation in 2030*	Feed-in tariff, permits, and tax incentives

AE = alternative energy, GW = gigawatt, Lao PDR = Lao People’s Democratic Republic, MW = megawatt, NRE = non-renewable energy, RE = renewable energy, RPS = renewable portfolio standard.
Note: * Large hydropower is excluded.
Source: ACE (2016).

Some countries in ASEAN have developed detailed policy instruments to ensure the set targets are achieved through various projects and programme implementation. Nonetheless, some countries are far behind in terms of policy design and implementation.

The following case study in Thailand on the review of policies to promote DES provides a snapshot and stock-taking in terms of policy design to promote DES as well as renewable energy so that other ASEAN member states may look into the case and develop their own policy to fit their own political and social contexts.

4.3. Case Study on Enabling Policy Framework: Thailand

Thailand has been seen as the country in Southeast Asia that has a comprehensive long-term energy development plan. Key energy policy documents are laid out in the new Power Development Plan (known as PDP, 2015–2036), the Alternative Energy Development Plan (AEDP, 2012–2021), and the Energy Efficiency Plan (EEDP, 2011–2030). The new PDP 2015–2036 highlighted energy security of power supply, transmission, and distribution system in response to the demands of electricity. It also strikes to find the best energy mix avoiding excessive reliance on gas as a source for power generation. The new PDP also aims to reduce CO_2 emissions by promoting electricity production from renewable energy and promote energy efficiency.

The Government of Thailand has continuously promoted private sector investment in the generation business through bid solicitations for power purchase from large-scale independent power producers (IPPs) and small power producers (SPPs), with the Electricity Generating Authority of Thailand (EGAT) being the single buyer of bulk electricity under terms and regulations set by the Energy Regulatory Commission (ERC) to ensure the best interests of public consumers, energy resource optimisation, and fairness to all. For DES-related renewable energy, Thailand has set a 30 percent share of renewables in the total final energy consumption by 2036 (Alternative Energy Development Plan (AEDP, 2015–2036)). In absolute amounts, renewable energy consumption is targeted at 39,388 kilotonnes of oil equivalent (Ktoe) out of the total final consumption at 131,000 Ktoe by 2036. Thailand has been introducing a feed-in tariff (FiT) to promote renewable energy (Table 6).

Table 6. Feed-in-Tariff Rate by Type of Renewable Energy Source in Thailand

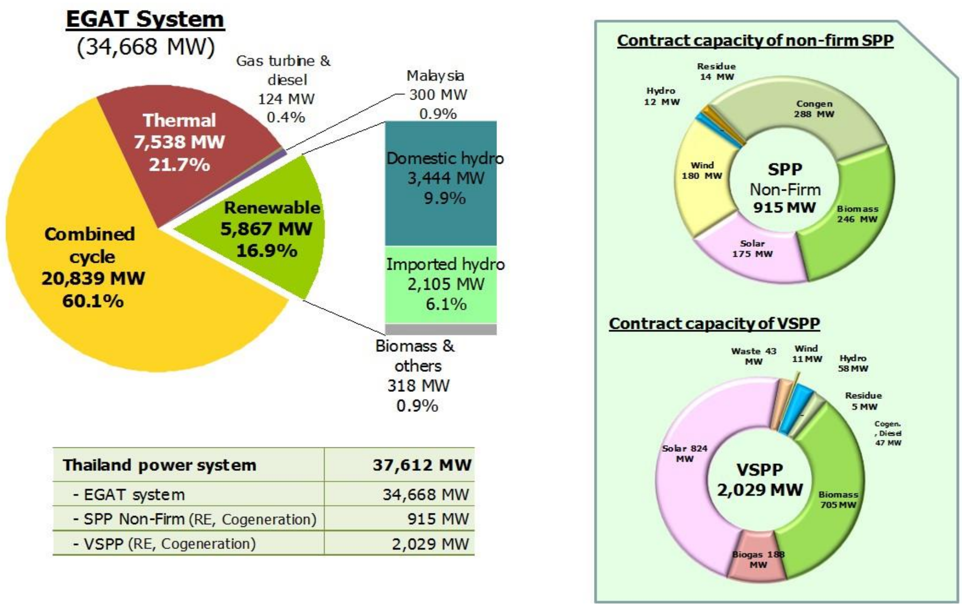
Capacity (MW)	FiT (B/kWh)			Period of Subsidy (Year)	FiT Premium (B/kWh)	
	FiT(f)	FiT(v),2017	FiT(1)		Biofuel Project (8 years)	Project in Southern Territory Area (throughout project period)
1) MSW (Hybrid Management)						
Existing Capacity ≤ 1 MW	3.13	3.21	6.34	20	0.70	0.50
Existing Capacity > 1–3 MW	2.61	3.21	5.82	20	0.70	0.50
Existing Capacity > 3 MW	2.39	2.69	5.08	20	0.70	0.50
2) MSW (Sanitary Landfill)	5.60	-	5.60	10	-	0.50
3) Biomass						
Existing Capacity ≤ 1 MW	3.13	2.21	5.34	20	0.50	0.50
Existing Capacity > 1-3 MW	2.61	2.21	4.82	20	0.40	0.50
Existing Capacity > 3 MW	2.39	1.85	4.24	20	0.30	0.50
4) Biogas (Waste Water/Sewage)	3.76	-	3.76	20	0.50	0.50
5) Biogas (Energy Crop)	2.79	2.55	5.34	20	0.50	0.50
6) Hydropower						
Existing Capacity ≤ 200 kW	4.90	-	4.90	20	-	0.50
7) Wind	6.06	-	6.06	20	-	0.50

B = Thai baht, FiT = feed-in tariff, MSW= municipal solid waste, MW = megawatt, kW = kilowatt.
Note: FiT(f) is FiT fix rate throughout the project; FiT(v) is FiT variable rate adjusted by inflation standard; FiT(i)=FiT(f)+FiT(v, i-1) * (1+Core Inflation(i-1))+FiT Premium.
Source: MOE, Thailand (2016).

The Department of Alternative Energy Development and Efficiency (DEDE) of Thailand has also developed the Energy Service Companies (ESCO) Fund to cope with the risk of and to encourage investment in renewables-focused ventures. In addition, a capital pooled fund has been set up with contributions from Thailand’s Energy Conservation and Promotion Fund (ENCON) and private investors. The ESCO Fund aims to support access to low-cost equipment leasing. To date, the ESCO Fund has invested B6.1 billion (B510 million from the government and the rest from private sources) in 54 separate projects accounting for total energy savings of B1.1 billion (DEDE, 2016).

It is noted that most DES-related schemes in Thailand are in the form of very small power producer (VSPPs). Thailand's VSPP regulations were approved by the Cabinet in 2002. These regulations allow small community-owned or small entrepreneur-owned renewable energy generation to connect to the grid and sell excess electricity to utilities. In December 2006, the Thai government announced important changes in VSPP regulations that allow each generator to export up to 10 MW to the grid and offer feed-in tariff subsidies for renewable electricity production. The VSPP programme is also now open to efficient fossil-fuel combined heat and power (CHP). Currently, the share of DES or the combined VSPP and SPP share in the generation mix is just about 5.4 percent (see Figure 4 and Table 7).

Figure 4. Current Status of Installed Capacity by Energy Type (as of 2014)



Thailand power system	37,612 MW
- EGAT system	34,668 MW
- SPP Non-Firm (RE, Cogeneration)	915 MW
- VSPP (RE, Cogeneration)	2,029 MW

EGAT = Electricity Generating Authority of Thailand, MW = megawatt, RE = renewable energy,
SPP = small power producer, VSPP = very small power producer.
Source: MOE, Thailand (2015).

Table 7. Installed Capacity by Types of Power Producer (as of 2014)

Types of Owner	Capacity (MW)	Share (%)
EGAT	15,482	**41.2**
Independent power producers (IPPs)	13,167	**35.0**
Small power producers (SPPs)	4,530	**12.0**
Very small power producers (VSPPs)	2,029	**5.4**
Power imports	2,404	**6.4**
Total	**37,612**	**100**

Source: MOE, Thailand (2015).

The future total capacity of VSPP power purchase to be online during 2015–2036 according to the AEDP is 9,735.6 MW, increasing from 2,029 MW in 2014. For VSPPs, this represents an almost fourfold increase from 2014 to 2036. According to the AEDP, the details are as follows: (*a*) renewable power plant with a capacity of 9,701 MW and (*b*) cogeneration power plants with a capacity of 34.6 MW.

The future installed capacity of SPPs will consist of 97 SPPs with a total capacity of 5,922 MW, which already have power purchase agreements (PPAs) with EGAT to be online during 2015–2025. For SPPs, this represents a 30.7 percent increase from 2014 to 2025. The details are as follows: (*a*) 41 projects of cogeneration power plants with a total capacity of 3,660 MW, (*b*) 25 extension projects of cogeneration power plants with a total capacity of 424 MW, and (*c*) 31 projects of renewable energy generation with a total capacity of 1,838 MW.

If Thailand’s case could be replicated in other ASEAN member states, or at least in Cambodia, Lao PDR, Myanmar, and Viet Nam (CLMV), the electricity coverage to be supplied by DES will be significantly important as it would represent 17.4 percent (both VSPPs and SPPs) of the generation mix. The future prospects of Thailand’s DES will significantly increase almost fourfold in terms of installed capacity during the 2015–2036 period. Thus, DES will play an important role in providing electricity access to CLMV and other ASEAN member states for now and in the coming future.

5. Conclusions and Policy Implications

ASEAN's primary energy supply is projected to increase from 592 Mtoe in 2013 to 1,697 Mtoe in 2040, representing a more than threefold increase from the 2013–2014 period. This increase in energy demand will put pressure on energy security, the overwhelming issue of energy access, and affordable energy price. Thus, DES is explored as part of an energy system that could promote energy access with less cost and higher efficiency. The study finds that DES is a kind of modern small power generation flexible to provide electricity to end-users more effectively because of its advantage of being less costly in terms of investment and easy to handle as opposed to the large national power plants and national grids. If DES is to be deployed widely, it could also address the daunting issue of electricity access to about 130 million people whose rights have been denied. The flexibility of DES at multiple locations through the increasing availability of small power generation has been shown in application, i.e., Thailand's SPPs and VSSPs have been used significantly and their share of 17.4 percent in the power generation mix in 2014 is expected to increase significantly into the future.

At the ASEAN level, the idea of transboundary grids is being promoted in the ASEAN Power Grid (APG). It is expected to contribute significantly to maximise ASEAN's benefit from avoiding the cost of power generation; however, they are expensive and it may take years to realise the connectivity. In contrast, DES has the ability to overcome the cost constraints that typically inhibit the development of large capital projects and transmission and distribution (T&D) lines. Thus, given the prospect of DES, it will be widely used. It is also expected that the modern grid system can handle the integration of DES into the grid system. DES could be used for stand-alone power generation or connect to the power grid, so its application is also very suitable for rural and remote, mountainous, and island areas.

The study also estimates the DES-related renewable capacity and needed investment at the ASEAN level. The estimated power generation from combined renewable energy such as wind, solar PV, geothermal, hydropower, and biomass in ASEAN will increase significantly when comparing BAU with APS, and it also implies investment opportunity in this sector. It is estimated that the investment opportunity by 2040 in BAU for combined solar, wind, biomass, hydropower, and geothermal amounts to about US$34 billion, and in the APS about US$56 billion. Among the DES-related renewable investment, solar and geothermal power investment is expected to double from BAU to APS. Wind will increase more than threefold in terms of investment required to meet the expected generation output by 2040.

The introduction of DES also implies reductions in CO_2 emissions. The study estimates that about 46.1 to 64.6 million metric tonnes of CO_2 emissions reduction could be realised from BAU to APS, respectively.

The study offers the following policy implications:

- DES, as a stand-alone generator or combined with the grid system, offers the opportunity to emerging ASEAN member states as one of the best options to respond to the increasing energy demand and also to provide energy access to remote rural, mountainous, and island areas and economic zones. The promotion of DES is crucial, but it will need careful policy support as it relates to the deployment of renewable energy. Basically, the policies will work around reducing upfront investment costs of DES-related renewable generation. These policies include the required top–down renewable energy targets such as the renewable portfolio standard (RPS) and other policies such as fiscal incentives and exemptions of VAT, fuel tax, income tax, import and export tax, local taxes, and accelerated depreciation through premium tariff rates such as feed-in tariffs. The introduction of a carbon tax could also be considered in the future. It is also important to note that banking institutions will need to enlarge their role and policy to finance DES-related renewable energy and find mechanisms to dispel risk and increase the profitability aspects of DES-related renewable investment.

- DES has been widely applied in Thailand through the application of SPPs and VSPPs. The current share of DES in Thailand is about 17.4 percent in the power generation mix, and its share and capacity will increase significantly in the future. This experience in Thailand could provide the best example for other ASEAN member states to use DES to respond to increasing energy demands and is one of the modern options of a decentralised energy system.

- The DES-related investment opportunity is large, and it will provide jobs and many business opportunities to people and the community. DES is a modern generation system and its deployment will also help address national energy security.

- A comprehensive DES study will need to be followed up by using questionnaires to capture the real situation of DES in some ASEAN member states. Thus, this type of study will be further examined at a later time using questionnaires to map out the current capacity of DES, its prospects, and applications in the future.

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