Economic Research Institute for ASEAN and East Asia

DISTRIBUTED ENERGY SYSTEM IN SOUTHEAST ASIA

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This report was prepared by the Working Group for Distributed Energy System (DES) in ASEAN under the Energy Project of the Economic Research Institute for ASEAN and East Asia (ERIA). Members of the Working Group, who were selected from ASEAN, discussed and agreed to certain key assumptions of DES as a basis for writing this report. This aimed to harmonise the forecasting techniques of the future growth of DES. Therefore, the projections presented here should not be viewed as official national projections of participating countries.

Cover Art by Artmosphere Design.

Book Design by Chrestella Budyanto.

National Library of Indonesia Cataloguing-in-Publication Data
ISBN: 978-602-5460-04-3

Preface and Acknowledgement

The recent economic growth in East Asia Summit (EAS) participating countries, especially the emerging ones, has led to a rapid rise in energy demand. Although these countries have been introducing energy supply infrastructures such as power plants, some of them are still faced with instability and high cost of energy supply as well as high emissions of greenhouse gases (GHGs). DES can solve these challenges due to the increasing availability of small power generation and intelligent grid technologies. It is necessary to assess what role DESs can play so that ASEAN participating countries could utilise these systems. The energy ministers, during the 9th EAS Energy Ministers Meeting, welcomed the DES as they realised the role of DES in enhancing electricity access and providing solutions to energy problems for the well-being of both investors and consumers.

The ASEAN primary energy supply is projected to increase almost threefold from 592 Mtoe in 2013 to 1,697 Mtoe in 2040 (Han and Kimura, 2016). This pattern of increasing energy demand threatens energy security, especially the provision of energy access, affordable prices, 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 maximising ASEAN's benefits from avoiding power generation cost; however, transboundary grids are expensive and it may take years to realise the connectivity. DESs, however, can overcome cost constraints that typically inhibit the development of large capital projects and transmission and distribution 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 DES application.

This study is a joint effort of Working Group members from selected ASEAN member states. It took a long time to agree on a definition and the assumptions of DES. The estimated future potential of DES for ASEAN as well as some selected ASEAN Member States is in line with the policy interests of ASEAN's energy security. We would like to acknowledge the support of everyone involved, and thank all those the authors of this study met and interviewed to obtain country data and information.

Special thanks go to Stefan Wesiak, chief editor and publication director of ERIA, and his team of editors and publishing staff for their help in editing the report and preparing it for publication.

The Authors

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Executive Summary

The recent economic growth in East Asia Summit (EAS) participating countries, especially emerging ones, has driven energy demand to rapidly rise. Although these countries have been introducing energy supply infrastructures such as power plants, some of them still face instability, high cost of energy supply, and high emission of greenhouse gases (GHGs). For example, islands, mountainous areas, and other remote off-grid areas mainly rely on diesel power and other energy sources, where high energy costs and reduced GHG emissions are the big challenge. Industrial and commercial zones of emerging countries of the Association of Southeast Asian Nations (ASEAN) are sometimes faced with unstable energy supply. This is likely to prevent companies from investing and providing goods and services. Distributed Energy Systems (DESs) can solve these challenges due to the increasing availability of small power generation and intelligent grid technologies. It is necessary to find what role DESs can play so that ASEAN participating countries could utilise these systems. The energy ministers, during the 9th EAS Energy Ministers Meeting, welcomed the DES study as they realised the role of DES in enhancing electricity access and providing solutions to energy problems for the well-being of both investors and consumers.

The DES concept is not new, and it has been applied since the 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 (Brandon, 2014). Now, the DES concept and application have been widely used to respond to increasing energy demand. The flexibility of DES at multiple locations makes it economically and technically viable, attracting many industrial, commercial, and residential units. Most widely installed DESs can be found in mountainous, island, and remote areas and in economic zones with microgrids because of their scale and flexibility.

Globally DES has gained popularity to provide secure, reliable, and affordable energy to customers. The wave of decentralised energy systems through DES applications is gaining market share because of their lower capital cost, thus making energy affordable in many parts of the world. The technological development of small and distributed generators from 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 a decade ago. DES creates a decentralised power system through which distributed generators meet local power demand. Because they are small and have lower capital requirements, they can be built and made operational faster with less risk than large power plants.

The ASEAN primary energy supply is projected to increase by almost threefold from 592 Mtoe in 2013 to 1,697 Mtoe in 2040 (Han and Kimura, 2016). This pattern of increasing energy demand threatens energy security, especially the provision of 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 significantly maximise ASEAN's benefit from avoiding power generation costs; however, they are expensive and it may take years to realise the connectivity. In contrast, DES can overcome cost constraints that typically inhibit the development of large capital projects and transmission and distribution lines.

Thus, this study will map out the current situation of DES in selected ASEAN Member States, and discuss 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.

Chapter 1 introduces DES and discusses the methodology of DES in ASEAN. Chapter 2 estimates the potential of ASEAN's DES from renewable energy. Chapters 3 to 6 are studies of Indonesia, Malaysia, the Philippines, and Thailand on DES and policies. The book is the first of its kind to come up with DES in ASEAN and in specific countries. The findings are as follows:

ASEAN

The estimated power generation from combined renewable energy such as wind, solar photovoltaic, geothermal, hydropower, and biomass in ASEAN will increase significantly from the business-as-usual scenario (BAU) to the alternative policy scenario (APS), thus implying investment opportunities in this sector. Investment opportunities in BAU by 2040 for combined solar, wind, biomass, hydropower, and geothermal total about US$34 billion, and in the APS, about US$56 billion. Amongst DES-related renewable investment, that for solar and geothermal power is expected to double from BAU to the APS. Investment in wind power will increase more than threefold to meet the expected generation output by 2040. The introduction of DES application also implies reduced CO_2 emissions of about 46.1–64.6 million metric tons from BAU to the APS, respectively.

Indonesia

DES can be implemented in regions like Indonesia where supply of grid-connected electricity is not available or not economically viable. It can also support electrification in a faster way rather than wait for grid-connected supply. DES is cost competitive compared to current diesel power plants. As DES projects use local energy resources, and are not necessarily technology intensive, these projects may also increase the involvement of local people in the construction and maintenance of the system, which may create jobs in the region.

As the potential of DES is huge in Indonesia, its development project can be even faster with the participation of local governments, for example, in providing lands for free for the site of the DES project. To optimise the development of DES projects and ensure their sustainability, government support – such as tax incentives, availability of low interest loan with longer tenor, and streamlined licensing process – is needed. Good electricity tariff for DES that considers the production costs and reasonable margins is also needed.

Malaysia

The implementation of DES is very important for the security of supply especially in remote areas where the connectivity is far from the grid. To ensure the stability of electricity supply without any disruption, equipment and other requirements for electricity generation should be properly installed and completed. It is costlier to install the transmission or distribution line to the national grid from remote areas. Using existing natural resources, such as biomass or biogas, DES can also reduce GHG emissions.

Through DES, a 100% electrification rate in rural areas can be achieved. Providing this basic amenity will help generate income for the economy. DES will also boost tourism on several islands of Malaysia. With some remote islands in the country located far from the national grid system, the implementation of DES will be a great solution.
Public and private funds are needed to ensure the success of DES' implementation. Government can offer attractive incentives to attract local and international investors.

Philippines

Evidently, the underlying principles of DES present substantial potentials that correspond to the current setting of the Philippine electric power industry, either through on-site embedded generation or stand-alone off-grid systems. As the government aspires to bring inclusive economic development to the grassroots level, the concept of DES applications undeniably has an integral role in ensuring the security of energy supply in the flourishing economic and industrial zones of the country, and, more importantly, in the remote communities.

Government has recognised that the deployment of DES applications is an alternative platform to complement centralised and decentralised electrification initiatives. Harnessing the full potential of the cleaner set of fuels such as renewables is admittedly an effective mitigating measure to drastically reduce GHG emissions. This in the long run is foreseen to counter the adverse impacts of climate change. To take full advantage of this benefit, the country should pursue the development and increased use of indigenous renewable energy sources that are abundant in rural locations. However, strong policy support and mechanisms from the government are imperative.

Fundamentally, DES applications are intended to provide an affordable and reasonable source of electricity. But because the private sector lacks confidence to invest in the off-grid generation business, the national government assumes the responsibility of bringing the necessary electricity services to spur local economic development. To sustain the operations of DES in off-grid communities, government subsidises the costs of generating power. In turn, DESs have become costly compared to grid-connected power systems.

Thailand

DESs in Thailand are mainly used in the private industrial section and investment according to the Thai government's policy on subsidy. DESs in Thailand mainly promote solar and biomass. The on-grid DES of the country is expected to grow in the near future. Per the current policy on DES, about 10,000 MW of DES growth is expected. However, off-grid DES demand could skyrocket were the price of the self-generated electricity to be lower than that of retailed electricity.

The new Cabinet provided the direction of Energy 4.0. To accommodate the government's policy, the Ministry of Energy has placed the Energy 4.0 policy focused on the Thailand Integrated Energy Blueprint to drive energy innovation and to continue the desire of King Rama IX to strengthen families and communities. To enhance the power sector, the Ministry of Energy has set policies related to DES in two areas: for places where unbalanced fuel diversification and unstable renewable generation occurred, and for places where centralised generation and distribution systems are faced with high investment in the transmission system.

Chapter 1
Introduction and Methodology of Distributed Energy System

Background and Objective

The recent economic growth in East Asia Summit (EAS) participating countries, especially emerging ones, has driven energy demand to rapidly rise. Although these countries have been introducing energy supply infrastructures such as power plants, some of them are still faced with instability, high cost of energy supply, and 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 reduced GHGs emissions are the big challenge. In the emerging countries of ASEAN, industrial and commercial zones, which contribute to economic growth, are sometimes faced with unstable energy supply; this will likely prevent companies from investing and providing goods and services. Distributed energy systems (DESs) can solve these challenges due to the increasing availability of small power generation and intelligent grid technologies. It is necessary to find what role DESs can play so that ASEAN participating countries could utilise these systems. The energy ministers, during the 9th EAS Energy Ministers Meeting, welcomed the DES study as they realised the role of DES in enhancing electricity access and providing solutions to energy problems for the well-being of both investors and consumers.

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Thus, this study will map out the current situation of DES in selected ASEAN member states and discuss 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.

Hypotheses of the Study

This study tries to understand the overall status and policies of DESs in selected ASEAN countries through a literature survey and information exchange with relevant parties, such as meetings of the ASEAN Renewable Energy Sub-Sector Network, Energy Research Institute Network, Japan–ASEAN Capacity Building Programme, and other conferences. The study focuses on the following key questions:

- Status of DESs, including
    - what kind of DESs have been introduced, and
    - how much energy they have supplied.

- Existing policies to promote introduction of the systems, such as
    - strategies, master plans, and roadmaps;

    - incentives/subsidies for renewable energy through the introduction of various policy instruments;
    - government-led model projects; and
    - small power producers (SPP) programmes.

- Analysis of the outcomes of the policies:
    - what kinds of DESs the policies have promoted;
    - how much energy they have supplied; and
    - what kind of impacts the introduction has had on stable supply of energy, electricity tariff, environment, and others on the communities and on the country.

The study developed questionnaires to address the above hypotheses that are critical in understanding the status, policies, and potentials of DESs in the ASEAN region. Since information on DES in each ASEAN country is difficult to capture, this study relies on various information from the power development plan, or any energy master plan of country studies.

Methodology of the Study

This study considered DES as a flexible energy system. It is small yet effective in responding to the growing energy demand. DES could offer an off-grid energy system for economic zones and isolated and remote areas. For urban areas, it could offer a smart energy system that could be integrated into the national grid system.

Generally, DES refers to two classes of technologies. First are the 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, DES is an on-site generation system and usually refers to industrial cogeneration or combined heat and power (CHP) systems that are fired by gas or coal slurry. 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, the working group of the DES study set up by ERIA considers the scope of the installed capacity of distributed generations by type of fuel as follows:

- Solar farm, solar PV, small hydro is the development of solar and hydroelectric power on a scale serving a small community or industrial plant. The definition of solar farm and a small hydro project varies but a generating capacity of 1–10 MW is generally acceptable, which aligns to the concept of distributed generation.
- However, small and mini thermal power plants are generally in the form of small and very small power producers (SPPs and VSPPs) in ASEAN countries. Generally, coal, gas, nuclear, geothermal, solar thermal electric, waste incineration plants, and biomass-fuelled thermal power plants are DESs if they have capacities of less than 100 MW.

Given the limited availability of data on DES in ASEAN member states, it is very crucial to roll out questionnaires (see Annex 1) designed to capture information gaps on DES. The Ministry of Economy, Trade and Industry of Japan commissioned the Economic Research Institute of ASEAN and East Asia (ERIA) to carry out this important study.

Thus, ERIA formed a working group to collect data and information through questionnaires distributed to selected ASEAN member states. The working group consisted of representatives from Cambodia, Indonesia, Malaysia, Philippines, and Thailand.

ERIA also designed the reporting template for each selected researcher to write for respective DES's situation and analysis of their countries (See Designed Questionnaire for Distributed Energy System, p. 5).

Scope of the Study

The regional and country reports
- highlight the merits of DES of each country studied;
- classify several patterns in the country case study (site survey) such as industry zone and off grid (islands) and study the economy of DES, energy security brought by DES, reduction of carbon dioxide (CO2) by DES, and cost–benefit analysis of grid and off-grid systems; and
- elucidate the feasibility of installing DES in ASEAN.

Designed Questionnaire for Distributed Energy System

Definition of DES: this study also considers the installed capacity of distributed generations by type of fuels as follows:

- *Solar farm, solar PV, small hydro refer to the development of solar and hydroelectric power on a scale serving a small community or industrial plant. The definition of a solar farm and a small hydro project varies, but a generating capacity of 1 to 10 megawatts (MW) is generally acceptable, which aligns to the concept of distributed generation.*

- *However, the small and mini thermal power plants are generally in the form of small and very small power producers (SPPs and VSPPs) in ASEAN countries. Generally, coal, gas, nuclear, geothermal, solar thermal electric, waste incineration plants, and biomass-fuelled thermal power plants, are DESs if they have capacities of less than 100 MW.*

1. Country Name:
2. Energy access/Electrification rate: % (percent) Year: (year of the data)
3. Current average off-grid/mini-grid electricity tariff: cent/kWh
4. What kind of distributed energy system (off-grid energy system)?

Applications	Current/existing capacity		Required capacity to meet off-grid/mini grid future demand (2025, 2040)		Comments
	MW	MWh	MW	MWh	
Solar PV					
Wind					
Biomass/biogas					
Micro hydro					
Geothermal					
Diesel generator					
Thermal power (coal, slurry, fuel oil, others)					
CHP incl. heat recovery facility					
Other generators					

5. Model case(s) of introduction of distributed energy system (off-grid/mini grid energy system)

(1) Site Name:

Applications	Current/existing capacity		Required capacity to meet off-grid/mini grid future demand (2025, 2040)		Comments
	MW	MWh	MW	MWh	
Solar PV					
Wind					
Biomass/biogas					
Micro hydro					
Geothermal					
Diesel generator					
Thermal power (coal, slurry, fuel oil, others)					
CHP incl. heat recovery facility					
Other generators					

(2) Site Name:

Applications	Current/existing capacity		Required capacity to meet off-grid/mini grid future demand (2025, 2040)		Comments
	MW	MWh	MW	MWh	
Solar PV					
Wind					
Biomass/biogas					
Micro hydro					
Geothermal					
Diesel generator					
Thermal power (coal, slurry, fuel oil, others)					
CHP incl. heat recovery facility					
Other generators					

6. What kind of distributed energy system (Industrial Zone)?

Applications	Current/existing capacity		Required capacity to meet off-grid/mini grid future demand (2025, 2040)		Comments
	MW	MWh	MW	MWh	
Solar PV					
Wind					
Biomass/biogas					
Micro hydro					
Geothermal					
Diesel generator					
Thermal power (coal, slurry, fuel oil, others)					
CHP incl. heat recovery facility					
Other generators					

7. Model case(s) of introduction of distributed energy system (Industrial Zone)
(1) Site Name:

Applications	Current/existing capacity		Required capacity to meet off-grid/mini grid future demand (2025, 2040)		Comments
	MW	MWh	MW	MWh	
Solar PV					
Wind					
Biomass/biogas					
Micro hydro					
Geothermal					
Diesel generator					
Thermal power (coal, slurry, fuel oil, others)					
CHP incl. heat recovery facility					
Other generators					

(2) Site Name:

Applications	Current/existing capacity		Required capacity to meet off-grid/mini grid future demand (2025, 2040)		Comments
	MW	MWh	MW	MWh	
Solar PV					
Wind					
Biomass/biogas					
Micro hydro					
Geothermal					
Diesel generator					
Thermal power (coal, slurry, fuel oil, others)					
CHP incl. heat recovery facility					
Other generators					

8. Current policy to promote distributed energy system (i.e. renewable and Very Small Power Producers Programme)

(1) Financial support

Policies	Feed-in-Tariff	Government Rebate System/ capital cost subsidy (*)	Other subsidy, if any	Comments
	US$ cent/kWh	US$/kW	US$/ kW	
Solar PV				
Wind				
Biomass/biogas				
Micro hydro				
Geothermal				
Diesel generator				
Thermal power (coal, slurry, fuel oil, others)				
CHP incl. heat recovery facility				
Other generators				

- Government rebate system (for solar and other renewable energy sources) through credit rebate, meaning 'upfront discount', could potentially reduce the upfront-system cost.

(2) Government-led project (i.e. demonstration project)
Project Name:
Outline of project:

9. Technology applications by location and purpose (just tick/check)

Policies	Locations of Application					Purposes of use			
	Isolated village	Island	Mountain	Industrial zone	Unban/ city	Residential use	Commercial use	Industrial use	Others
Solar PV									
Wind									
Biomass/ biogas									
Micro hydro									
Geothermal									
Diesel generator									
Thermal power (coal, slurry, fuel oil, others)									
CHP incl. heat recov-ery facility									
Other generators									

Chapter 2
The Potential of Distributed Energy System from Renewable Energy in ASEAN

Introduction

The Distributed Energy System (DES) is a decentralised power system where electric power is produced and consumed locally at or near the point of use. DES involves the distributed power technologies, which can be stationary (typical of electrical applications) or mobile (as in marine and locomotive applications). There is no universal consensus on or standard definition of DES. DESs stand 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.

This is a study on the overall status and policies of DESs in selected ASEAN countries. It uses literature surveys and information exchange through meetings with relevant parties, such as the ASEAN Renewable Energy Sub-Sector Network, Energy Research Institute Network, Japan–ASEAN Capacity Building Programme, and other conferences. The study focuses on the following key questions:

- status of introduction of DESs, including what kind of DESs have been introduced, and
- how much energy they have supplied;

• Existing policies to promote introduction of the systems, such as

- strategies, master plans, and roadmaps;
- incentives/subsidies for renewable energy through the introduction of various policy instruments;
- government-led model projects; and
- small-power producers (SPPs) programmes;

- Analysis of the outcomes of the policies:
    - What kind of DESs the policies have promoted;
    - How much energy they have supplied; and
    - What kind of impacts the introduction has had on stable energy supply, electricity tariff, environment, etc. in the country communities.

The study team developed questionnaires to address the above hypotheses. This is critical in understanding the status, policies, and potentials of DES in the ASEAN region. Since DES information in each ASEAN country is difficult to obtain, this study also relies on various information from the power development plan or any energy master plan of countries. Using the current data from the Energy Outlook and Energy Saving Potential in the EAS region, the study estimated the generation output of DES-related energy sources in ASEAN, particularly the renewable sources such as solar, wind, biomass, hydropower, and geothermal.

Key Drivers of Distributed Energy System

Energy access

The ASEAN region has seen spectacular growth over the past 2 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 countries still lack access to electricity and therefore have yet to enjoy the health, social, and economic benefits (ACE, 2013). As the ASEAN Community declared in end 2015, the lack of power and energy access could threaten the region's economic growth and economic transition. Energy is largely linked with economic opportunities. The expansion of energy infrastructure projects is slow, and affects the potential of industrial development and growth. In ASEAN countries, small and very small power producers (SPPs and VSSPs) are playing a significant role in supply electricity gap and in meeting growing electricity demand. However, economic zones are also increasing to promote economic growth in ASEAN Member States. As often, the electricity supply in the economic zones are in the form of DES as auto-electricity producers. In some cases, the auto-producers also supply surplus electricity to the grid or nearby area. In rural areas of developing countries, schools and clinics operate with zero or little power. Therefore, DES has been recognised as a decentralised electricity system to meet end-use demand more effectively, and to serve areas where grid expansion is not economically viable. This situation is observed in Cambodia, Lao PDR, Myanmar, and some remote islands of Indonesia.

Table 2.1 shows electricity access in the ASEAN region. It also informs the progress of electricity access in urban and rural areas from 1990 to 2012, and only aggregate at the national level in 2016. While tremendous progress of 100% energy access has been observed in Australia, China, Japan, Republic of Korea, Malaysia, New Zealand, Singapore, Thailand, and Viet Nam, some countries in Southeast Asia have struggled to improve energy access of their population.

The rural areas of Cambodia and Myanmar still have very low access to electricity (Table 2.1). Only 31.1% of Cambodia's population and 32% of Myanmar's have access to electricity. While this rate is higher for major cities, large parts of rural Cambodia and Myanmar have very low or no electricity at all. India also harbours a large population without access to electricity.

Increasing energy access requires investment in infrastructure for grid expansion and off-grid electricity system. For both on-grid and off-grid systems, DES can be well used depending on the context and the development of the energy market in the country and the region.

Increasing energy demand

The key drivers of energy consumption in the EAS region are population, gross domestic product (GDP), growth of the transport sector as result of improved per capita GDP, and policies affecting the universal coverage of electricity access. The predicted primary energy supply and final energy demand almost doubled from 2013 to 2040 (Figures 2.1 and 2.2).

Increase of final energy consumption. 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% and 4.1% per year, respectively, because of industry expansion and motorisation driven by increasing disposable incomes in ASEAN Member States. The demand of commercial and residential ('Others') sector will grow 2.5% per year. Figure 2.1 shows final energy consumption by sector under the business-as-usual (BAU) scenario in ASEAN in 2013–2040.

Increase of primary energy supply. The above drivers have influenced the increase of estimated energy supply to meet final energy consumption by 2040. The ASEAN primary energy supply – the total primary energy supply of all energy sources – is projected to increase from 592 Mtoe in 2013 to 1,697 Mtoe in 2040 (Figure 2.2).

Table 2.1. Access to Electricity, 1990–2016

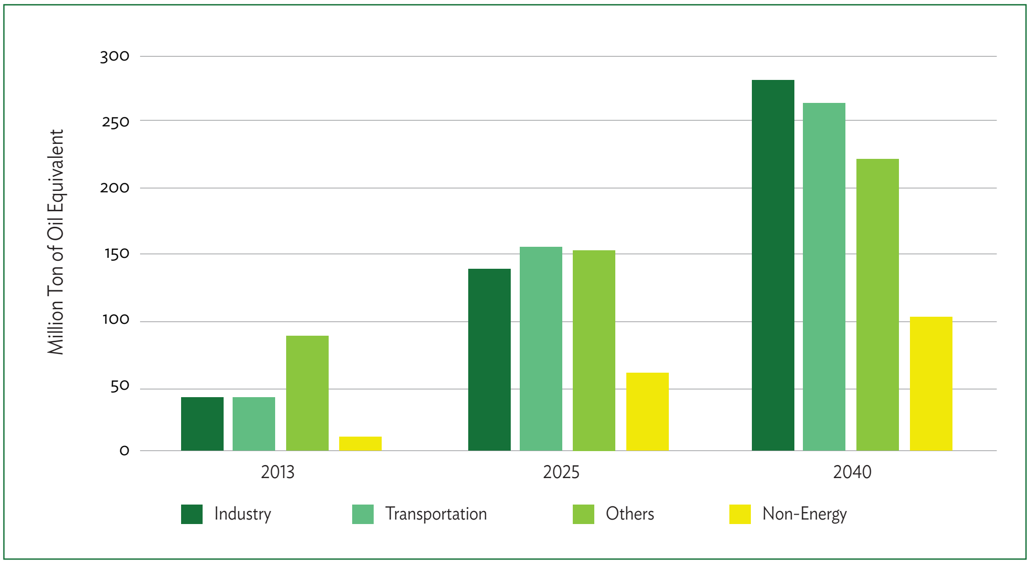
	1990			2000			2012			2016
	Rural	Urban	National	Rural	Urban	National	Rural	Urban	National	National
Cambodia	5.0	36.6	19.2	9.0	49.9	16.6	18.8	91.3	31.1	49.8
Myanmar	.	.	.	.	.	.	.	.	32*	57
Lao PDR	39.7	100.0	51.5	40.0	68.7	46.3	54.8	97.9	70	87.1
Brunei Darussalam	56.4	70.5	65.7	61.2	72.7	69.4	67.1	79.0	76.2	100
India	38.7	86.5	50.9	48.4	98.6	62.3	69.7	98.2	78.7	84.5
Indonesia	.	.	66.9	.	.	.	.	.	74**	97.6
Viet Nam	84.5	100	87.9	86.6	96.9	89.1	97.7	100.0	99	100
Philippines	46.4	85.5	65.4	51.9	92.3	71.3	81.5	93.7	87.5	91
Malaysia	89.2	97.3	93.2	93.0	98.5	96.4	100	100	100	100
Singapore	99	100	100	99	100	100	99	100	100	100
Thailand	82	75.2	80	87.0	72.6	82.5	99.8	100	100	100

*The number was taken from the presentation of Khin Seint Wint (2014), Renewable Energy Association of Myanmar.

**The number was taken from ASEAN Guideline on Off-grid Rural Electrification Approaches (ACE, 2013).

Source: World Bank (2018).

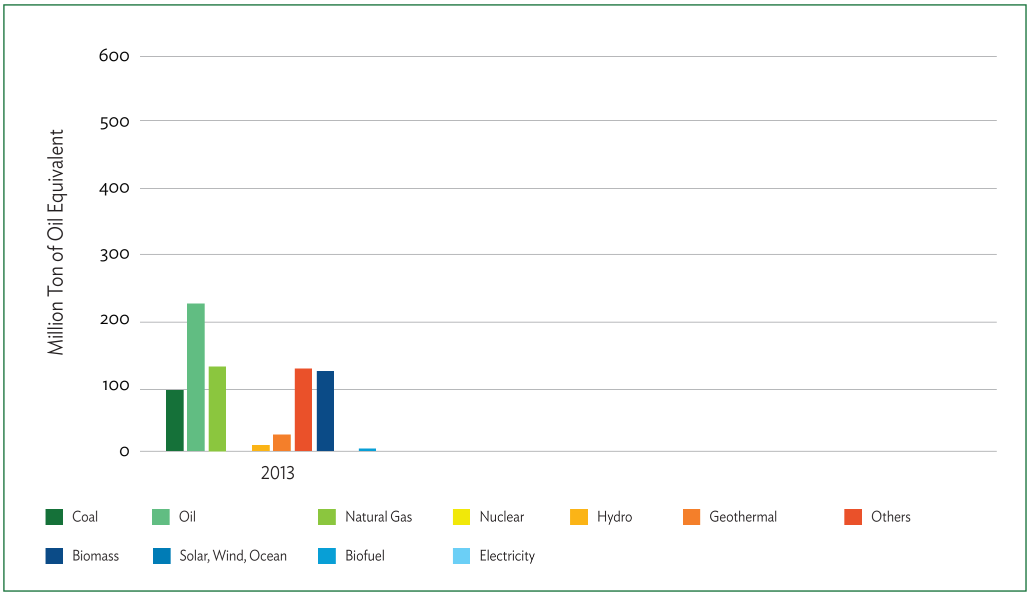
Figure 2.1. ASEAN's Final Energy Demand by Sector (2013 to 2040), BAU



BAU = business as usual scenario.

Source: Author's calculation.

Figure 2.2. ASEAN's Primary Energy Suppl by Energy Sources (2013 to 2040), BAU



BAU = business as usual scenario.

Source: Author's calculation.

Oil continues to have the largest share of primary energy supply but its share is forecast to drop to 34.5% in 2040 from 36.6% in 2013. Coal is predicted to have the fastest growth rate at 5.7% per year in 2013–2040, and its share will increase from 16% to 25% during the same period. Coal will be the second-largest share after oil. Natural gas is predicted to grow at 4.4% per year in 2013–2040. Its share will increase from 21.5% to 23.8% during the same period. Hydropower, geothermal, wind, and solar energy will see some increase of their share as well, although small.

Amongst the fossil sources of energy, natural gas is projected to see the fastest growth in 2013–2040, increasing at an annual average rate of 3.7%. Its share in the total will consequently increase from 9.1% (equivalent to 499 Mtoe) in 2013 to 12.7% (equivalent to 1,339 Mtoe) in 2035. Nuclear energy is also projected to increase at a rapid rate of 6.4% per year on average and its share is forecast to increase from 1.5% in 2013 to 4.3% 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.

Estimates of Energy Supply, Needed Investment, and CO2 Emission Reduction from the Application of DES

Estimates of energy supply from DES Application. DES uses renewable energy sources such as biomass, wind power, small hydro, solar power, biogas, geothermal power, and other thermal plants with small capacity. However, DES estimates here are only for renewable energy sources. DES plays an important role in the electric power distribution system. The shift in preference towards green energy is one major factor that encourages the demand for DESs across the globe. Moreover, the opportunity in developing nations and development of eco-friendly DESs are the key opportunities for the growth of the market.

The global DES market is categorised into off-grid and on-grid segments. The DES market is estimated to increase because of the adoption of financial incentive schemes worldwide to promote clean energy as emphasised in COP21 (Conference of the Parties) and Nationally Determined Contributions (NDC) commitments. DES is also predicted to significantly increase in the ASEAN region to meet energy demand (Table 2.2). All ASEAN countries are expected to have increased solar, wind, and biomass from 26,927 GWh (BAU case) to 44,731 GWh (APS case) by 2040. Hydropower and geothermal outputs are also expected to increase in countries with resource potential.

Table 2.2. Estimates of Off-grid DES Generation Output (MWh) in ASEAN (solar, wind, biomass, hydro and geothermal)

EAS Region	BAU vs APS	Generation output (GWh) 2013			Generation output (GWh) 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	1921	1033	738	3,028
	APS				1952	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**

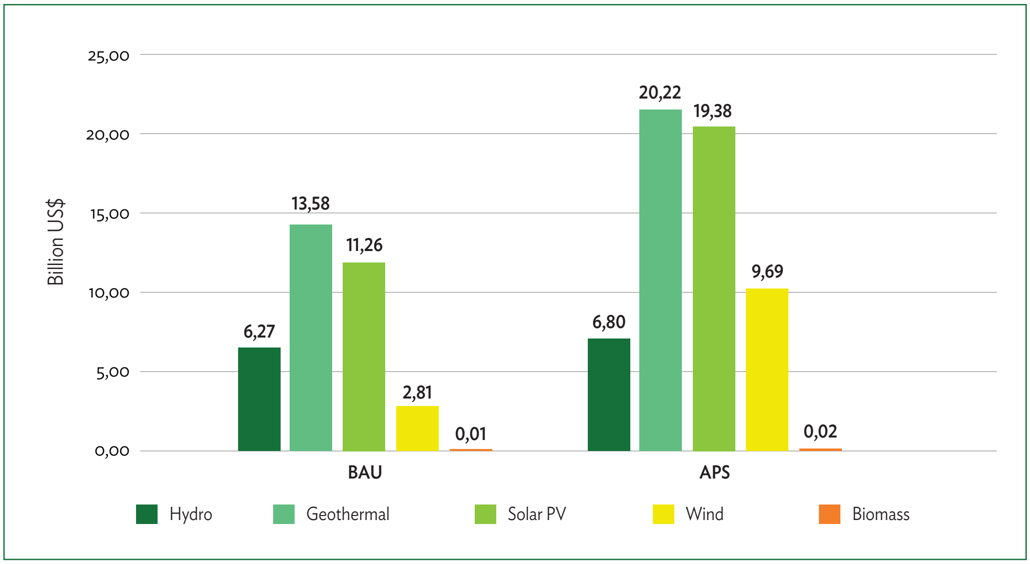
DES = Distributed Energy System; ASEAN = Association of Southeast Asian Nations; MWh = megawatt-hour, APS = alternative policy scenario, BAU = business-as-usual scenario, GWh = gigawatt-hour.

Note: Various assumptions were made to calculate the future potential off-grid for solar, wind, biomass, hydro, and geothermal energy.

Source: Authors' calculation.

Estimates of needed investment from application of DES. The increase in DES energy supply in the ASEAN region also implies the opportunities for DES-related renewable investment (Figure 2.3). The figure shows that investment opportunities by 2040 in BAU for combined solar, wind, biomass, hydropower, and geothermal are about US$34 billion, and in the APS, about US$56 billion. Investments for solar and geothermal power are expected to double from BAU to APS. For wind power, investments will increase more than threefold to meet the expected generation output by 2040.

Figure 2.3. Estimates of Off-grid DES-Related Renewable Investment Opportunities by 2040



APS = alternative policy scenario, BAU = business-as-usual scenario.

Note: Various assumptions were made to calculate the estimated DES-related renewable investment opportunity.

Source: Authors' calculation.

Table 2.3. Estimates of CO_2 Emission Reduction from Off-grid Application of DES (MWh) in ASEAN (solar, wind, biomass, hydro, and geothermal)

	Generation Output (GWh) 2040				CO_2 Emission Reduction *(Million Metric Ton)
	Solar, wind, biomass	Hydropower	Geothermal	Total	
BAU	26,927	20,008	18,673	65,608	46.1
APS	44,731	21,182	25,941	91,854	64.6

DES = Distributed Energy System; MWh = megawatt-hour, APS = alternative policy scenario, BAU = business-as-usual scenario. GWh = gigawatt-hour.

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

Source: Authors' calculation.

Estimates of CO2 emission reduction from the application of DES. The increase in DES-related renewable energy supply in the ASEAN region will strongly reduce CO_2 emission in the region. Estimates show reduced CO_2 emission – of about 46.1 million metric tons in BAU, and 64.6 million metric tons in the APS – from the application of solar, wind, biomass, geothermal, and hydropower (Table 2.3). The method of calculating CO_2 emission reduction is referred to as the Greenhouse Gas Equivalencies; it uses the emission factor of 7.03×10^{-4} metric tons CO_2/kWh (EPA, 2016).

Potential System Cost of Generating Electricity and the Need for an Enabling Policy Framework to Promote DES in ASEAN

Potential system cost of generating electricity. The potential reduction of total system levelised 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 the LCOE from all renewable resources have high potential of lowering total system LCOE. The potential LCOE ranged from 4.1 cents/kWh to 5.1 cents/kWh for geothermal, 8.1–11.5 cents/kWh for biomass, 4.3–7.8 cents/kWh for wind, and 6.5–12.6 cents/kWh for solar PV. The LCOE of these renewable resources look competitive to their fossil fuel-generating plants (Table 2.4). However, these estimates of technology development are for technology entering the US market in 2022 (EIA, 2016).

Table 2.4. Estimates of System Levelized Cost of Electricity (LCOE) for Various Generation Plants Entering the Market 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

CC = , CCS = , PV = photovoltaic.
Source: EIA (2016).

The need for enabling policy framework to promote DES. Although DES is mainly a decentralised energy resources system, the policy framework promoting it is related to renewable energy policies, and it has always been 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 investment in DES and renewable energy. The enabling policy frameworks used so far are the following:

- **National policy design** aims to provide a trajectory for future energy mix. This includes renewable energy target; renewable energy law or strategy; biomass and biofuels law or programme; solar heating, solar power, wind, and geothermal law or programme.

- **Fiscal incentives** aim to reduce upfront costs by introducing fiscal policy instruments such as tax exemptions (value added, fuel, income, import and export, and local taxes); introduction of carbon tax; and accelerated depreciation.

- **Grid access** aims to give project developers confidence through grid access priority and transmission discount policy if the production of electricity is from renewables.

- **Regulatory instruments** provide incentives for investing in renewables through the implementation of energy policies such as feed-in tariff (FiT), feed-in premium, auction, net metering, and quota.

- **Finance** reduces risk for investors through the implementation of currency hedging, dedicated fund, eligible fund, or guarantees.

- Other policies aim to help and target energy access in remote areas through the promotion of renewable energy in social housing, rural access programmes, cookstove programmes, and other energy access activities by non-governmental organisations, and communities.

The above policy frameworks need 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. Various policy instruments are being promoted in ASEAN. At the regional level, ASEAN has targeted 23% share of the renewable energy in the primary energy supply by year 2025. ASEAN Member States also set up the renewable targets in each country and developed various instruments to promote renewable energy (Table 2.5).

Table 2.5. Renewable Target in ASEAN Member States

Country	Renewable 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

* large hydropower is excluded.

GW = gigawatt, NRE = non-renewable energy, RE = renewable energy.

Source: ACE (2016).

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

The case study of Thailand on the review of policies to promote DES provides a snapshot and stock-taking in terms of policy design in promoting DES and renewable energy. Other ASEAN countries may learn from this case study and develop their own policy to fit the political and social contexts.

Case study on enabling policy framework: Thailand's DES-related energy development planning

Thailand is the only country in Southeast Asia with 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 Development Plan (EEDP, 2011–2030). The new PDP 2015–2036 highlights energy security of power supply and transmission and distribution systems in response to the demand for electricity. It also seeks the best energy mix, avoiding too much reliance on gas as a source of power generation. The new PDP also aims to reduce CO2 emissions by promoting electricity production from renewable energy sources and to promote energy efficiency.

The Government of Thailand has continuously promoted private sector investment in the generation business through bid solicitations to buy power 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. This is done under the terms and regulations set by the Energy Regulatory Commission to ensure the best interests of public consumers, optimisation of energy resources, and fairness to all. For DES-related renewable energy, Thailand has set a 30% share of renewables in total final energy consumption by 2036 (AEDP 2015–2036). In absolute terms, renewable consumption is targeted at 39,388 Ktoe out of total final consumption of 131,000 Ktoe by 2036. Thailand has been introducing FiT to promote renewable energy by type of energy source (Table 2.6).

The Department of Alternative Energy Development and Efficiency (DEDE) of Thailand also developed the Energy Saving Company (ESCO) fund to cope with risk and to encourage investment in renewable-focused ventures. In addition, the fund pools capital was set up with contribution from Thailand's Energy Conservation and Promotion Fund and private investors. The ESCO fund aims to support access to low-cost equipment leasing. As of the time of writing, the ESCO fund has invested 6.1 billion baht (B) – 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).

Table 2.6. Feed-in-Tariff Rate by Type of Renewable Energy Source in Thailand

Capacity (MW)	FiT (THB/kWh)			Period of Subsidy (Year)	FiT Premium (THB/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

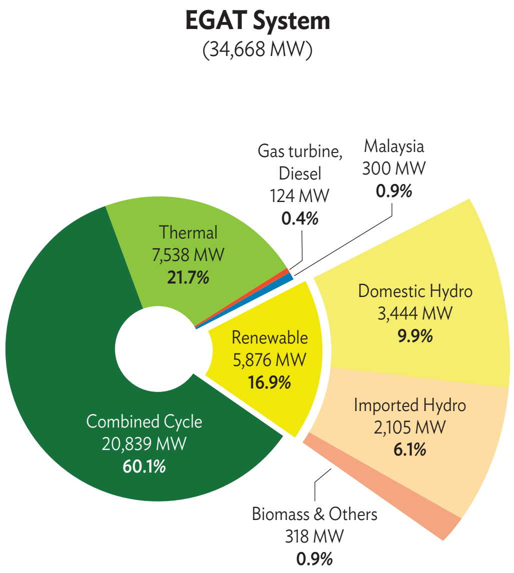
kW = kilowatt, kWh = kilowatt-hour, MSW = , MW = megawatt, THB = Thai Baht.

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.

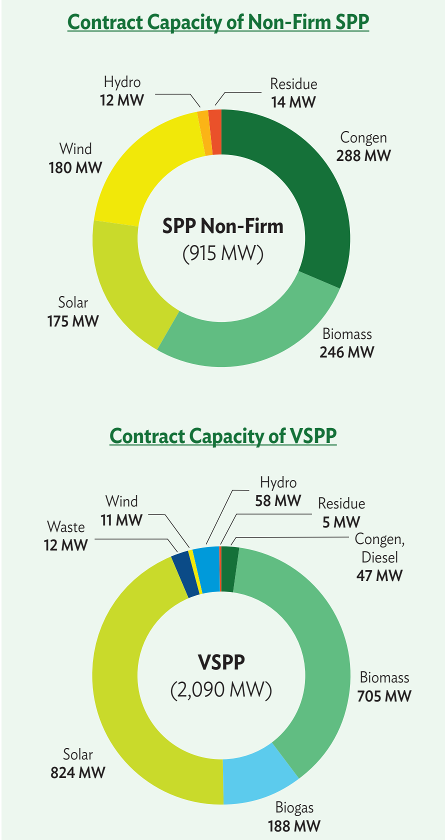
Source: Ministry of Energy (2016).

Most DES-related schemes in Thailand are in VSPPs. Thailand's VSPP regulations were approved by its government 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 government announced important changes in VSPP regulations that allow each generator to export up to 10 MW to the grid and offer FiT subsidies for renewable electricity production. The VSPP programme is now also open to efficient fossil-fuel combined heat and power (CHP). Currently, the share of DES or the combined VSPP and SPP to the generation mix is only about 5.4% (Figure 2.4 and Table 2.7).

Figure 2.4. 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)	2,209 MW



EGAT = Electricity Generating Authority of Thailand, MW = megawatt, RE = renewable energy, SPP = small power producer, VSPP = very small power producer.

Source: Ministry of Energy (2015).

Table 2.7. Installed Capacity by Type of Power Producer (as of 2014)

Types of Owner	Capacity (MW)	Share (%)
Electricity Generating Authority of Thailand (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**	**100.0**

MW = megawatt.
Source: Ministry of Energy, The Power Development Plan (PDP), 2015.

The future total capacity of VSPP power purchase to be online in 2015–2036 according to the AEDP would be 9,735.6 MW, increasing from 2,029 MW in 2014, with renewable power plants having a capacity of 9,701 MW, and cogeneration power plants, with a capacity of 34.6 MW. So, the increase of VSPPs in 2014–2036 was almost fourfold during this period.

The future installed capacity of 97 SPPs, which already have power purchasing agreements with EGAT to be online in 2015–2025, is 5,922 MW. So, the increase of SPPs from 2014 to 2025 is 30.7%. The details are as follows: (i) 41 projects of cogeneration power plants with a total capacity of 3,660 MW; (ii) 25 extension projects of cogeneration power plants with a total capacity of 424 MW; and (iii) 31 projects of renewable energy generation with a total capacity of 1,838 MW.

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

Case study on enabling policy framework: Myanmar's DES-related energy development planning

Myanmar is endowed with rich natural resources. Its renewable energy resources are sufficient to meet most daily energy needs if developed. However, about 70% of the population and 84% of rural households lacked grid electricity access in 2014 (World Bank, 2015). Off-grid schemes are rare and typically provide high-cost, low-reliability power service for a few hours per day. Myanmar is the largest country in mainland Southeast Asia but has one of the lowest population densities of the region. This imposes a diseconomy of scale for conventional centralised electricity grid development and expansion. Electrification varies widely between urban and rural areas. Although about 27% of the 64,346 villages are electrified, the national power grid covers only 7% of the total villages (Tin Ngwe, 2014). Considering the broad distribution of abundant renewable energy resources such as biomass, hydropower, solar, and wind, Myanmar can potentially accelerate on- and off-grid electrification with renewable energy, delivering universal electricity access much quicker than conventional centralised generation and grid expansion.

The Government's National Electrification Plan (NEP) 2015, developed with World Bank technical assistance, aims to electrify 7.2 million households and to achieve universal access to electricity by 2030. The plan calls for investments of US$5.8 billion over the next 15 years to extend the distribution grid and electrify off-grid areas. The government has also developed a complementary Energy Master Plan with the assistance of the Asian Development Bank and a Power Sector Master Plan (for generation and transmission sub-sectors) with the assistance of the Japan International Cooperation Agency.

Given decades of closed economy, the energy sector's institutional and regulatory frameworks have been fragmented, particularly in rural electrification. The Ministry of Energy is responsible for overall energy policy, while the Ministry of Electric Power leads power sector development. The rural off-grid electrification falls under the Department of Rural Development in the Ministry of Livestock, Fisheries and Rural Development. Myanmar has undertaken reform in all sectors, including the energy sector, after the 2015 national election. Major energy-related master plans in Myanmar include the following:

- NEP 2015 highlighted universal electricity access by 2030, or 7.2 million new connections. The plan uses a two-pronged approach: rapid extension of the national grid, coupled with off-grid electricity, including modern solar home systems and mini-grids. The first phase of the plan calls for 1.7 million households to be connected to electricity by 2020 and an investment of about US$700 million. The plan started off with $400 million in funds from the World Bank's International Development Association, out of which US$80 million would be used for off-grid electrification. Total grid investment is estimated at as much as US$ 6 billion.

- The Power Sector Master Plan 2013–2030 highlighted the strategies to ensure a sustainable, affordable, and secure supply of energy for Myanmar over the longer term. The plan also aims to develop a mix of energy sources to provide a stable and reliable energy supply through to 2030, in which coal-fired power generation would see its share increase from 2% in 2015 to 20% in 2030. By 2030, it targets the following primary energy mix: 33% biomass, 22% oil, 20% coal, 13% gas, 11% hydro, and 1% renewable energy. The plan estimates Myanmar's total energy sector needs to amount to US$30 billion–US$40 billion over the next 15 to 20 years,

Myanmar's electrification, following NEP (Tables 2.8 and 2.9), would cover almost 100% by 2030. This also implies that there would be huge installed generation capacity from different fuel-based generators not limited to coal, gas, and hydropower but small DESs such that renewable energy would play a significant role in covering electricity access. The off-grid renewable energy and DES generators are expected to have a share of 7%–10% in the generation mix.

Table 2.8. Power Generation Mix

Applications	Existing installed capacity (2013)	Future installed capacity (2030)
	MW	MW
Coal-fired Plant	120	5,030
Gas-fired Plant	115	2,484
Hydro Plant	2,780	19,037
Renewables	5	2,000-4,200*

Note: *Japan International Cooperation Agency predicts the increase of renewable energy installed capacity up to 2,000 MW by 2030. And ERIA's Energy Outlook and Saving Potential Study (2015) predicted the ambitious renewable energy installed capacity of up to 4,000 MW of wind power plant, and 200 MW installed capacity of solar power plant by 2035.
Source: JICA Electric Power Master Plan Study and EOSP (ERIA, 2015).

Table 2.9. National Electrification Rate and its future electrification plan in NEP 2015

	Reference: 2015	Plan: 2020	Plan: 2025	Plan: 2030	Comment
Households (HH) electricity rate	33%	47%	76%	100%	If 99% are electrified (source: WB, 2015)
Household (HH) connection to grid (cumulative)	3,630,000 (HH)	567,4939 (HH)	8,260,788 (HH)	11,000,000 (HH)	It needs at least a 500,000 HH connection every year
New HH connection required	N/A	2,044,939 (HH)	4,640,000 (HH)	7,220,000 (HH)	And doubling the connection rate is required

Source: NEP (2015) targets and Author's calculation based on NEP 2015.

Currently, about 7.2 million households have yet to connect to modern electricity sources. NEP 2015 mainly addresses this issue to cover the 100% electrification in Myanmar. NEP also recognises the need of DES for off-grid electricity. About half a million new connections will be needed every year to meet the full coverage of electricity. This is an enormous task and will require huge investment and coordination. Perhaps, it would be realistic if the plan mentions DES for not only the off-grid but its role in providing an effective energy system in Myanmar.

Myanmar's enabling policy framework

Direction of Energy Policy Development in Myanmar. Myanmar´s Energy Master Plan prepared by the National Energy Management Committee, assisted by the Asian Development Bank, considers renewable energy (solar, hydro, wind, and biomass electricity generation) for both grid connection and off-grid applications (Table 2.10). In the draft document of the Myanmar Renewable Energy Policy (EMP, 2014), an indicative assessment of the anticipated share and volume of the various renewable energy technologies to electricity generation leads to the following distribution towards the year 2030. The overall renewable energy contribution to the newly installed generation capacity (without large hydro) will then be 26.8% or 3,995 MW compared to a total capacity of 14.9 GW.

Table 2.10. Myanmar's Renewable Energy Policy and Targets

Renewable Sources	Installed Capacity by 2035
Hydro Power off-grid	198 MW
Wind Power grid connected	446 MW
Solar Power grid connected	2,658 MW
Solar Power off-grid	544 MW
Biomass grid connected	147 MW
Biogas gasification off-grid	3 MW
Total	**3,995 MW**

Source: National Energy Management Committee (NEMC), 2014.

The draft Myanmar renewable energy policy and the proposed policy directions to support DES:

- Very small power producer (VSPP): For installations up to 50 kW erected by owners on their legal premises. All electricity produced and not used for own consumption or that of neighbours can be freely fed to the grid. The responsible grid operator should issue a permit within 2 months from application, if applicable standard generation equipment is demonstrated. Connection by the grid operator should be completed within 1 month from the 'ready for commissioning' notice by the owner. Investment for the generator shall be tax deductible.

- Small power producer (SPP): For installations from 50 kW up to 1,000 kW erected by owners on their legal premises. All electricity produced and not used for own consumption or that of neighbours shall be metered and purchased by the responsible grid operator, who should issue a permit within 3 months from application, if applicable standard of the generation equipment is demonstrated. Connection by the grid operator will be completed within 1 month from the owner's notice that it is ready for commissioning. Generators of this size could affect grid performance. The Government of Myanmar would take a liberal view on these installations as long as these are below 10% of the national generation. However, it may impose regulations for power management and power purchase. Applicable standards of the generation equipment, therefore, include an adjustable power factor and a facility for remote power management (gradual shutdown) by the grid operator. The power purchase agreement will compensate for losses caused by such shutdown. Renewable energy–based generation shall be preferred to conventional generation.

- Independent power producer (IPP): For installations from 1 MW up erected by owners on their legal premises, the electricity produced and not used for own consumption or that of neighbours shall be metered and purchased by the responsible grid operator, who should issue a permit within 3 months from application, if applicable standards of the generation equipment are demonstrated. The generation equipment needs to have adjustable power factor and power management facility. The power purchase agreement will be negotiated by the Government of Myanmar based on tendering a concession, where the bidder with lowest FiT shall be preferred. The government will tender for concessions of 200 MW annually to be installed in different parts of the country to benefit from the favourable effects of distributed generation.

- Power purchase by application of a FiT shall be valid for 20 years from the date of first connection. With due notice, the government reserves the right to adjust the tariff for additional generators to account for lower costs and efficiency gains. Likewise, tariff bonus can be granted for feed-in at peak hours. Tariff shall never be reduced retroactively. FiT shall be determined in consideration of the real generation cost and in recognition of the macro-economic effect on electricity prices. Tariff shall encourage self-consumption. For the benefit of planning, a uniform tariff of 150K/kWh shall be proposed. Variations may be established for generators of different size and technology. The government published FiT for the next period in due time, beginning in 2014. The RET owner shall bear the cost of connection and lines to the next suitable connection point if so required.

- To facilitate long-term financing for renewable energy investments, a financing window at development banks shall be made available. Generation equipment may be considered as collateral with its marketable value. The Government of Myanmar shall provide a financing volume at interest reflecting government rates. Taxing of income from private renewable energy generation shall be equal to the taxing of public generation.

- Off-grid renewable energy applications find their dominant use in rural electrification. While the government considers countrywide grid electrification the goal, it will strongly encourage renewable energy solutions to achieve rural electrification targets as swiftly and efficiently as possible. These solutions shall include local power generation from hydro energy, solar radiation, and biomass, depending on the economic and operational preferences. Both the public and the private sectors shall be entrusted with the implementation in the form of energy service providers and they will cooperate in planning and operation. The cost shall be borne jointly by the Government of Myanmar and the users. Knowing the important role of Myanmar communities in rural electrification, the government will enable villages to sustainably operate and maintain energy systems. To lessen the burden for rural citizens, the government shall apply the tool of a connection premium to public and private developers.

- The government shall publish an off-grid electrification support regulation, describing duties and eligibilities of energy service providers and consumers, procedures, and standards applicable as well as funding and time frame available.

- New electricity connections in clusters of at least 20 households shall be built, operated, and maintained for the long term by operators, who may be village committees or private entrepreneurs. Operators will seek to connect a maximum number of households for best efficiency but are free to determine connection priority. Renewable energy installations providing at least 200 Wh daily all year round shall be eligible for a connection premium of K150,000 per newly connected household. For the remaining cost, each newly connected household shall contribute in lump or loan. Operation and maintenance (O&M) shall be organised at the village level and a sufficient O&M fee shall be collected from users.

- The government is aware that currently numerous rural generation systems exist for which the upgrading, repair, or conversion into hybrid generation using renewable energy technology will be the least cost alternative. For these the same connection premium of K150,000 per newly connected household providing at least 200 Wh/d from renewable energy all days all year shall apply.

- In case the national grid will eventually be connected, the continued operation of the renewable energy supply system as a valuable and reliable resource shall be assured. The system operator shall ensure that the existing system will not interfere with grid standards like voltage and frequency, shall act as retailer of the grid electricity, and shall retain the operation and maintenance fees applied before connection.

Chapter 3
Distributed Energy System in Indonesia

Introduction

Indonesia experienced a high energy growth of about 5% in the last couple of years due to industrialisation and population growth. This growth varies in different regions, but provinces outside Java – Sumatera, Kalimantan, and Sulawesi – are experiencing higher growth. These regions have diverse energy sources in terms of quality and quantity for both fossil and renewable types of primary energy.

In 2016, total installed capacity in Indonesia was 59,656 MW, 41% of which was powered by state-owned company PT PLN, and the remainder by independent power producers (IPPs) (13,781 MW); PPU (2,434 MW); and IO non-oil (2,392 MW). Electrification ratio is 92% and consumption is 956 KWh/capita. Indonesia has set a target of 2,500 kWh/capita by 2025 (RUEN); 2,764 kWh/capita (RUKN); and 3,347 kWh by 2034 (RUKN). Almost all installed capacity is on grid, whether in large or smaller system; however, some small portion of scale off-grid renewable energy is also included in the calculation.

Given the nature of Indonesia's geography, distributed on- and off-grid electricity system is promoted through a series of policies, including the development of small-scale renewable energy, especially micro hydro and solar photovoltaic (PV). The private sector can develop its own integrated generation and distribution activities in remote areas using renewable energy, which may or may not be subsidised.

Methodology

Questionnaires

- Using questionnaires (Chapter 1), the type of distributed energy system (DES) is categorised based on energy sources: geothermal, hydro/micro hydro, solar PV, biomass, coal, diesel, and gas. The data fields are current/existing capacity and required capacity to meet off-grid/mini grid future demand by 2025.

Estimation method of future DES capacity

- Terminology and categorisation of DES is based on the definition by the Economic Research Institute for ASEAN and East Asia (ERIA).
- DES is any type of power plant with an installed capacity of less than 100 MW either on grid or off grid. It is a decentralised power system producing electric power that is consumed locally at or near the point of use.
- Off-grid DES is a stand-alone generation without national grid connection. Off-grid DES includes stand-alone micro-grid and off-grid generators.
- This study considers the installed capacity of DES by type of fuel, as follows:
  - Solar PV, small hydro of installed capacity 0–50 MW;
  - Coal, gas, geothermal, solar thermal, electric, waste incineration plants, and biomass-fuelled thermal power plants, of installed capacity less than 100 MW.
- Current data about DES condition comes from the Ministry of Energy and Mineral Resources (MEMR) and PLN. The data is processed based on the regional distribution and type of power plant. The projection of future DES capacity comes from several long-term planning documents including the Electricity Power Supply Business Plan (RUPTL) prepared by state-owned company PLN approved by the MEMR, RUEN (prepared by the government and approved by the National Energy Council), and RUKN (prepared and published by the MEMR).
- Estimation of DES (total on grid and off grid)
  Estimation is based on the definition of DES
  - Solar PV, small hydro of installed capacity 0–50 MW;
  - Coal, gas, geothermal, solar thermal electric, waste incineration plants, and biomass-fuelled thermal power plants, of installed capacity less than 100 MW
- Estimation of DES (total on grid and off grid) using RUPTL, RUEN, and RUKN.

Current Situation of Distributed Energy System

Current installed capacity by type of energy source

Geothermal

- Geothermal resources

Geothermal resources in Indonesia are estimated at 29,000 MW. However, the development of this capacity is far from optimum with only around 5% of total resources. In 2016, Total installed capacity of geothermal power plant was 1,643.50 MW or up by 14% compared to 2015. Most of the power plants are in Java. Based on the National Energy General Plan (MEMR, 2017), the capacity of geothermal power plant is targeted to reach 7,241 MW equivalent, around 16% of the total 23% renewable energy target in 2025. Table 3.1 shows the potential of geothermal resources.

Table 3.1. Geothermal Sources in Indonesia

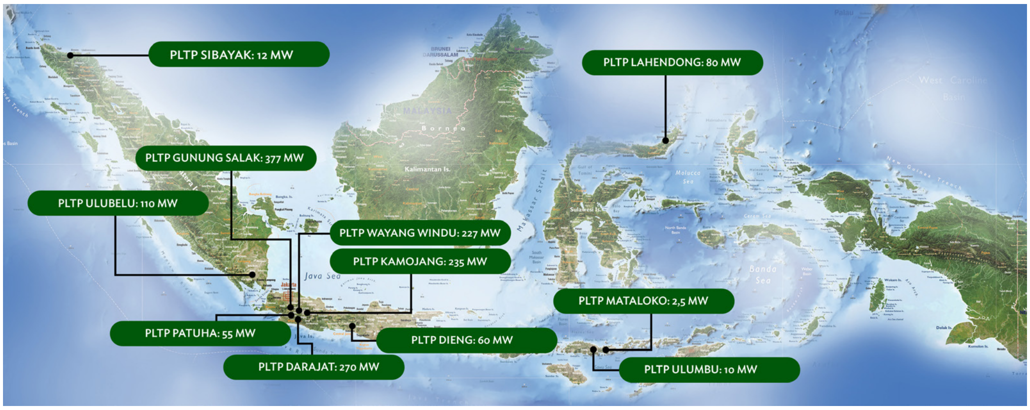
No	Province	Resources			Reserves			
		Speculative	Hypothetical	Total	Possible	Probable	Proven	Total
1	West Java	1225	934	2159	1687	543	1535	3765
2	North Sumatera	300	134	434	1996		320	2316
3	Lampung	600	643	1243	1319		20	1339
4	South Sumatera	273	645	918	964			964
5	Central Java	130	387	517	949	115	280	1344
6	West Sumatera	532	269	801	1035			1035
7	NTT	226	403	629	748		15	763
8	East Java	105	257	362	1012			1012
9	Bengkulu	357	223	580	780			780
10	Aceh	640	340	980	332			332
11	Jambi	348	74	422	566	15	40	621
12	North Sulawesi	55	73	128	540	150	78	768
13	North Maluku	190	7	197	580			580
14	Central Sulawesi	349	36	385	368			368
15	Maluku	370	84	454	220			220
16	Banten	100	161	261	365			365
17	West Sulawesi	316	53	369	162			162
18	South Sulawesi	172	120	292	163			163
19	Bali	70	22	92	262			262
20	Southeast Sulawesi	200	25	225	98			98
21	Gorontalo	129	11	140	110			110
22	NTB	0	6	6	169			169
23	Bangka Belitung	100	6	106	0			0
24	West Papua	75	0	75	0			0
25	West Kalimantan	65	0	65	0			0

26	South Kalimantan	50	0	50	0			0
27	North Kalimantan	20	30	50	0			0
28	Riau	41	0	41	0			0
29	East Kalimantan	18	0	18	0			0
30	Yogyakarta	0	0	0	10			10
	Total	**7056**	**4943**	**11999**	**14435**	**823**	**2288**	**17546**

NTB = West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB), NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: Statistics of New Renewable Energy and Energy Conservation, 2016.

Table 3.2 and Figure 3.1 show the location of current geothermal power plants.

Figure 3.1. Regional Distribution of Geothermal Power Plants



Source: Statistics of New Renewable Energy and Energy Conservation (2016).

- Current/existing capacity

Most geothermal power plants comprise several units, with an installed capacity of 5–100 MW, so many of them can be classified as DES (Table 3.3).

Indonesia has huge potential for hydropower generation. Besides promotinwg large hydropower, the government also encourages the private sector to develop mini and micro-hydro power plants. Small-scale micro-hydro power plant uses run-off river and can fulfil the demand of remote communities. The total potential of large, mini-, and micro-hydro power plants is about 75,000 MW, but only 6.4% produces electricity. Table 3.4 shows the potential for hydropower development across the country.

Table 3.2. Existing Geothermal Power Plants in Indonesia

Province	Region System	Capacity (MW)										
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
West Java	G. Salak	375	375	375	375	375	377	377	377	377	377	376.8
West Java	Darajat	145	255	255	255	255	270	270	270	270	270	270
West Java	W. Windu	110	110	110	227	227	227	227	227	227	227	227
West Java	Kamojang	140	140	200	200	200	200	200	200	200	235	235
North Sulawesi	Lahendong	20	40	40	60	60	80	80	80	80	80	120
Central Java	Dieng	60	60	60	60	60	60	60	60	60	60	60
North Sumatera	Sibayak	2	2	12	12	12	12	12	12	12	12	12
NTT	Ulumbu	0	0	0	0	0	0	0	5	10	10	10
NTT	Mataloko	0	0	0	0	0	0	0	2.5	2.5	2.5	2.5
West Java	Patuha	0	0	0	0	0	0	0	0	55	55	55
North Sumatera	Sarulla	0	0	0	0	0	0	0	0	0	0	110
Lampung	Ulubelu	0	0	0	0	0	0	110	110	110	110	220
Total		**852.0**	**982.0**	**1052.0**	**1189.0**	**1189.0**	**1226.0**	**1336.0**	**1343.5**	**1403.5**	**1438.5**	**1698.3**

Source: Directorate General of New Renewable Energy and Energy Conservation, 2017.

Table 3.3. Geothermal Power Plants with Installed Capacity of Less than 100 MW per Unit

No.	Province	PLTP	Turbine Capacity	Capacity each unit (MW)	Total Capacity (MW)
1	Sibayak – Sinabung North Sumatera	Sibayak	(monobloc	2	12
			1 x 5 MW	5	
			1 X 5 MW	5	
2	Cibeureum – Parabakti, West Java	Salak	1 x 60 MW	60	376.8
			1 x 60 MW	60	
			1 x 60 MW	60	
			1 x 65.6 MW	65.6	
			1 x 65.6 MW	65.6	
			1 x 65.6 MW	65.6	
3	Pangalengan, West Java	Patuha	1 x 55 MW	55	55
		Kamojang	1 x30 MW	30	235
			1 x 55 MW	55	
			1 X 55 MW	55	
			1 x 60 MW	60	
			1 x 35 MW	35	
		Darajat	1 x 55 MW	55	149
			1 x 94 MW	94	
4	Dataran Tinggi Dieng, Central Java	Dieng	1 x 60 MW	60	60
5	Lahendong – Tompaso, North Sulawesi	Lahendong	1 x 20 MW	20	120
			1 x 20 MW	20	
			1 x 20 MW	20	
			1 x 20 MW	20	
			1 x 20 MW	20	
			1 x 20 MW	20	
6	Waypanas – Lampung	Ulubelu	1 x 55 MW	55	220
			1 x 55 MW	55	
			1 x 55 MW	55	
			1 x 55 MW	55	
7	Ulumbu - NTT	Ulumbu	1 x 2.5 MW	2.5	10
			1 x 2.5 MW	2.5	
			1 x 2.5 MW	2.5	
			1 x 2.5 MW	2.5	
8	Mataloko - NTT	Mataloko	1 x 2.5 MW	2.5	2.5
	Total				**1240.3**

MW = megawatt, NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT), PLTP = Indonesia Power, monobloc = type of turbine rotor construction.
Source: Statistics of New Renewable Energy and Energy Conservation, 2016.

Hydropower

- Hydropower resources

Indonesia has huge potential for hydropower generation. Besides promoting large hydropower, the government also encourages the private sector to develop mini and micro-hydro power plants. Small-scale micro-hydro power plant uses run-off river and can fulfil the demand of remote communities. The total potential of large, mini-, and micro-hydro power plants is about 75,000 MW, but only 6.4% produces electricity. Table 3.4 shows the potential for hydropower development across the country.

Table 3.4. Hydropower Source in Indonesia

No.	Province	Potential (MW)
1	Papua	22,371
2	Kalsel, Kalteng, Kaltim	16,844
3	Sulsel, Sultra	6,340
4	Aceh	5,062
5	West Kalimantan	4,737
6	Sulut, Sulteng	3,967
7	North Sumatera	3,808
8	West Sumatera, Riau	3,607
9	Sumsel, Bengkulu, Jambi, Lampung	3,102
10	West Java	2,861
11	Central Java	813
12	Bali, NTB, NTT	624
13	East Java	525
14	Maluku	430
	Total	**75,091**

MW = megawatt, NTB = West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB),
NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: National Energy General Plan (RUEN) (2017).

- Current/existing capacity

Table 3.5 illustrates some of the existing hydro power plants with capacity less than 100 MW per unit.

Table 3.5. Hydro Power Plants with Installed Capacity of Less than 100 MW per Unit

No.	Power Plant	Province	Region Power System	Installed capacity (MW)
1	PLTMH	Aceh	Tersebar Aceh	2.62
2	PLTMH	North Sumatera	Tersebar Sumut	7.5
3	PLTA	North Sumatera	Sipan	50
4	PLTA	North Sumatera	Renun	82
5	PLTA	West Sumatera	Maninjau	68
6	PLTA	West Sumatera	Batang Agam	10.5
7	PLTMH	West Sumatera	Tersebar Sumbar	66
8	PLTA	West Java	Ubrug	18
9	PLTA	West Java	Kracak	19
10	PLTA	West Java	Plengan	7
11	PLTA	West Java	Lamajan	20
12	PLTA	West Java	Cikalong	19
13	PLTA	West Java	Bengkok	3
14	PLTA	West Java	Dago	1
15	PLTA	West Java	Parakan	10
16	PLTA	Central Java	Jelok	21
17	PLTA	Central Java	Timo	12
18	PLTA	Central Java	Keteranganenger	8
19	PLTA	Central Java	Gerung	26
20	PLTA	Central Java	Wonogiri	12
21	PLTA	Central Java	Sempor	1
22	PLTA	Central Java	Wadas Lintang	18
23	PLTA	Central Java	Kedung Ombo	23
24	PLTA	Central Java	Lambu	1
25	PLTA	Central Java	Pengkol	1
26	PLTA	Central Java	Selorejo	1
27	PLTA	East Java	Wlingi	54
28	PLTA	East Java	Ledoyo	5
29	PLTA	East Java	Selorejo	5
30	PLTA	East Java	Sengguruh	29
31	PLTA	East Java	Tulung Agung	36
32	PLTA	East Java	Mendalan	23
33	PLTA	East Java	Siman	11
34	PLTA	East Java	Madiun	8
35	PLTA	South Kalimantan	Sistem Barito	30
36	PLTA	North Sulawesi	Sistem Minahasa-Kotamobagu	58.4
37	PLTA/M	Central Sulawesi	Sistem Poso-Tentena	74.8
38	PLTA/M	Central Sulawesi	Luwuk-Tolli	8.4

39	PLTA/M	Central Sulawesi	Ampana-Bunta	3.3
40	PLTA/M	Central Sulawesi	Toli-toli	1.6
41	PLTA/M	Central Sulawesi	Moutong-Kotaraya	2
42	PLTA/M	Central Sulawesi	Kolonedale	3
43	PLTA/M	Central Sulawesi	Bungku	2
44	PLTMH	Gorontalo	Gorontalo	3
45	PLTA	South Sulawesi	Bakaru 1	63
46	PLTA	South Sulawesi	Bakaru 2	63
47	PLTA	South Sulawesi	Bili Bili	20
48	PLTMH	South Sulawesi	Sawitto	1.6
49	PLTMH	South Sulawesi	Balla Mamasa	0.7
50	PLTMH	South Sulawesi	Kalukku Mamuju	1.4
51	PLTMH	South Sulawesi	Bonehau Mamasa	4
52	PLTMH	South Sulawesi	Budong-budong Mamuju	2
53	PLTMH	South Sulawesi	Tangka Manipi Sinjai	10
54	PLTMH	South Sulawesi	Simbuang Luwu	3
55	PLTMH	South Sulawesi	Siteba Palopo	7.5
56	PLTMH	South Sulawesi	Malea Tator	14
57	PLTMH	South Sulawesi	Ranteballa Palopo	2.4
58	PLTMH	South Sulawesi	Bungin Enrekang	3
59	PLTA	South Sulawesi	Poso 1	65
60	PLTA	South Sulawesi	Poso 2	65
61	PLTA	South Sulawesi	Poso 3	65
62	PLTMH	South Sulawesi	Saluanoa Luwu	2
63	PLTA	South Sulawesi	Malili (PT Vale Excess Power)	10.7

MW = megawatt, PLTA = hydropower plant, PLTA/M = mini hydropower plant, PLTMH = micro hydropower plant.
Source: MEMR (2016a).

- Micro-hydro resources

Mini/micro hydro is one of the potential sources to be developed in many parts of the country. Its estimated potential is 19,385 MW (Table 3.6).

Table 3.6. Mini and Micro Hydro Potential in Indonesia

No.	Province	Potential (MW)	No.	Province	Potential (MW)
1	East Kalimantan	3,562	17	Riau	284
2	Central Kalimantan	3,313	18	Maluku	190
3	Aceh	1,538	19	South Kalimantan	158
4	West Sumatera	1,353	20	West Kalimantan	124
5	North Sumatera	1,204	21	Gorontalo	117
6	East Java	1,142	22	North Sulawesi	111
7	Central Java	1,044	23	Bengkulu	108
8	North Kalimantan	943	24	NTT	95
9	South Sulawesi	762	25	Banten	72
10	West Java	647	26	NTB	31
11	Papua	615	27	North Maluku	24
12	South Sumatera	448	28	Bali	15
13	Jambi	447	29	West Sulawesi	7
14	Central Sulawesi	370	30	DI Yogyakarta	5
15	Lampung	352	31	West Papua	3
16	Southeast Sulawesi	301		**Total**	**19,385**

MW = megawatt, NTB =West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB), NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: Author.

- Current/existing capacity

Table 3.7 shows the existing micro hydro power plants with capacity less than 100 MW per unit.

Table 3.7. Micro Hydropower Plant with Installed Capacity of Less than 100 MW per Unit

No.	Province	Region System	Installed capacity (MW)
1	Gorontalo	Gorontalo	0.0372
2	West Java	Ciamis	0.0244
3	Central Kalimantan	Gunung Mas	0.3290
4	NTT	Ngada	0.0260
5	NTB	Lombok	0.0300
6	North Sulawesi	Sangihe	0.0141
7	North Sumatera	Samosir	0.0312

8	Central Sulawesi	Lamantoli Morowali	0.0206
9	NTT	Manggarai Timur	0.0800
10	NTT	Rote Tengah	0.0200
11	NTT	Sumba Tengah	0.0120
12	Papua	Pegunungan Bintang	0.0300
13	NTB	Lombok Timur	0.0200
14	NTT	Timor Tengah Selatan	0.0500
15	Papua	Pegunungan Bintang	0.0400
16	Papua	Teluk Bintuni	0.0084
17	Gorontalo	Gorontalo Utara	0.0180
18	South Sumatera	Oku Selatan	0.0230
19	NTT	Timor Tengah Selatan	0.0350
20	West Kalimantan	Kapuas Hulu	0.4000
21	West Papua	Sorong Selatan	0.2850
22	West Sumatera	Pasaman Barat	0.0160
23	Papua	Yalimo	0.0500
24	West Sulawesi	Mamasa	0.1200
25	West Papua	Maybrat	0.2660
26	Lampung	Lampung Barat	0.0800
27	Riau	Kampar	0.0080
28	East Java	Situbondo	0.0150
29	Gorontalo	Bone Bolango	0.0400
30	Gorontalo	Gorontalo Utara	0.0200
31	Papua	Pegunungan Bintang	0.0350
32	Jambi	Sarolangun	0.0180
33	Central Kalimantan	Lamandau	0.0160
34	Southeast Sulawesi	Konawe Utara	0.0160
35	South Sulawesi	Luwu Utara	0.0400
36	West Kalimantan	Landak	0.0500
37	Maluku	Seram Bagian Barat	0.0300
38	West Sumatera	Kep. Mentawai	0.0250
39	West Papua	Manokwari	0.0450
40	NTB	Sumbawa	0.3000
41	Gorontalo	Gorontalo	0.0300
42	South Sumatera	Muara Enim	0.0200
43	Papua	Jayapura	0.0230
44	West Sumatera	Solok	0.0130
45	North Sumatera	Tapanuli Selatan	0.0250
46	Southeast Sulawesi	Buton Utara	0.0120
47	NTT	Manggarai Timur	0.0500

MW = megawatt, NTB =West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB), NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: MEMR (2015).

Solar power

- Solar power resources

The potential of solar power in Indonesia is estimated at 207,888 MW, with West Kalimantan having the largest potential at 20.113 MW (Table 3.8). The development of solar power is still very limited at about 0,08 GWp (80 MWp) consisting of stand-alone solar PV located in remote areas and some on-grid larger capacity up to 5 MW that has been installed in Kupang, East Nusa Tenggara. In 2025, solar power is expected to reach 6,500 MW. Table 3.8 shows the potential of solar power.

Table 3.8. Solar Power Potential in Indonesia

No.	Province	Potential (MW)	No.	Province	Potential (MW)
1	West Kalimantan	20,113	19	North Kalimantan	4,643
2	South Sumatera	17,233	20	Southeast Sulawesi	3,917
3	East Kalimantan	13,479	21	Bengkulu	3,475
4	North Sumatera	11,851	22	North Maluku	3,036
5	East Java	10,335	23	Bangka Belitung	2,810
6	NTB	9,931	24	Banten	2,461
7	West Java	9,099	25	Lampung	2,238
8	Jambi	8,847	26	North Sulawesi	2,113
9	Central Java	8,753	27	Papua	2,035
10	Central Kalimantan	8,459	28	Maluku	2,020
11	Aceh	7,881	29	West Sulawesi	1,677
12	Riau Islands	7,763	30	Bali	1,254
13	South Sulawesi	7,588	31	Gorontalo	1,218
14	NTT	7,272	32	DI Yogyakarta	996
15	West Papua	6,307	33	Riau	753
16	Central Sulawesi	6,187	34	DKI Jakarta	225
17	South Kalimantan	6,031		**Total**	**207,898**
18	West Sumatera	5,898			

MW = megawatt, NTB =West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB),
NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT)
Source: MEMR (2017).

- Current/existing capacity

Table 3.9 shows the existing solar power plants with capacity less than 100 MW per unit.

Table 3.9. Solar Power Plants with Installed Capacity of Less than 100 MW per Unit

No.	Province	Region Power System	Installed capacity (MW)
1	West Sumatera	Kep. Mentawai	0.01
2	West Kalimantan	Kayong Utara	0.01
3	Southeast Sulawesi	Buton Utara	0.01
4	NTT	Belu	0.005
5	NTT	Kupang	0.01
6	NTT	Manggarai Barat	0.01
7	NTT	Rote Ndao	0.005
8	Papua	Nabire	0.01
9	Papua	Tolikara	0.075
10	West Sumatera	Sijunjung	0.015
11	West Sumatera	Solok	0.015
12	West Sumatera	Pasaman	0.015
13	West Sumatera	Pasaman Barat	0.03
14	Riau	Kep. Meranti	0.015
15	Riau	Kep. Meranti	0.015
16	Riau	Rokan Hulu	0.015
17	Riau	Indragiri Hilir	0.015
18	Riau	Kuantan Singingi	0.015
19	Riau	Bengkalis	0.015
20	Jambi	Tanjung Jabung Timur	0.015
21	Jambi	Bungo	0.015
22	Jambi	Sarolangun	0.015
23	Jambi	Batanghari	0.015
24	South Sumatera	Banyuasin	0.03
25	South Sumatera	Banyuasin	0.03
26	South Sumatera	Banyuasin	0.015
27	South Sumatera	Ogan Komering Ilir	0.03
28	Bengkulu	Seluma	0.015
29	Bengkulu	Kaur	0.015
30	Bengkulu	Kaur	0.015
31	Bengkulu	Kaur	0.015
32	Bengkulu	Kaur	0.015
33	Bangka Belitung	Bangka Selatan	0.015
34	Bangka Belitung	Bangka Selatan	0.015
35	Bangka Belitung	Bangka Barat	0.015
36	Bangka Belitung	Belitung Timur	0.015
37	Bangka Belitung	Bangka Barat	0.015
38	DKI Jakarta	Kep. Seribu	0.015
39	Banten	Serang	0.03

40	West Java	Cianjur	0.015
41	West Java	Cianjur	0.015
42	West Java	Cianjur	0.015
43	Central Java	Banyumas	0.015
44	Central Java	Banjarnegara	0.015
45	Central Java	Blora	0.015
46	Yogyakarta	Cirebon	0.015
47	Yogyakarta	Gunung Kidul	0.015
48	East Java	Sumenep	0.015
49	East Java	Jombang	0.015
50	East Java	Bojonegoro	0.015
51	Bali	Bangli	1
52	Bali	Karangasem	1
53	Bali	Karangasem	0.015
54	Bali	Bangli	0.015
55	Bali	Bangli	0.015
56	Bali	Bangli	0.015
57	Bali	Bangli	0.015
58	Bali	Klungkung	0.015
59	NTB	Sumbawa	1
60	NTB	Lombok Timur	0.015
61	NTB	Sumbawa	0.015
62	NTB	Lombok Barat	0.015
63	NTB	Lombok Tengah	0.015
64	NTB	Bima	0.015
65	NTT	Timor Tengah Selatan	0.015
66	NTT	Rote Ndao	0.015
67	NTT	Belu	0.015
68	NTT	Belu	0.015
69	NTT	Belu	0.015
70	West Kalimantan	Ketapang	0.015
71	West Kalimantan	Sanggau	0.015
72	West Kalimantan	Landak	0.015
73	West Kalimantan	Kapuas Hulu	0.015
74	Central Kalimantan	Katingan	0.015
75	Central Kalimantan	Lamandau	0.015
76	Central Kalimantan	Murung Raya	0.015
77	Central Kalimantan	Seruyan	0.015
78	Central Kalimantan	Barito Timur	0.015
79	Central Kalimantan	Barito Utara	0.015

80	Central Sulawesi	Sigi	0.015
81	Central Sulawesi	Donggala	0.015
82	Central Sulawesi	Toli-toli	0.015
83	Central Sulawesi	Parigi Moutong	0.015
84	Southeast Sulawesi	Kolaka Utara	0.015
85	Southeast Sulawesi	Buton	0.03
86	Southeast Sulawesi	Kolaka	0.03
87	Southeast Sulawesi	Bombana	0.015
88	Southeast Sulawesi	Bau-bau	0.015
89	Gorontalo	Gorontalo	0.015
90	Gorontalo	Bone Bolango	0.015
91	Gorontalo	Pohuwato	0.015
92	Gorontalo	Gorontalo Utara	0.015
93	West Sulawesi	Majene	0.015
94	West Sulawesi	Mamuju Utara	0.015
95	West Sulawesi	Majene	0.015
96	West Sulawesi	Mamuju Utara	0.015
97	West Sulawesi	Mamasa	0.015
98	Maluku	Maluku Barat Daya	0.015
99	Maluku	Maluku Tenggara	0.015
100	Maluku	Maluku Tenggara Barat	0.015
101	Maluku	Maluku Tenggara Barat	0.015
102	Maluku	Maluku Tenggara Barat	0.015
103	Maluku	Maluku Tenggara Barat	0.015
104	Maluku Utara	Halmahera Tengah	0.015
105	Maluku Utara	Kep. Sula	0.015
106	Maluku Utara	Halmahera Timur	0.015
107	Maluku Utara	Halmahera Utara	0.015
108	West Papua	Sorong	0.015
109	West Papua	Kota Sorong	0.015
110	West Papua	Manokwari	0.015
111	West Papua	Kaimana	0.015
112	West Papua	Sorong Selatan	0.015
113	West Papua	Sorong Selatan	0.015
114	West Papua	Sorong Selatan	0.015
115	West Papua	Sorong Selatan	0.015
116	Papua	Keerom	0.015
117	Papua	Keerom	0.015
118	Papua	Keerom	0.015
119	Papua	Yalimo	0.015

120	Papua	Yalimo	0.015
121	Papua	Yalimo	0.015
122	Papua	Peg. Bintang	0.015
123	North Sumatera	Nias Selatan	0.01
124	North Sumatera	Nias Barat	0.005
125	West Sumatera	Kep. Mentawai	0.005
126	South Sumatera	OKU Selatan	0.002
127	Bangka Belitung	Bangka Selatan	0.003
128	Lampung	Mesuji	0.005
129	West Kalimantan	Sekadau	0.023
130	West Kalimantan	Melawi	0.005
131	Central Kalimantan	Gunung Mas	0.005
132	Central Kalimantan	Seruyan	0.005
133	NTT	Alor	0.004
134	NTT	Belu	0.007
135	NTT	Manggarai	0.0075
136	NTT	Sumba Barat	0.006
137	NTT	Sumba Timur	0.005
138	NTT	Timor Tengah Utara	0.015
139	NTT	Manggarai Barat	0.01
140	NTT	Nagekeo	0.005
141	NTT	Sumba Barat Daya	0.005
142	NTT	Sumba Tengah	0.005
143	NTT	Sabu Raijua	0.005
144	Maluku	Kep. Aru	0.005
145	Papua	Paniai	0.05
146	Papua	Yahukimo	0.015
147	Papua	Peg. Bintang	0.015
148	Papua	Yalimo	0.05
149	Papua	Intan Jaya	0.05
150	West Papua	Sorong Selatan	0.01
151	West Papua	Maybrat	0.03
152	West Papua	Tambrauw	0.015
153	Aceh	Singkil	0.015
154	Aceh	Simeulue (2)	0.015
155	Aceh	Simeuleu	0.015
156	Aceh	Simeuleu	0.015
157	Aceh	Singkil	0.015
158	North Sumatera	Tapanuli Utara	0.015
159	North Sumatera	Tapanuli Selatan	0.02

160	North Sumatera	Tapanuli Tengah	0.015
161	North Sumatera	Mandailing Natal	0.02
162	North Sumatera	Nias Selatan	0.015
163	North Sumatera	Nias Utara	0.02
164	West Sumatera	Pasaman	0.015
165	West Sumatera	Sijunjung	0.015
166	Riau	Kep. Meranti	0.02
167	Riau	Indragiri Hilir	0.015
168	Jambi	Tanjung Jabung Barat	0.02
169	Jambi	Tebo	0.015
170	Jambi	Muaro Jambi	0.015
171	Jambi	Batang Hari	0.015
172	South Sumatera	Banyuasin	0.015
173	South Sumatera	Banyuasin	0.015
174	South Sumatera	Banyuasin	0.015
175	Bangka Belitung	Belitung Timur	0.015
176	Bangka Belitung	Bangka Selatan	0.015
177	Bangka Belitung	Bangka Barat	0.015
178	Lampung	Pesawaran	0.025
179	Lampung	Mesuji	0.015
180	Lampung	Mesuji	0.015
181	Lampung	Mesuji	0.015
182	Lampung	Mesuji	0.015
183	Lampung	Tangamus	0.02
184	Lampung	Tangamus	0.02
185	Lampung	Lampung Utara	0.02
186	Kep. Riau	Bintan	0.02
187	Kep. Riau	Bintan	0.015
188	Kep. Riau	Natuna	0.015
189	Kep. Riau	Lingga	0.015
190	Banten	Serang	0.025
191	West Java	Bogor	0.015
192	Central Java	Jepara	0.025
193	Central Java	Tegal	0.02
194	East Java	Ponorogo	0.015
195	East Java	Bangkalan	0.02
196	East Java	Sumenep	0.02
197	Bali	Karangasem	0.015
198	Bali	Karangasem	0.015
199	NTB	Lombok Utara	0.02

200	NTB	Lombok Tengah	0.015
201	NTB	Lombok Barat	0.015
202	NTB	Bima	0.015
203	NTT	Kupang	0.015
204	NTT	Rote Ndao	0.015
205	NTT	Sabu Raijua	0.015
206	West Kalimantan	Landak	0.015
207	West Kalimantan	Ketapang	0.015
208	West Kalimantan	Kapuas Hulu	0.015
209	Central Kalimantan	Kotawaringin Timur	0.025
210	Central Kalimantan	Katingan	0.015
211	South Kalimantan	Hulu Sungai Tengah	0.015
212	South Kalimantan	Tapin	0.025
213	South Kalimantan	Tabalong	0.015
214	South Kalimantan	Tabalong	0.015
215	South Kalimantan	Hulu Sungai Selatan	0.015
216	South Kalimantan	Kotabaru	0.015
217	South Kalimantan	Kotabaru	0.015
218	East Kalimantan	Paser	0.015
219	East Kalimantan	Kutai Barat	0.015
220	East Kalimantan	Kutai Barat	0.015
221	East Kalimantan	Malinau	0.015
222	East Kalimantan	Nunukan	0.015
223	North Sulawesi	Kep. Siau Tagulandong Biaro	0.015
224	North Sulawesi	Kep. Siau Tagulandong Biaro	0.015
225	North Sulawesi	Kep. Sangihe	0.015
226	North Sulawesi	Kep. Sangihe	0.015
227	South Sulawesi	Pangkep	0.015
228	South Sulawesi	-	0.015
229	South Sulawesi	Luwu Timur	0.015
230	South Sulawesi	Pinrang	0.025
231	South Sulawesi	Kep. Selayar	0.015
232	South Sulawesi	Takalar	0.015
233	Southeast Sulawesi	Buton Utara	0.015
234	Southeast Sulawesi	Konawe Utara	0.02
235	Southeast Sulawesi	Wakatobi	0.02
236	Maluku Utara	Halmahera Selatan	0.015
237	Gorontalo	Bone Bolango	0.015
238	Gorontalo	Pohuwato	0.015
239	Gorontalo	Gorontalo Utara	0.015

240	Gorontalo	Gorontalo Utara	0.025
241	West Sulawesi	Polewali Mandar	0.015
242	West Sulawesi	Mamuju	0.015
243	West Sulawesi	Mamuju	0.015
244	West Sulawesi	Mamuju Utara	0.02
245	West Papua	Raja Ampat	0.015
246	West Papua	Tambraw	0.025
247	West Papua	Tambraw	0.015
248	West Papua	Tambraw	0.015
249	West Papua	Tambraw	0.015
250	West Papua	Tambraw	0.025
251	Bangka Belitung	Bangka	1
252	South Sulawesi	Pangkajene Kepulauan	1
253	North Sumatera	Kuantan Singingi	0.1
254	Riau	Nias	0.05
255	Lampung	Lampung Barat	0.075
256	South Sumatera	Banyuasin	0.15
257	East Java	Sumenep	0.05
258	East Kalimantan	Kutai Barat	0.1
259	NTT	Timor Tengah Selatan	0.03
260	NTT	Sumba Tengah	0.05
261	NTB	Sumbawa	0.03
262	West Papua	Kaimana	0.075
263	Papua	Mappi	0.05
264	Papua	Kep. Yapen	0.15
265	Papua	Tolikara	0.05
266	Papua	Tolikara	0.05
267	Papua	Tolikara	0.05
268	Papua	Tolikara	0.05
269	Papua	Mamberamo Raya	0.15
270	Papua	Mamberamo Raya	0.05
271	Papua	Mamberamo Raya	0.075
272	Papua	Mamberamo Raya	0.15
273	Papua	Mamberamo Raya	0.1
274	North Sumatera	Nias	0.005
275	South Sumatera	Musi Rawas	0.04
276	South Sumatera	Ogan Komering Ulu Selatan	0.135
277	East Java	Bangkalan	0.015
278	East Java	Bangkalan	0.0075
279	East Java	Bondowoso	0.03

280	East Java	Sumenep	0.026
281	Central Kalimantan	Gunung Mas	0.018
282	North Sulawesi	Bolaang Mongondow Utara	0.015
283	Gorontalo	Boalemo	0.015
284	Gorontalo	Pohuwato	0.015
285	Gorontalo	Pohuwato	0.007
286	Gorontalo	Gorontalo Utara	0.03
287	South Sulawesi	Sinjai	0.015
288	Southeast Sulawesi	Konawe Selatan	0.015
289	Bali	Bangli	0.0075
290	NTB	Sumbawa	0.015
291	NTB	Sumbawa Barat	0.015
292	NTT	Belu	0.01
293	NTT	Sumba Timur	0.015
294	NTT	Sumba Tengah	0.005
295	Maluku Utara	Pulau Morotai	0.015
296	Papua	Jayawijaya	0.015
297	Papua	Pegunungan Bintang	0.015
298	West Papua	Tambrauw	0.015
299	North Sumatera	Tapanuli Selatan	0.015
300	North Sumatera	Tapanuli Tengah	0.015
301	North Sumatera	Karo	0.02
302	North Sumatera	Tapanuli Selatan	0.02
303	Riau	Rokan Hulu	0.015
304	Riau	Bengkalis	0.02
305	Riau	Siak	0.05
306	Riau	Pelalawan	0.075
307	Jambi	Tanjung Jabung Barat	0.02
308	South Sumatera	Banyuasin	0.015
309	South Sumatera	Ogan Ilir	0.03
310	Lampung	Mesuji	0.015
311	Lampung	Tangamus	0.03
312	Lampung	Pesawaran	0.03
313	Lampung	Tanggamus	0.05
314	Lampung	Tanggamus	0.03
315	Lampung	Tanggamus	0.03
316	Kep. Riau	Natuna	0.03
317	Kep. Riau	Natuna	0.02
318	Kep. Riau	Bintan	0.015
319	Bangka Belitung	Belitung	0.015

320	Bangka Belitung	Bangka Tengah	0.015
321	Central Java	Tegal	0.015
322	Central Java	Jepara	0.075
323	East Java	Pamekasan	0.015
324	East Java	Pamekasan	0.015
325	Bali	Karangasem	0.02
326	NTB	Lombok Timur	0.03
327	NTB	Lombok Utara	0.03
328	NTB	Sumbawa	0.015
329	NTB	Bima	0.05
330	West Kalimantan	Landak	0.02
331	South Kalimantan	Kotabaru	0.02
332	South Kalimantan	Hulu Sungai Tengah	0.015
333	North Kalimantan	Nunukan	0.03
334	East Kalimantan	Kutai Kertanegara	0.03
335	East Kalimantan	Penajam Paser Utara	0.015
336	East Kalimantan	Penajam Paser Utara	0.015
337	East Kalimantan	Penajam Paser Utara	0.015
338	East Kalimantan	Penajam Paser Utara	0.015
339	South Sulawesi	Luwu Utara	0.03
340	South Sulawesi	Luwu Timur	0.015
341	South Sulawesi	Pangkajene Kepulauan	0.02
342	Southeast Sulawesi	Muna	0.015
343	Southeast Sulawesi	Konawe Selatan	0.015
344	Gorontalo	Gorontalo Utara	0.02
345	West Sulawesi	Polewali Mandar	0.015
346	Maluku Utara	Halmahera Timur	0.015
347	Maluku Utara	Halmahera Timur	0.015
348	West Papua	Sorong	0.015
349	West Kalimantan	Bengkayang	0.03
350	West Kalimantan	Sintang	0.02
351	West Kalimantan	Sintang	0.015
352	West Kalimantan	Kapuas Hulu	0.015
353	West Kalimantan	Kapuas Hulu	0.015
354	West Kalimantan	Kapuas Hulu	0.015
355	North Kalimantan	Nunukan	0.03
356	North Kalimantan	Nunukan	0.05
357	North Kalimantan	Nunukan	0.05
358	East Kalimantan	Mahakam Ulu	0.05
359	East Kalimantan	Mahakam Ulu	0.05

360	NTT	Kupang	0.02
361	North Sumatera	Nias Selatan	0.05
362	Kep. Riau	Natuna	0.05
363	Bengkulu	Bengkulu Utara	0.05
364	East Kalimantan	Berau	0.05
365	East Kalimantan	Nunukan	0.05
366	NTT	Alor	0.03
367	Central Sulawesi	Toli-toli	0.03
368	North Sulawesi	Minahasa Utara	0.05
369	North Sulawesi	Kep. Sangihe	0.05
370	North Sulawesi	Kep. Talaud	0.03
371	North Sulawesi	Kep. Sangihe	0.03
372	North Sulawesi	Kep. Talaud	0.05
373	Maluku	Maluku Tenggara Barat	0.1
374	Maluku	Kep. Aru	0.03
375	Maluku	Maluku Barat Daya	0.03
376	Maluku	Maluku Barat Daya	0.03
377	Maluku	Maluku Barat Daya	0.05
378	Maluku	Maluku Barat Daya	0.05
379	Maluku	Maluku Barat Daya	0.03
380	Maluku	Maluku Barat Daya	0.05
381	Maluku	Maluku Tenggara Barat	0.05
382	Papua	Sarmi	0.03
383	Papua	Supiori	0.03
384	Papua	Supiori	0.05
385	Papua	Merauke	0.05
386	Aceh	Simeuleu	0.015
387	North Sumatera	Nias	0.005
388	North Sumatera	Nias	0.008
389	North Sumatera	Nias Selatan	0.02
390	North Sumatera	Nias Barat	0.005
391	North Sumatera	Nias Barat	0.005
392	South Sumatera	Ogan Komering Ulu Selatan	0.005
393	South Sumatera	Ogan Komering Ulu Selatan	0.005
394	South Sumatera	Ogan Komering Ulu Selatan	0.004
395	Yogyakarta	Gunung Kidul	0.015
396	East Java	Bangkalan	0.01
397	East Java	Bondowoso	0.005
398	Central Kalimantan	Katingan	0.02
399	Central Kalimantan	Seruyan	0.005

400	Central Kalimantan	Seruyan	0.01
401	South Sulawesi	Sinjai	0.015
402	Southeast Sulawesi	Kolaka	0.015
403	Southeast Sulawesi	Konawe Selatan	0.015
404	Southeast Sulawesi	Buton Utara	0.008
405	NTB	Dompu	0.015
406	NTB	Sumbawa Barat	0.015
407	NTB	Lombok Utara	0.01
408	NTT	Belu	0.01
409	NTT	Sumba Tengah	0.005
410	Maluku	Maluku Barat Daya	0.023
411	Maluku Utara	Morotai	0.015

MW = megawatt, NTB =West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB),
NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: Statistics of New Renewable Energy and Energy Conservation, 2015

Bioenergy

- Bioenergy resources

Indonesia is endowed with various types of bioenergy that can be developed. The potential of biomass or biofuel is equivalent to 32,653 MW (Table 3.10). Indonesia uses around 1,671 MW of bioenergy, or about 5.1% of its potential reserves.

Table 3.10. Bioenergy Sources in Indonesia

No.	Province	Potential (MW)		
		Biomass/Biofuel	Biogas	Total
1	Riau	4,157.4	37.7	4,195.1
2	East Java	2,851.3	569.6	3,420.9
3	North Sumatera	2,796.1	115.5	2,911.6
4	West Java	1,979.8	574.3	2,554.1
5	Central Java	1,884.1	348.4	2,232.5
6	South Sumatera	2,061.4	71.2	2,132.6
7	Jambi	1,821.0	18.9	1,839.9
8	Central Kalimantan	1,486.7	12.2	1,498.9
9	Lampung	1,407.6	84.5	1,492.1
10	West Kalimantan	1,279.3	28.9	1,308.2
11	South Kalimantan	1,266.3	23.6	1,289.9
12	Aceh	1,136.6	37.7	1,174.3
13	East/North Kalimantan	946.6	17.7	964.3

14	South Sulawesi	890.3	69.1	959.4
15	West Sumatera	923.1	34.7	957.8
16	Bengkulu	633.0	11.8	644.8
17	Banten	346.5	118.6	465.1
18	NTB	341.3	52.8	394.1
19	Central Sulawesi	307.4	19.5	326.9
20	NTT	192.5	48.0	240.5
21	DI Yogyakarta	183.1	41.1	224.2
22	Bangka Belitung	217.7	5.4	223.1
23	West Sulawesi	197.8	8.1	205.9
24	Bali	146.9	44.7	191.6
25	North Sulawesi	150.2	13.8	164.0
26	Southeast Sulawesi	132.8	17.7	150.5
27	Gorontalo	119.1	11.5	130.6
28	DKI Jakarta	0.5	126.1	126.6
29	Papua	81.4	15.1	96.5
30	West Papua	50.8	4.1	54.9
31	West Maluku	27.5	7.0	34.5
32	Maluku	23.6	9.0	32.6
33	Riau Islands	11.6	4.3	15.9
	Total	**30,051.3**	**2,602.6**	**32,653.9**

* Administratively, DKI Jakarta is divided into four city administrations (City Administration of South Jakarta, East Jakarta, Central Jakarta, West Jakarta, and North Jakarta), and one administrative regency (Thousand Islands or Kepulauan Seribu). MW = megawatt, NTB = West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB), NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: MEMR (2017).

- Current/existing capacity

Table 3.11 shows some of the existing bioenergy power plant – biomass, biogas, and municipal solid waste – with a capacity of less than 100 MW per unit.

Coal

- Coal resources

The total national coal produced in 2015 was 461.6 million tons, of which 79.3% or 365.8 million tons were exported and only 20.7% or 95.8 million tons used domestically, particularly for power plants, making Indonesia he largest coal exporter. Coal sources potential in 2015 was 120.5 billion tons, coal reserves was 32.4 billion tons, and production was 393 million tons.

Table 3.11. Bioenergy Power Plants with Installed Capacity of Less than 100 MW per Unit

No.	Province	Type	Installed capacity (MW)	On/Off grid
1	Riau	Palm waste	5	On grid
2	North Sumatera	Palm waste	9	On grid
3	Bangka	Palm waste	5	On grid
4	Riau	Palm waste	2	On grid
5	Belitung	Palm waste	7	On grid
6	Riau	Palm waste	2	On grid
7	Riau	Palm waste	5	On grid
8	North Sumatera	Palm waste	10	On grid
9	North Sumatera	Palm waste	10	On grid
10	Bekasi	MSW	6	On grid
11	Bali	MSW	2	On grid
12	North Sumatera	Palm waste	10	On grid
13	Bekasi	MSW	4.5	On grid
14	Bekasi	MSW	2	On grid
15	Belitung	POME	1.2	On grid
16	Gorontalo	Tongkol Jagung	0.4	On grid
17	Jambi	Palm waste	10	On grid
18	Sumatera	POME	9	Off grid
19	Sumatera	Sugar cane	66	Off grid
20	Kalimantan	Palm waste	91	Off grid
21	Jawa-Bali	Palm waste	2	Off grid
22	Jawa-Bali	MSW	0	Off grid
23	Sulawesi	Palm waste	11	Off grid
24	Sulawesi	Sugar cane	11	Off grid
25	Papua	Palm waste	4	Off grid

MSW = municipal solid waste, MW = megawatt, POME = palm oil mill effluent.
Source: MEMR (2015).

- Current/existing capacity

Table 3.12 shows coal power plants with installed capacity less than 100 MW.

Other fuels

Table 3.13 shows power plants with installed capacity less than 100 MW that use other fuels.

Table 3.12. Coal Power Plants with Installed Capacity of Less than 100 MW per Unit

No.	Province	Region System	Installed capacity (MW)
1	North Sulawesi	Amurang 1	25
2	North Sulawesi	Amurang 2	25
3	Southeast Sulawesi	Kendari 2	10
4	Riau	Tj Balai Karimun 2	7
5	South Sulawesi	Barru 2	50
6	South Kalimantan	Asam-asam 3	65
7	South Kalimantan	Asam-asam 4	65
8	Bangka Belitung	Bangka 2	30
9	Riau	Tj Balai Karimun 1	7
10	South Sulawesi	Barru 1	50
11	Southeast Sulawesi	Kendari 1	10
12	NTT	Kupang 1	16.5
13	NTT	Kupang 2	16.5
14	Bangka Belitung	Belitung 1	16.5
15	NTT	Ende 1	7
16	Bangka Belitung	Bangka 1	30
17	NTB	Lombok 1	25
18	Central Kalimantan	Pulang Pisau 1	60
19	Bangka Belitung	Belitung 2	16.5
20	NTT	Ende 2	7
21	Kep. Riau	Bukit Carok	14
22	Kep. Riau	Air Raja (Sewa)	30
23	Bangka Belitung	PLTU Suge	16.5
24	Bangka Belitung	PLTU 3 Babel	60
25	South Kalimantan	Sistem Barito (Swasta Excess)	86
26	Central Kalimantan	Sistem Barito (Swasta Excess)	3
27	Central Kalimantan	Sistem Pangkalan Bun (Swasta IPP)	11
28	East Kalimantan	Sistem Berau	27.6
29	North Sulawesi	Sistem Minahasa-Kotamobagu	50
30	Central Sulawesi	Sistem Palu-Parigi	27
31	Gorontalo	Gorontalo	21
32	South Sulawesi	Barru 1	50
33	South Sulawesi	Barru 2	50

IPP = independent power producer, MW = megawatt, PLTU = Indonesia Power.
Source: Ministry of Energy and Mineral Resources (2016).

Table 3.13. Power Plants that Use Other Fuels with Installed Capacity of Less than 100 MW

No.	Fuels	Type of Power Plant	Province	Region Power System	Installed capacity (MW)
1	HSD	PLTD	Aceh	PLTD Tersebar (Sewa)	7
2	HSD	PLTG	Aceh	Mobil Unit	22.11
3	HSD	PLTD	Aceh	Pusat Listrik Lueng Bata	58.17
4	HSD	PLTD	North Sumatera	Titi Kuning	24.85
5	HSD	PLTG	North Sumatera	Glugur	31.71
6	HSD	PLTG	North Sumatera	Paya Pasir	75.55
7	HSD	PLTD	North Sumatera	PT Bima Golden Powerindo (Sewa)	40
8	HSD	PLTD	North Sumatera	PT Prastiwahyu Trimitra Engineering Tamora (Sewa)	45
9	HSD	PLTD	North Sumatera	PT Kurnia Purnama Tama (Sewa)	75
10	HSD	PLTD	North Sumatera	PLTD Tersebar Sumut	1.06
11		PLTD	North Sumatera	PLTD Gunung Sitoli (p.Nias)	33.64
12		PLTD	North Sumatera	PLTD Teluk Dalam (p.Nias)	8.605
13		PLTD	North Sumatera	PLTD Pulau Tello (p. Nias)	0.3
14	HSD	PLTD	West Sumatera	Tersebar Sumbar	1.6
15	HSD	PLTD	West Sumatera	Tersebar Sumbar (Sewa)	1.3
16	HSD	PLTD	Riau	PLTD PT BGP GI BINA (Sewa)	30
17	HSD	PLTD	Riau	PLTD Tersebar WRKR (Sewa)	78
18	HSD	PLTD	Riau	PLTD Tembilahan	23
19	HSD	PLTB	Riau	PLTD Tanjung Batu (Sewa)	5
20	HSD	PLTD	Riau	PLTD Tembilahan (Sewa)	23
21	HSD	PLTD	Kep. Riau	PLTD Tersebar WRKR	87.5
22	HSD	PLTD	Kep. Riau	Kota Lama	23.9
23	HSD	PLTD	Kep. Riau	Air Raja	56.2
24	HSD	PLTD	Kep. Riau	Sukaberenang	42.3
25	HSD	PLTD	Kep. Riau	Bukit Carok	22.2
26	HSD	PLTD	Kep. Riau	Bukit Carok (Sewa)	22.2
27	HSD	PLTGB	Kep. Riau	Air Raja (Sewa)	30
28	HSD	PLTD	Kep. Riau	Sukaberenang (Sewa)	42.3
29	HSD	PLTD	Kep. Riau	Air Raja (Sewa)	56.2
30	HSD	PLTD	Kep. Riau	Kota Lama (Sewa)	23.9
31	HSD	PLTD	Kep. Bangka Belitung	PLTD Tersebar Babel	9.19
32	HSD	PLTD	Kep. Bangka Belitung	PLTD Tersebar Babel (Sewa)	27
33	HSD	PLTD	Kep. Bangka Belitung	PLTD Pilang	27.44

34	HSD	PLTD	Kep. Bangka Belitung	PLTD Merawang	42.3
35	HSD	PLTD	Kep. Bangka Belitung	PLTD Merawang (Sewa)	42.3
36	HSD	PLTD	Kep. Bangka Belitung	PLTD Pilang (Sewa)	27.4
37	HSD	PLTD	Kep. Bangka Belitung	PLTD Air Anyir Sewatama (Sewa)	52
38	HSD	PLTD	West Sumatera	Sikabaluan Kep Mentawai	0.1
39	HSD	PLTD	West Sumatera	Sikakap Kep Mentawai	0.4
40	HSD	PLTD	West Sumatera	Sipora Kep Mentawai	0.1
41	HSD	PLTD	West Sumatera	Seay Baru Kep Mentawai	0.1
42	HSD	PLTD	West Sumatera	Saumangayak Kep Mentawai	0.2
43	HSD	PLTD	West Sumatera	Simalakopa Kep Mentawai	0
44	HSD	PLTD	West Sumatera	Simalepet Kep Mentawai	0.2
45	HSD	PLTD	West Sumatera	Tua Pejat Kep Mentawai	1.6
46	HSD	PLTD	West Sumatera	Lakuak Pesisir Selatan	1.9
47	HSD	PLTD	West Sumatera	Balai Selasa Pesisir Selatan	0.6
48	HSD	PLTD	West Sumatera	Indra Pura Pesisir Selatan	1.3
49	HSD	PLTD	West Sumatera	Tapan Pesisir Selatan	0.9
50	HSD	PLTD	West Sumatera	Lunang Pesisir Selatan	2.2
51	HSD	PLTD	Bengkulu	PLTD Tersebar S2JB	20.6
52	HSD	PLTD	Bengkulu	PLTD Tersebar S2JB (Sewa)	9.3
53	HSD	PLTD	Lampung	PLTD Tersebar Lampung	0
54	HSD	PLTD	Lampung	PLTD Tersebar Lampung (Sewa)	0
55	HSD	PLTD	Lampung	Tarahan	23.2
56	HSD	PLTG	Lampung	Tarahan (G)	16.2
57	HSD	PLTD	Lampung	Tarahan (Sewa)	23.2
58	HSD	PLTD	Lampung	PLTD Tersebar Lampung	1.2
59	HSD	PLTD	Lampung	PLTD Tersebar Lampung (Sewa)	0
60	HSD	PLTG	DKI Jakarta	Priok	52
61	BBM	PLTD	Jambi	Pelabuhan Dagang	6.4
62	BBM	PLTD	Jambi	Sungai Lokan	1.2
63	BBM	PLTD	Jambi	Mendahara Tengah	0.4
64	BBM	PLTD	Jambi	Kuala Tungkal	3.5
65	BBM	PLTD	Jambi	Batang Asai	0.8
66	BBM	PLTD	Jambi	Sarolangun	3
67	BBM	PLTG	Central Java	Cilacap	55
68	BBM	PLTG	East Java	Gilitimur	40

69	BBM	PLTG	Bali	Pemaron	98
70	BBM	PLTD	Bali	Pesanggaran	0
71	BBM	PLTD	Bali	Pesanggaran BOO	10
72	BBM	PLTD	Bali	Pesanggaran BOT	51
73	BBM/Hydro	PLTD/M	West Kalimantan	Bengkayang	4
74	BBM	PLTD	West Kalimantan	Ngabang	9
75	BBM/Hydro	PLTD	West Kalimantan	Sanggau	24
76	BBM	PLTD	West Kalimantan	Sekadau	12
77	BBM	PLTD	West Kalimantan	Sintang	22
78	BBM	PLTD	West Kalimantan	Putussibau	7
79	BBM	PLTD	West Kalimantan	Nangapinoh	8
80	BBM	PLTD	West Kalimantan	Ketapang	31
81	BBM	PLTD	West Kalimantan	Sistem Isolated	70
82	BBM	PLTG	South Kalimantan	Sistem Barito	21
83	BBM	PLTD	South Kalimantan	Sistem Barito	87.11
84	BBM	PLTD	South Kalimantan	Sistem Barito (Sewa)	74.5
85	BBM	PLTD	South Kalimantan	Sistem Kotabaru	5.4
86	BBM	PLTD	South Kalimantan	Sistem Kotabaru (Sewa)	10
87	BBM	PLTD	South Kalimantan	Sistem ULD Isolated Tersebar	14.4
88	BBM	PLTD	Central Kalimantan	Sistem Barito	32.4
89	BBM	PLTD	Central Kalimantan	Sistem Barito (Sewa)	41.5
90	BBM	PLTD	Central Kalimantan	Sistem Pangkalan Bun	12.82
91	BBM	PLTD	Central Kalimantan	Sistem Pangkalan Bun (Swasta Sewa)	13.4
92	BBM	PLTD	Central Kalimantan	Sistem Buntok	5.58
93	BBM	PLTD	Central Kalimantan	Sistem Buntok (Sewa)	7
94	BBM	PLTD	Central Kalimantan	Sistem Muara Taweh	3.53
95	BBM	PLTD	Central Kalimantan	Sistem Muara Taweh (Sewa)	7.5
96	BBM	PLTD	Central Kalimantan	Sistem Kuala Pambuang	1.8
97	BBM	PLTD	Central Kalimantan	Sistem Kuala Pambuang (Sewa)	4
98	BBM	PLTD	Central Kalimantan	Sistem Nanga Bulik	2.5
99	BBM	PLTD	Central Kalimantan	Sistem Nanga Bulik (Sewa)	2
100	BBM	PLTD	Central Kalimantan	Sistem Kuala Kurun	2.07
101	BBM	PLTD	Central Kalimantan	Sistem Kuala Kurun (Sewa)	3
102	BBM	PLTD	Central Kalimantan	Sistem Puruk Cahu	1.5
103	BBM	PLTD	Central Kalimantan	Sistem Puruk Cahu (Sewa)	4
104	BBM	PLTD	Central Kalimantan	Sistem Sukamara	1
105	BBM	PLTD	Central Kalimantan	Sistem Sukamara (Sewa)	2

106	BBM	PLTD	Central Kalimantan	Sistem ULD Isolated Tersebar	19.7
107	BBM/Gas	PLTD/MG	East Kalimantan	Sistem Petung	21.2
108	BBM	PLTD	East Kalimantan	Sistem Tanah Grogot	17.2
109	BBM	PLTD	East Kalimantan	Sistem Melak	24.7
110	BBM	PLTD	East Kalimantan	Sistem Sangatta	19.7
111	BBM	PLTD	North Kalimantan	Sistem Bulungan	18.9
112	BBM/Gas	PLTD/MG	North Kalimantan	Sistem Nunukan	24.7
113	BBM	PLTD	North Kalimantan	Sistem Malinau	13.1
114	BBM	PLTD	North Kalimantan	Sistem Tidung Pale	3.4
115	BBM/Gas	PLTD/MG	North Kalimantan	Sistem Bunyu	4
116	BBM/Solar	PLTD/S	North Kalimantan	Sistem Sebatik	5.3
117	BBM	PLTD	North Sulawesi	Tahuna	11.4
118	BBM	PLTD	North Sulawesi	Talaud	6.3
119	BBM	PLTD	North Sulawesi	Siau/Ondong	4.9
120	BBM	PLTD	North Sulawesi	Lirung	3.9
121	BBM	PLTD	North Sulawesi	Tagulandang	3.7
122	BBM	PLTD	North Sulawesi	Molibagu	5.2
123	BBM	PLTD	North Sulawesi	Tahuna (isolated tersebar)	3.4
124	BBM	PLTD	North Sulawesi	Manado (isolated tersebar)	4
125	BBM	PLTD	Central Sulawesi	Sistem Palu-Parigi	91
126	BBM	PLTD	Central Sulawesi	Sistem Poso-Tentena	6
127	BBM	PLTD	Central Sulawesi	Luwuk-Tolli	25.2
128	BBM	PLTD	Central Sulawesi	Ampana-Bunta	9.8
129	BBM	PLTD	Central Sulawesi	Toli-toli	14.5
130	BBM	PLTD	Central Sulawesi	Moutong-Kotaraya	12.3
131	BBM	PLTD	Central Sulawesi	Kolonedale	5.9
132	BBM	PLTD	Central Sulawesi	Bungku	7.5
133	BBM	PLTD	Central Sulawesi	Banggai	4.8
134	BBM	PLTD	Central Sulawesi	Leok	11.2
135	BBM	PLTD	Central Sulawesi	Bangkir	4.2
136	BBM	PLTD	Central Sulawesi	Palu (isolated tersebar)	5
137	BBM	PLTD	Central Sulawesi	Luwuk (isolated tersebar)	15.4
138	BBM	PLTD	Central Sulawesi	Toli-toli (isolated tersebar)	3.3
139	BBM	PLTD	Gorontalo	Gorontalo	59.6
140	BBM	PLTG	South Sulawesi	Westcan	14.4
141	BBM	PLTG	South Sulawesi	Altshom 1	21.3

142	BBM	PLTG	South Sulawesi	Altshom 2	20.1
143	BBM	PLTG	South Sulawesi	GE 1	33.4
144	BBM	PLTG	South Sulawesi	GE 2	33.4
145	BBM	PLTD	South Sulawesi	Mitsubishi 1	12.6
146	BBM	PLTD	South Sulawesi	Mitsubishi 2	12.6
147	BBM	PLTD	South Sulawesi	SWD 1	12.4
148	BBM	PLTD	South Sulawesi	SWD 2	12.4
149	BBM	PLTD	South Sulawesi	Suppa	62.2
150	BBM	PLTD	South Sulawesi	Tallasa (Sewa)	80
151	BBM	PLTD	South Sulawesi	Tallo Lama (Sewa)	20
152	BBM	PLTD	South Sulawesi	Sewatama Masamba (Sewa)	5
153	BBM	PLTD	South Sulawesi	Selayar	8.8
154	BBM	PLTD	Southeast Sulawesi	Lambuya	16.5
155	BBM/Hydro	PLTD/M	Southeast Sulawesi	Kolaka	25.1
156	BBM	PLTD	Southeast Sulawesi	Raha	11.8
157	BBM/Hydro	PLTD/M	Southeast Sulawesi	Bau-Bau	47.4
158	BBM	PLTD	Southeast Sulawesi	Wangi-Wangi	5.9
159	BBM/Hydro	PLTD/M	Southeast Sulawesi	Lasusua	10.1
160	BBM	PLTD	Southeast Sulawesi	Bombana	7.6
161	BBM	PLTD	Southeast Sulawesi	Ereke	3.4
162	BBM	PLTD	West Sulawesi	Pasang Kayu	8.41
163	BBM	PLTD	Maluku	Hative Kecil	21.5
164	BBM	PLTD	Maluku	Hative Kecil (Sewa)	20
165	BBM	PLTD	Maluku	Poka	20.8
166	BBM	PLTD	Maluku	Poka (Sewa)	26
167	BBM	PLTD	Maluku	Masohi	4.7
168	BBM	PLTD	Maluku	Masohi (Sewa)	6
169	BBM	PLTD	Maluku	Waipia	0.4
170	BBM	PLTD	Maluku	Liang	0
171	BBM	PLTD	Maluku	Liang (Sewa)	1
172	BBM	PLTD	Maluku	Kairatu	1.3
173	BBM	PLTD	Maluku	Kairatu (Sewa)	4
174	BBM	PLTD	Maluku	Piru	1.5
175	BBM	PLTD	Maluku	Piru (Sewa)	2
176	BBM	PLTD	Maluku	Namlea	4.6
177	BBM	PLTD	Maluku	Namlea (Sewa)	5
178	BBM	PLTD	Maluku	Mako	1.3
179	BBM	PLTD	Maluku	Mako (Sewa)	2

180	BBM	PLTD	Maluku	Saparua	3.2
181	BBM	PLTD	Maluku	Langgur	9.8
182	BBM	PLTD	Maluku	Sistem Tual (Sewa)	4
183	BBM	PLTD	Maluku	Saumlaki	7
184	BBM	PLTD	Maluku	Sistem Saumlaki (Sewa)	1.5
185	BBM	PLTD	Maluku	Dobo	2.5
186	BBM	PLTD	Maluku	Sistem Dobo (Sewa)	1.5
187	BBM	PLTD	Maluku Utara	Kayu Merah	11.6
188	BBM	PLTD	Maluku Utara	Kayu Merah (Sewa)	14
189	BBM	PLTD	Maluku Utara	Soa Siu	4.9
190	BBM	PLTD	Maluku Utara	Soa Siu (Sewa)	10
191	BBM	PLTD	Maluku Utara	Tobelo	6.8
192	BBM	PLTD	Maluku Utara	Tobelo (Sewa)	4
193	BBM	PLTD	Maluku Utara	Malifut	3.2
194	BBM	PLTD	Maluku Utara	Jailolo-Sidangoli	4.6
195	BBM	PLTD	Maluku Utara	Jailolo (Sewa)	3
196	BBM	PLTD	Maluku Utara	Sofifi	3
197	BBM	PLTD	Maluku Utara	Sofifi (Sewa)	3.2
198	BBM	PLTD	Maluku Utara	Payahe	0.4
199	BBM	PLTD	Maluku Utara	Bacan	3.2
200	BBM	PLTD	Maluku Utara	Sistem Bacan (Sewa)	3
201	BBM	PLTD	Maluku Utara	Sanana	2.4
202	BBM	PLTD	Maluku Utara	Sistem Sanana (Sewa)	4
203	BBM	PLTD	Maluku Utara	Daruba	7.3
204	BBM	PLTD	Papua	Genyem	14.7
205	BBM	PLTD/M	Papua	Wamena	7.3
206	BBM	PLTD	Papua	Timika	28.8
207	BBM	PLTD	Papua	Biak	21
208	BBM	PLTD	Papua	Serui	8.4
209	BBM	PLTD	Papua	Merauke	17.7
210	BBM	PLTD	Papua	Nabire	34.5
211	BBM/Solar	PLTD/S	Papua	Lisdes tersebar	13.9
212	BBM/Gas	PLTD/G	West Papua	Sorong	52.8
213	BBM/Hydro	PLTD/M	West Papua	Fak Fak	9.4
214	BBM	PLTD	West Papua	Teminabuan	3.2
215	BBM	PLTD	West Papua	Kaimana	8.7

216	BBM	PLTD	West Papua	Manokwari	31.5
217	BBM	PLTD	West Papua	Bintuni	12.2
218	BBM/Solar	PLTD/S	West Papua	Lisdes tersebar	11.9
219	BBM/Hydro	PLTD/M	NTB	Sumbawa	49.61
220	BBM	PLTD	NTB	Bima	50.72
221	BBM	PLTD	NTB	Sebotok	0.12
222	BBM	PLTD	NTB	Labuhan Haji	0.1
223	BBM	PLTD	NTB	Lebin	0.37
224	BBM	PLTD	NTB	Bugis Medang	0.21
225	BBM	PLTD	NTB	Klawis	0.13
226	BBM	PLTD	NTB	Lunyuk	1.88
227	BBM	PLTD	NTB	Lantung	0.47
228	BBM	PLTD	NTB	Bajo Pulau	0.22
229	BBM	PLTD	NTB	Nggelu	0.07
230	BBM	PLTD	NTB	Pekat	0.62
231	BBM	PLTD	NTT	Sistem Seba, Oesao	2.2
232	BBM	PLTD	NTT	Sistem Soe	7
233	BBM	PLTD	NTT	Sistem Kefamananu	7.1
234	BBM	PLTD	NTT	Sistem Atambua	14.1
235	BBM	PLTD	NTT	Sistem Betun	4.1
236	BBM	PLTD	NTT	Sistem Kalabahi	6.1
237	BBM	PLTD	NTT	Sistem Rote Ndao	4.9
238	BBM/Coal/ Hydro	PLTD/U/M	NTT	Sistem Ende	18.4
239	BBM	PLTD	NTT	Sistem Wolowaru	2.2
240	BBM	PLTD	NTT	Sistem Aesesa	3.2
241	BBM/Solar/ Hydro	PLTD/S/MH	NTT	Sistem Bajawa	12.7
242	BBM/Solar/ Hydro	PLTD/S/MH	NTT	Sistem Ruteng	20.7
243	BBM	PLTD	NTT	Sistem Labuhan Bajo	6.5
244	BBM	PLTD	NTT	Sistem Maumere	14.7
245	BBM	PLTD	NTT	Sistem Larantuka	6.7
246	BBM	PLTD	NTT	Sistem Adonara	5.1
247	BBM/Solar	PLTD/S	NTT	Sistem Lembata	5.5
248	BBM	PLTD	NTT	Sistem Waingapu	8.2
249	BBM/Solar/ Hydro	PLTD/S/MH	NTT	Sistem Waikabubak-Waitabula	10.4
250	BBM/Solar	PLTD/S	NTT	Gab isolated area Kupang	8.7

251	BBM	PLTD	NTT	Gab isolated area FBB	8.8
252	BBM/Solar	PLTD/S	NTT	Gab isolated area FBT	4.6
253	BBM/Hydro	PLTD/MH	NTT	Gab isolated area Sumba	0.8
254	MFO	PLTD	South Sumatera	PT Asta Kramasan Energi (Sewa)	65
255	IDO	PLTD	Jambi	PLTD Tersebar S2JB	0.9
256	IDO	PLTD	South Sumatera	Sungai Juaro	25

BBM = fuel and oil, HSD = high-speed diesel, MFO = marine fuel oil ,NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT), PLTD = Pembangkit Listrik Tenaga Diesel, PLTG = Pembangkit Listrik Tenaga Gas.
Source: MEMR (2016a).

Merits of DES

DES is a good option to fulfil electricity demand of regions consisting of many islands like Indonesia. It has several advantages such as cost competitiveness and its role in optimising local content.

Economy of DES by industrial zone, island, and/or off grid

DES projects, such as micro hydro or solar, when installed in remote areas, will ease the logistics issue of supplying fuel to remote locations. This can result in a more competitive cost of production when compared to diesel power plants. DES installed in a grid-connected system, such as geothermal and hydro, will help reduce distribution losses.

A case study of a micro-hydro power plant in a remote area in East Java shows that the net present value (NPV) of the total production of 101,478 MWh per year, with a 7% interest rate, is 4,2 billion rupiah with payback period of 8 years and return on investment (ROI) of 2.07%.

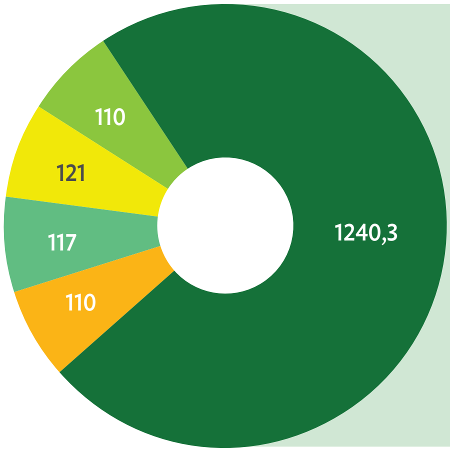
Another study on solar PV in Nias island in North Sumatera evaluated the saving that can be obtained using solar PV when compared to diesel power plants. The size of solar panel of 200Wp (200 watt peak), with total 9,800 panel (1.27 m2 each), electricity production is 2.81 GWh/year. With the solar PV's lifetime of 25 years, interest rate of 7.5% per year, the cost of production is 2,475 rupiah/kWh. The study shows that savings from the use of diesel power plants would be about 759 kilolitre/year.

Energy security brought by DES

- Geothermal power plant

In 2016, the total capacity of geothermal power plants was 1,698.3 MW. This included that of DES geothermal power plants, which is about 1,240.3 MW (73.03% of overall capacity) (Figure 3.2).

Figure 3.2. Geothermal Power Plants
(MW)



Sibayak 1	5	Dieng	60
Sibayak 2	5	Lahendong 1	20
Salak 1	60	Lahendong 2	20
Salak 2	60	Lahendong 3	20
Salak 3	60	Lahendong 4	20
Salak 4	65,6	Lahendong 5	20
Salak 5	65,6	Lahendong 6	20
Salak 6	65,6	Ulubelu 1	55
Patuha 1	55	Ulubelu 2	55
Kamojang 1	30	Ulubelu 3	55
Kamojang 2	55	Ulubelu 4	55
Kamojang 3	55	Ulumbu 1	2,5
Kamojang 4	60	Ulumbu 2	2,5
Kamojang 5	35	Ulumbu 3	2,5
Darajat 1	55	Ulumbu 4	2,5
Darajat 2	94	Mataloko	2,5

Source: Ministry of Energy and Mineral Resources, 2016

Reduction of CO2 emissions through DES

The use of renewable energy will reduce the dependence on fossil fuels and, hence, reduce greenhouse gas (GHG) emission. Based on Indonesia Energy Outlook 2016, if the target on renewable energy and energy intensity could be achieved, reduced emission in 2030 would be 402 million tons of CO2, thus meeting the government target. In the case of geothermal where the share of geothermal capacity less than 100 MW (categorised as DES) is dominant, the contribution from DES will also be substantial in reducing GHG emission.

The method of calculating CO2 emission reduction is referred to as the Greenhouse Gas Equivalencies, which uses the emission factor of 7.03 x 10-4 metric tons CO2/kWh (US EPA, 2016).

Cost–benefit analysis between on grid and off grid

The following section compares the cost of providing electricity to remote, mountainous, and island areas (using average national grid cost) and that of off grid (system cost).

Case Study: Sumba Island

Based on Ministerial Decree No 3051 K/30/MEM/2015 on Sumba Island, an iconic 'Island of Renewables', the Government of Indonesia, in collaboration with local governments, non-governmental organisations, Hivos in Indonesia, and international donors such as the Asian Development Bank and the Norwegian Embassy, established a programme aimed 'to create access to alternative renewable energy which will enable gender-balanced economic well-being to all'. The programme's report in Least-Cost Electrification Plan for the Iconic Island states on the levelised cost of electricity (LCOE) based on a base scenario of 10–20 MW storage hydro and pumped storage scenario of 10 MW Storage Hydro is shown in Table 3.14.

Table 3.14. LCOE Comparison on the Sumba Iconic Island

Base Scenario – 20 MW Storage Hydro	Base Scenario – 10 MW Storage Hydro	Pumped Storage Scenario – 10 MW Storage Hydro	Diesel Only
Solar power 10 MW Wind power 10 MW, Micro-hydro PP 4.5 MW, Hydro (storage) 20 MW, Biomass 10 MW, Diesel 49.3 MW	Solar power 10 MW, Wind power 10 MW, Micro-hydro PP 4.5 MW, Hydro (storage) 20 MW, Biomass 10 MW, Diesel 49.3 MW	Solar power 30 MW, Wind power 20 MW, Micro-hydro PP 4.5 MW, Hydro (storage) 10 MW, Pumped storage 18 MW, Biomass 10 MW, Diesel 49.3 MW	
LCOE: Total generating systems on busbars, including current generators but excluding network costs			
US$0.357/kWh	US$0.279/kWh	US$0.276/kWh	US$0.450/kWh

LCOE = levelised cost of electricity, kWh = kilowatt-hour, MW = megawatt, PP = power plant.
Source: The Government of Indonesia and ADB (2014).

Case study

Based on the characteristics of power plant locations, such as island, remote, and mountainous areas and economic zones, three provinces were selected for the case study: Sumatera Barat (West Sumatera), Jambi, and Kepulauan Riau (Riau Island). West Sumatera has some projects on solar PV, biogas, micro hydro, and geothermal with capacities in line with DES classification. The same is the case for Jambi and Riau islands. Table 3.15 details the current situation and required additional capacities to meet demand.

Table 3.15. Case Study of DES Power Plants in Some Provinces

Model case(s) of introduction of DES (off-grid energy system)		
(1) Site Name	**West Sumatera Province**	
Applications	**Current/existing capacity**	**Required capacity to meet off-grid/mini grid future demand (2025)**
	MW	**MW**
Solar PV		
Wind		
Biomass/biogas		10.0
Micro hydro	66.0	300.2
Geothermal		205.0
Diesel generator	2.9	
Thermal power (coal, slurry, fuel oil, others)		
CHP (incl. heat recovery facility)		
Other generators		
(2) Site Name	**Jambi Province**	
Applications	**Current/existing capacity**	**Required capacity to meet off-grid/mini grid future demand (2025)**
	MW	**MW**
Solar PV		
Wind		
Biomass/biogas		25.0
Micro hydro		20.7
Geothermal		110.0
Diesel generator		
Thermal power (coal, slurry, fuel oil, others)		
CHP (incl. heat recovery facility)		
Other generators (gas)	1,186.8	205.0
(3) Site Name	**Kepulauan Riau (Special Economic Zone)**	
Applications	**Current/existing capacity**	**Required capacity to meet off-grid/mini grid future demand (2025)**
	MW	**MW**
Solar PV		
Wind		

Biomass/biogas	4.8	1.0
Micro hydro		
Geothermal		
Diesel generator	406.7	
Thermal power (coal, slurry, fuel oil, others)	44.0	47.0
CHP (incl. heat recovery facility)		
Other generators (gas)		220.0

CHP = combined heat and power, MW = megawatt, PV = photovoltaic.
Source: MEMR (2016a).

Current policy

Indonesia issued Presidential Decree No. 22 of 2017 on National Energy General Plan (RUEN), which details the country's National Energy Policy. It presents the existing energy condition, target, and measures to achieve the targets: (i) energy consumption per capita to increase to 1.4 toe/capita in 2025 from its current level of 0.4 toe/capita; (ii) on energy mix, 23% renewable energy and reduced share of oil to less than 25% by 2025; and (iii) 2,500 kWh/capita of electricity consumption by 2025 from its current level of below 1,000 kWh/capita.

The government also issued several policies to accelerate the development of energy infrastructure, including lighting remote areas with small-scale renewable energy, which match the criteria of DES.

a. Ministerial Regulation No. 38 of 2016 on Acceleration of Electrification on Less Developed Villages, Remote and Boundary Areas and Small Island Through Small-Scale Electricity Supply

This regulation allows the private sector (non-PLN) to generate electricity and build transmission lines with less than 50 MW capacities using renewable energy. The governor proposes the business area to the minister and offers the area to non-PLN entities (local state-owned and private companies and cooperatives). The proposed area can be classified as either subsidy or non-subsidy based.

b. Ministerial Regulation No. 11 of 2017 on the Utilisation of Gas for Power Plant
This regulation allows the use of wellhead power plants to make the price more competitive. The use of wellhead gas for power plants can be a direct offer or general tender.

c. Ministerial Regulation No. 50 of 2017 on the Utilisation of Renewable Energy Sources for Electricity Supply

This regulation allows PT PLN (Persero) as buyer and the private sector as seller to negotiate the electricity price from renewable energy sources, the mechanism of buying electricity using direct elections, and the build-own-operate-transfer scheme.

Future Development of DES

Based on Government Regulation 79 of 2014 on National Energy Policy, by 2025, renewable energy shall be at least 23% (92.3 Mtoe), oil at most 25%, and gas at least 23% of national energy mix. According to the DES definition, DES is flexible for island, mountainous, and remote areas and economic zones. DES also supports the use of renewable energy resources (geothermal, solar PV, micro hydro, and biomass) to meet future energy demand.

Future installed capacity by type of energy sources

Geothermal

Table 3.16 shows the future development of geothermal.

Hydropower

In 2025, the target for large-scale hydropower is 17,986 MW while for mini/micro-hydro, around 3,000 MW. Tables 3.17 and 3.18 show the future development plan of hydropower and mini/micro hydro based on the National Energy General Plan.

Solar power

Table 3.19 shows the projection of solar power development.

Bioenergy

Table 3.20 shows the projection of bioenergy development until 2025.

Table 3.16. Existing Geothermal Power Plants in Indonesia

No.	Province	Annual Total Installed Capacity (MW)										
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	West Java	1,164.0	1,194.0	1,194.0	1,194.0	1,269.0	1,449.0	1,569.0	1,767.0	1,767.0	1,917.0	1,972.0
2	Lampung	110.0	165.0	220.0	220.0	220.0	220.0	220.0	275.0	495.0	605.0	825.0
3	North Sumatera	12.0	122.0	232.0	342.0	347.0	507.0	587.0	587.0	587.0	717.0	717.0
4	Central Java	60.0	60.0	70.0	70.0	80.0	140.0	200.0	420.0	640.0	710.0	710.0
5	East Java						55.0	165.0	165.0	220.0	440.0	520.0
6	Bengkulu				55.0	110.0	140.0	140.0	255.0	255.0	340.0	505.0
7	South Sumatera			55.0	110.0	110.0	201.0	201.0	256.0	371.0	371.0	505.0
8	West Sumatera					80.0	80.0	80.0	100.0	100.0	300.0	300.0
9	North Sulawesi	80.0	100.0	125.0	130.0	150.0	150.0	170.0	170.0	170.0	210.0	250.0
10	Aceh					10.0	10.0	10.0	65.0	65.0	120.0	230.0
11	Jambi					55.0	60.0	115.0	115.0	145.0	145.0	200.0
12	Banten								110.0	110.0	150.0	150.0
13	NTT	12.5	12.5	12.5	12.5	42.5	77.5	82.5	92.5	102.5	102.5	117.5
14	North Maluku								20.0	20.0	55.0	70.0
15	Central Sulawesi											60.0
16	NTB										20.0	40.0
17	Southeast Sulawesi											20.0
18	Gorontalo										20.0	20.0
19	Maluku					20.0	20.0	20.0	20.0	20.0	20.0	20.0
20	Bali											10.0
21	Central Kalimantan											
	Total Installed Capacity	**1,438.5**	**1,653.5**	**1,908.5**	**2,133.5**	**2,493.5**	**3,109.5**	**3,559.5**	**4,417.5**	**5,067.5**	**6,242.5**	**7,241.5**
	Total Additional per year	**215.0**	**255.0**	**225.0**	**360.0**	**616.0**	**450.0**	**858.0**	**650.0**	**1175.0**	**999.0**	

MW = megawatt, NTB =West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB), NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: MEMR (2017).

Table 3.17. Projection of Hydropower Development (2015–2025)

No.	Province	Annual Total Installed Capacity (MW)										
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	West Java	1,991.9	1,991.9	2,038.9	2,038.9	2,148.9	2,148.9	2,148.9	2,148.9	2,148.9	2,148.9	3,116.6
2	South Sulawesi	521.6	521.6	521.6	521.6	521.6	569.1	803.6	965.6	1,586.6	2,051.6	2,412.6
3	North Sumatera	922.5	967.5	967.5	967.5	1,204.0	1,211.5	1,211.5	1,241.5	1,916.5	1,916.5	2,269.8
4	Papua	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	27.9	47.9	2,208.9
5	Aceh	2.4	2.4	12.4	110.4	128.4	128.4	187.4	187.4	318.4	318.4	1,573.4
6	NTT	-	-	-	-	-	10.0	16.5	16.5	16.5	16.5	929.9
7	West Sulawesi	-	-	-	-	-	-	-	28.0	56.0	206.0	847.8
8	Central Java	306.8	306.8	306.8	306.8	306.8	306.8	306.8	306.8	306.8	656.8	667.1
9	East Kalimantan	-	-	-	-	-	-	-	-	-	275.0	605.0
10	East Java	293.2	293.2	293.2	293.2	293.2	293.2	293.2	430.2	430.2	430.2	430.2
11	Central Sulawesi	195.0	195.0	195.0	195.0	195.0	265.0	265.0	265.0	265.0	345.0	425.0
12	West Sumatera	254.2	254.2	254.2	254.2	254.2	254.2	254.2	306.2	306.2	395.2	395.2
13	Jambi	-	-	-	-	-	-	-	175.0	350.0	350.0	370.7
14	West Papua	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	22.0	22.0	358.1
15	Bengkulu	248.0	248.0	248.0	269.0	269.0	269.0	269.0	296.5	321.5	321.5	348.5
16	West Kalimantan	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	243.5
17	North Kalimantan	-	-	-	-	-	-	-	-	-	110.0	220.0
18	Southeast Sulawesi	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	146.6	182.6	182.6
19	South Kalimantan	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	95.0
20	North Sulawesi	51.4	51.4	51.4	51.4	51.4	63.4	93.4	93.4	93.4	93.4	93.4
21	Lampung	-	-	-	56.0	56.0	56.0	56.0	83.0	83.0	83.0	83.0
22	Riau	-	-	-	-	-	-	-	-	-	-	76.4
23	NTB	-	-	-	-	-	-	-	-	12.0	18.0	18.0
24	Maluku	-	-	-	-	-	-	-	-	16.0	16.0	16.0
	Total Installed Capacity	**4,826.7**	**4,871.7**	**4,928.7**	**5,103.7**	**5,468.2**	**5,615.2**	**5,945.2**	**6,583.7**	**8,455.7**	**10,036.7**	**17,986.7**
	Total Additional per year	**-**	**45.0**	**57.0**	**175.0**	**364.5**	**147.0**	**330.0**	**638.5**	**1,872.0**	**1,581.0**	**7,950.0**

- = missing data , MW = megawatt, NTB = West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB), NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: MEMR (2017).

Table 3.18. Projection of Mini/Micro Hydro Development (2015–2025)

No.	Province	Annual Total Installed Capacity (MW)										
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	North Sumatera	23.9	40.8	48.9	93.9	150.8	160.8	170.8	236.3	236.3	289.8	352.0
2	Central Kalimantan	0.5	0.5	0.5	28.9	28.9	59.5	93.3	122.3	164.8	199.5	243.9
3	West Java	18.3	23.3	48.3	91.3	113.8	132.1	167.6	178.1	195.3	219.7	237.4
4	East Kalimantan	0.7	0.8	0.8	13.4	13.4	32.7	71.5	97.8	144.9	173.9	173.9
5	NTT	4.1	5.2	5.6	23.6	25.2	46.7	66.4	85.7	111.0	134.9	163.5
6	West Sumatera	18.8	20.1	37.8	37.8	77.8	91.2	91.2	111.8	117.8	142.5	142.5
7	Aceh	1.1	1.1	1.1	9.3	11.5	21.8	44.6	81.7	88.5	107.7	132.4
8	Papua	3.5	3.7	8.4	13.6	27.4	28.5	46.5	61.4	84.0	101.5	124.5
9	South Sulawesi	39.1	39.4	48.6	68.9	97.3	107.3	107.3	109.0	109.0	122.3	122.3
10	Central Java	4.7	8.3	9.2	9.2	16.2	25.3	25.3	39.0	47.8	91.9	119.0
11	West Sulawesi	5.0	5.1	5.1	13.3	13.3	27.3	43.2	56.7	76.6	92.6	113.4
12	Bengkulu	0.7	0.7	0.7	0.7	0.7	0.7	7.4	13.4	29.4	34.4	95.4
13	Central Sulawesi	42.3	42.3	43.5	43.5	74.6	74.6	74.6	76.0	76.0	90.0	90.0
14	Southeast Sulawesi	2.9	2.9	7.7	7.7	12.7	14.0	29.4	40.1	58.8	70.7	88.0
15	Jambi	0.3	0.3	0.3	4.4	4.4	11.4	27.4	37.9	57.3	68.7	86.0
16	Maluku	-	-	-	3.3	37.1	42.1	42.1	42.1	50.7	60.7	76.2
17	NTB	13.2	13.3	13.3	14.6	32.0	32.0	32.0	32.3	49.0	58.7	73.6
18	North Maluku	-	-	-	3.2	3.2	8.7	22.5	31.2	47.8	57.2	71.8
19	East Java	1.7	1.7	1.7	1.7	1.7	4.5	4.5	8.9	37.1	49.2	63.0

20	Gorontalo	4.0	4.1	4.1	4.1	6.1	6.1	16.4	24.1	40.6	48.2	61.7
21	Banten	0.1	4.3	15.3	15.3	16.8	21.8	34.8	43.3	43.3	58.3	58.3
22	Lampung	0.6	0.6	0.6	0.6	0.6	0.6	10.1	31.8	35.1	41.2	54.4
23	South Sumatera	1.3	1.3	1.3	2.7	2.7	2.7	20.2	30.2	30.2	36.2	52.4
24	West Kalimantan	0.9	0.9	1.0	2.3	17.5	17.5	17.5	17.5	29.7	34.7	46.2
25	Riau	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.4	20.5	22.9	33.8
26	North Kalimantan	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	14.4	14.4	28.4
27	North Sulawesi	8.2	8.2	8.2	8.7	16.4	16.4	19.7	19.7	19.7	26.1	26.1
28	South Kalimantan	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	15.1	16.3	25.8
29	Bali	-	-	-	1.4	1.4	1.4	1.4	7.3	7.3	23.5	23.5
30	West Papua	1.0	1.0	1.0	2.0	11.0	11.0	11.0	11.0	11.1	11.5	19.8
31	Yogyakarta	0.2	0.2	0.2	0.2	0.2	0.8	0.8	0.8	0.8	0.8	0.8
	Total Installed Capacity	**197.4**	**230.5**	**313.6**	**520.0**	**815.1**	**999.9**	**1,299.9**	**1,650.0**	**2,049.9**	**2,500.0**	**3,000.0**
	Total Additional per year	**-**	**33.1**	**83.2**	**206.3**	**295.1**	**184.9**	**300.0**	**350.0**	**400.0**	**450.0**	**500.0**

- = Missing data, MW = megawatt, NTB =West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB), NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: MEMR (2017).

Table 3.19. Projection of Solar Power Development (2015–2025)

No.	Province	Annual Total Installed Capacity (MW)										
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	NTT	4.2	14.2	15.0	15.0	20.3	40.5	96.8	159.6	238.0	320.7	414.9
2	West Kalimantan	1.3	1.3	1.6	15.1	24.3	43.8	88.3	140.9	209.2	282.4	366.4
3	Gorontalo	0.7	4.7	9.7	9.7	19.7	19.7	35.7	65.4	128.8	218.6	343.3
4	South Sumatera	1.1	1.1	1.1	12.8	20.0	35.8	71.7	114.1	169.3	228.5	296.6
5	NTB	4.7	4.9	25.2	90.2	90.2	90.2	90.2	112.3	167.2	225.4	292.0
6	West Sulawesi	0.5	0.5	0.5	2.4	9.8	23.3	60.5	100.7	150.4	202.6	261.8
7	Jambi	1.0	1.0	3.0	7.1	13.6	27.1	60.7	98.6	146.7	197.9	256.3
8	East Kalimantan	1.6	1.9	2.0	8.4	15.3	27.7	56.1	89.3	132.5	178.9	232.1
9	North Sumatera	16.0	17.7	57.7	57.7	57.7	57.7	57.7	86.2	128.0	176.2	224.1
10	Central Sulawesi	1.4	1.4	11.4	11.4	31.4	31.4	52.7	86.2	128.4	173.1	224.1
11	Central Kalimantan	0.8	1.1	1.1	6.7	13.4	23.7	52.5	85.0	126.5	170.6	221.1
12	Papua	7.8	8.2	19.4	19.4	39.4	39.4	50.7	84.2	125.7	169.3	218.8
13	Southeast Sulawesi	1.9	2.4	9.6	9.6	10.5	21.6	49.7	81.9	122.1	164.6	212.9
14	Aceh	0.8	0.8	2.8	6.2	12.7	22.5	50.2	81.3	121.0	163.2	211.4
15	North Maluku	4.5	4.6	9.6	9.6	9.7	18.9	47.3	78.3	116.8	157.3	203.5
16	Central Java	0.4	0.4	0.4	6.7	12.3	22.1	44.6	71.7	106.6	143.8	186.4
17	East Java	0.5	0.6	3.4	7.7	13.2	23.1	44.9	71.7	106.4	143.6	186.4
18	South Sulawesi	3.9	7.0	8.1	8.1	11.5	21.2	43.8	70.8	105.2	142.0	184.0
19	Maluku	5.0	5.3	10.3	15.3	15.3	17.6	41.9	69.6	103.8	139.9	180.8
20	West Papua	1.8	4.1	4.1	5.0	15.0	19.0	39.8	64.6	96.1	129.5	167.8
21	West Java	0.3	0.3	0.4	6.8	11.5	20.2	39.3	62.7	93.1	125.6	163.0
22	South Kalimantan	1.9	3.9	3.9	4.8	9.7	18.1	38.0	61.5	91.5	123.5	160.0
23	Bengkulu	0.6	0.7	0.7	3.1	8.2	16.5	37.3	61.2	91.3	123.0	159.2

24	West Sumatera	1.7	2.0	2.9	4.6	9.3	17.2	35.9	58.1	86.4	116.6	151.0
25	Lampung	1.3	1.6	1.6	2.1	6.5	13.5	31.3	51.6	77.0	103.8	134.3
26	Riau Islands	1.1	1.1	1.1	5.8	9.5	16.5	31.5	50.2	74.4	100.5	130.4
27	North Sulawesi	3.8	3.8	3.8	3.8	5.6	11.5	26.5	43.7	65.1	87.8	113.6
28	Bangka Belitung	1.6	1.6	3.6	3.6	5.9	11.7	25.9	42.4	63.2	85.2	110.3
29	Bali	4.4	7.5	8.2	8.2	8.2	108.2	108.2	108.2	108.2	108.2	108.2
30	North Kalimantan	0.4	0.6	0.6	3.6	6.6	12.0	24.3	39.1	58.1	78.5	101.7
31	Banten	0.2	0.2	0.3	2.1	5.1	10.0	22.2	36.3	54.0	72.9	94.3
32	Riau	0.9	1.0	1.0	1.0	4.1	9.0	21.8	36.2	54.1	72.8	94.2
33	DI Yogyakarta	0.1	0.1	0.1	1.1	3.7	8.0	18.9	31.3	46.8	63.0	81.5
34	Jakarta	0.2	0.2	0.3	0.3	0.7	1.4	3.2	5.3	7.9	10.7	13.8
	Total Installed Capacity	**78.4**	**107.8**	**224.5**	**375**	**550**	**900**	**1600**	**2500**	**3700**	**5000**	**6500**
	Total Additional per year	**-**	**29.3**	**116.6**	**150.5**	**175.0**	**350.0**	**700.0**	**900.0**	**1200.0**	**1300.0**	**1500.0**

- = missing data, DI = Special Region of Yogyakarta, MW = megawatt, NTB =West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB), NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT) .
Source: MEMR (2017).

Table 3.20. Projection of Bioenergy Development (2015–2025)

No.	Province	Annual Total Installed Capacity (MW)										
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	Riau	179.4	183.4	193.4	195.4	195.4	195.4	195.4	220.7	260.9	306.8	359.0
2	NTT	38.8	39.8	43.8	81.0	110.5	136.9	161.4	190.2	224.0	263.3	308.1
3	East Java	145.4	145.4	145.4	145.4	145.4	145.4	145.4	172.5	204.7	240.9	281.9
4	North Sumatera	126.0	174.5	174.5	176.5	176.5	176.5	176.5	176.5	192.2	226.1	264.5
5	Jambi	88.4	104.4	104.4	104.4	104.4	108.9	132.2	157.1	185.5	218.1	255.2
6	West Sulawesi	30.0	30.0	31.0	41.2	75.3	100.7	120.3	142.3	167.9	197.3	230.9
7	Central Java	98.5	98.5	98.5	98.5	98.5	98.5	111.3	134.5	159.6	187.8	219.8
8	South Sumatera	94.6	98.6	101.1	101.1	101.1	101.1	110.0	132.7	157.4	185.2	216.7
9	West Java	109.3	121.8	121.8	121.8	121.8	121.8	121.8	131.7	157.0	184.9	216.4
10	Central Kalimantan	71.7	72.7	72.7	82.7	82.7	84.2	105.0	125.8	148.9	175.1	204.9
11	Lampung	70.6	70.6	70.6	70.6	70.6	79.5	100.2	120.4	142.6	167.7	196.3
12	West Kalimantan	63.9	63.9	85.9	105.9	105.9	105.9	105.9	117.6	139.2	163.8	191.7
13	Aceh	58.2	71.2	81.0	82.5	82.5	82.5	92.2	110.9	131.3	154.4	180.8
14	West Papua	10.2	10.2	10.2	10.8	49.8	75.5	92.0	109.5	129.3	152.0	177.9
15	NTB	31.1	31.1	32.1	32.1	46.5	74.6	91.6	109.3	129.2	151.9	177.8
16	South Kalimantan	60.4	66.8	66.8	66.8	66.8	66.8	81.9	99.6	118.4	139.4	163.1
17	Southeast Sulawesi	20.8	20.8	20.8	20.8	38.0	65.5	81.1	97.0	114.7	134.9	157.9
18	Central Sulawesi	26.5	26.5	26.5	26.5	33.6	63.1	78.9	94.6	112.0	131.8	154.2
19	North Maluku	16.2	16.2	16.2	16.2	35.7	62.6	77.8	93.0	110.1	129.4	151.5
20	Bengkulu	36.8	42.8	42.8	42.8	42.8	58.2	74.8	90.4	107.3	126.2	147.7
21	South Sulawesi	47.3	47.3	57.3	57.3	57.3	57.3	72.5	88.5	105.2	123.8	144.9
22	Maluku	15.2	15.2	21.2	21.2	30.5	58.1	72.8	87.4	103.5	121.7	142.4
23	Gorontalo	17.8	23.8	23.8	29.8	29.8	53.6	68.3	82.3	97.6	114.8	134.3

24	West Sumatera	46.1	46.1	47.1	47.1	47.1	47.6	66.2	81.6	97.4	114.7	134.2
25	East Kalimantan	45.2	46.2	58.3	67.8	67.8	67.8	67.8	67.8	67.8	76.7	89.8
26	North Sulawesi	14.5	14.5	14.5	14.5	14.5	28.9	43.2	54.2	64.9	76.5	89.6
27	Banten	24.8	24.8	24.8	24.8	24.8	24.8	41.2	53.2	64.1	75.7	88.6
28	Papua	21.2	21.2	21.2	31.2	31.2	31.2	41.8	52.4	62.8	74.1	86.7
29	Bangka Belitung	15.9	25.7	25.7	65.7	65.7	65.7	65.7	65.7	65.7	70.7	82.7
30	DI Yogyakarta	15.4	15.4	15.4	15.4	15.4	20.2	35.7	46.3	56.0	66.1	77.3
31	North Kalimantan	-	-	-	-	-	9.0	29.8	42.1	51.8	61.4	71.8
32	Bali	11.7	12.1	12.1	12.1	12.1	12.1	19.2	29.7	37.3	44.3	51.8
33	Riau Islands	13.0	14.0	14.0	14.0	14.0	14.0	14.0	16.2	22.1	26.6	31.1
34	DKI Jakarta	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	11.8	15.8	18.4
	Total Installed Capacity	**1671**	**1801.7**	**1881**	**2030**	**2200**	**2500**	**2900**	**3400**	**4000**	**4700**	**5500**
	Total Additional per year	**-**	**130.6**	**79.4**	**149.0**	**170.0**	**300.0**	**400.0**	**500.0**	**600.0**	**700.0**	**800.0**

* Administratively, DKI Jakarta is divided into four city administrations (City Administration of South Jakarta, East Jakarta, Central Jakarta, West Jakarta, and North Jakarta) and one Administrative Regency (Thousand Islands or Kepulauan Seribu).
- = missing data , DI = Special Region of Yogyakarta, MW = megawatt, NTB = West Nusa Tenggara (Indonesian: Nusa Tenggara Barat – NTB), NTT = East Nusa Tenggara (Indonesian: Nusa Tenggara Timur – NTT).
Source: MEMR (2017).

Chapter 4
Distributed Energy System in Malaysia

Introduction

Off-grid power generation is meant to supply remote or rural areas, where grid connection is almost impossible in terms of cost and geography, such as island, aboriginal villages, and areas where nature preservation is a concern. Harnessing abundant renewable energy sources using versatile hybrid power systems can offer the best, least-cost alternative solution for extending modern energy services to remote and isolated communities.

The Tenth Malaysia Plan (2011–2015) prioritised rural development to enhance inclusivity as the nation progressed towards becoming an advanced inclusive nation. Rural development focused on uplifting the well-being of the rural community and stimulating economic activities based on land and natural resources. It also emphasised providing rural basic infrastructure, which resulted in the increase of rural water and electricity supply as well as nationwide road coverage. The coverage of rural roads expanded by 11.7% from 45,905 kilometres (km) in 2009 to 51,262 km in 2014. In Sarawak, 250 km of ex-logging roads were upgraded to provide access to 31,512 people in underserved rural areas. In terms of utilities, coverage of rural electricity reached 97.6% and water supply 93.8%; 188,270 water tanks were also provided to supply clean water to 251,200 rural households in the remote areas of Sabah and Sarawak.

Under the Eleventh Malaysia Plan (2016–2020), the Rural Electricity Supply Programme will continue to focus on off-grid generation for remote and isolated areas. The government will also establish partnerships with non-governmental organisations to develop renewable energy sources for the rural community. Micro and pico grids will support the alternative system of solar hybrid and mini hydro to increase coverage. The local community will be trained and encouraged to collaborate in maintaining these facilities to ensure sustainability of the rural alternative electrification system. According to the plan, 99% of rural households will have access to electricity, reaching an additional 36,800 houses.

Current Situation of Distributed Energy System

Current installed capacity by type of energy source

Malaysia's total installed capacity as of end 2015 was 30,439 MW, an increase of 1.5% from 29,974 MW in 2014 (Table 4.1).

In Malaysia, the Electricity Supply Act 1990 (and amendment in year 2001) regulates DES. The act requires any activity related to the supply of electricity to be licensed. In accordance with the Electricity Regulations 1994 (and amendment 2003), two types of licences may be granted: public and private. The Energy Commission (ST) issues licences for the operation of such facilities in Peninsular Malaysia and Sabah. A public licence allows the licensee to operate a public installation to supply energy to others, whereas a private licence is granted to operate a private installation to generate electricity for its own use or at its own property. In terms of renewable energy, the public licensee can sell electricity generated from energy sources to utilities. The private licensee can generate electricity for its own use using efficient technologies such as cogeneration or power generation.

Based on the National Energy Balance report for 2015, the data on DES for Malaysia is as follows (Table 4.2)

Model Case 1: Felda Palm Industries Sdn. Bhd. (Table 4.3)

> 1.Felda Palm Industries Sdn. Bhd. (FPISB) was incorporated in Malaysia on 14 September 1995 under Companies Act 1965 as a private limited company. Formally known as Felda Mills Corporation, it was established on 1 July 1975 under Section 42 of the Land Development Ordinance 1956 as an agency of Federal Land Development Authority (FELDA).
> 2.The FPISB has a paid-up capital of RM202 million (US$1.00 = RM3.9)and the shareholders comprise Felda Holding Berhad (72%) and Koperasi Permodalan Felda (28%). The company's core activities are purchasing and processing of fresh fruit bunch from the Felda estates, settlers, and external suppliers to produce crude palm oil and palm kernel.

Table 4.1. Installed Capacity as of 31 December 2015 in MW

		Hydro	Natural Gas	Coal	Diesel / MFO	Biomass	Solar	Biogas	Others	Total
Peninsular Malaysia	TNB	2,149.1	4,150.0	0.0	0.0	0.0	0.0	0.0	0.0	6,299.1
	IPPs	0.0	6,344.5	8,066.0	0.0	0.0	0.0	0.0	0.0	14,410.5
	Cogeneration	0.0	876.1	0.0	0.0	90.7	0.0	69.5	0.0	1,036.2
	Self-generation	2.1	0.0	0.0	399.0	351.8	1.0	4.9	0.0	758.8
	FiT	23.6	0.0	0.0	0.0	44.4	206.7	30.4	0.0	305.1
	Subtotal	**2,174.8**	**11,370.6**	**8,066.0**	**399.0**	**486.9**	**207.7**	**104.7**	**0.0**	**22,809.8**
Sabah	SESB	76.0	112.0	0.0	180.9	0.0	0.0	0.0	0.0	368.9
	IPPs	0.0	1,012.6	0.0	189.9	0.0	0.0	0.0	0.0	1,202.5
	Cogeneration	0.0	106.8	0.0	0.0	122.7	0.0	0.0	0.0	229.5
	Self-generation	0.0	0.0	0.0	526.8	135.8	0.1	3.4	0.0	666.1
	FiT	6.5	0.0	0.0	0.0	43.0	18.1	2.7	0.0	70.3
	Subtotal	**82.5**	**1,231.4**	**0.0**	**897.6**	**301.5**	**18.3**	**6.1**	**0.0**	**2,537.3**
Sarawak	SEB	1,058.8	614.6	480.0	158.3	0.0	0.0	0.0	0.0	2,311.7
	IPPs	2,400.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,400.0
	Cogeneration	0.0	289.0	0.0	0.0	0.0	0.0	0.0	0.0	289.0
	Self-generation	0.0	0.0	0.0	11.6	74.1	0.3	0.5	5.1	91.5
	Subtotal	**3,458.8**	**903.6**	**480.0**	**169.9**	**74.1**	**0.3**	**0.5**	**5.1**	**5,092.2**
	Total	**5,716.1**	**13,505.6**	**8,546.0**	**1,466.5**	**862.5**	**226.3**	**111.3**	**5.1**	**30,439.3**
	Share (%)	**18.8**	**44.4**	**28.1**	**4.8**	**2.8**	**0.7**	**0.4**	**0.0**	**100.0**

FiT = feed-in tariff, IPP = independent power producer, MFO = , SEB = , SESB =, TNB = . Tenaga Nasional Berhad.

Source: National Energy Balance (NEB) 2015 .

Table 4.2. Electricity Generation and Installed Capacity of Renewable Energy by Private Licensee by Region in 2015

Region	Fuel Type	Installed Capacity (MW)	Generation (GWh)
Peninsular Malaysia	Natural gas	354.48	719.71
	Industrial process waste heat	11.49	17.99
	Diesel	399.03	11.06
	Empty fruit bunch	299.38	76.20
	Palm oil shell and fibre	5.38	0.45
	Palm oil mill effluent	4.85	7.14
	Wood dust	4.14	0.25
	Solar	1.00	0.12
	Hydro	2.13	5.28
	Palm oil waste	17.9	25.69
	Paddy husk	25.00	0.03
	Subtotal	**1,124.77**	**863.92**
Sabah	Empty fruit bunch	11.12	50.27
	Agricultural waste	6.50	0.61
	Diesel	4.15	73.22
	Subtotal	**21.77**	**124.10**
Sarawak	Natural gas	93.00	411.94
	Diesel	9.56	6.35
	Palm oil waste	19.90	34.66
	Wood/sawmill dust	23.90	52.56
	Others	5.05	6.91
	Subtotal	**151.41**	**512.42**
	Grand total	**1,297.95**	**1,500.44**

Source: National Energy Balance (NEB) 2015.

3.The FPISB is the largest crude palm oil producer with a yield of 2.51 million tons per year, which is 17% of Malaysia's total production. Currently, the FPISB operates 69 palm oil mills throughout the country. Total milling capacity currently stands at 3,364 tons of fresh fruit bunch per hour or 17 million tons per year. The FPISB has a total workforce of 5,800 comprising of professionals and semi-skilled workers.

Table 4.3. Background of Umas Palm Oil Mill in Tawau, Sabah

Location	Umas Palm Oil Mill, Tawau, Sabah
Design Biogas Output	1,200 m3/hour
Gas Engine Capacity	1.2 MW
Point of Electricity Injection	Existing Felda Distribution Facility
Electricity Supply Areas	Umas Complex (3,000 houses, offices, and commercial premises)
	Settler family (2,500 houses)
	Staff Quarters (500 houses)

Source: Felda Palm Industries Sdn. Bhd., 2015.

Model Case 2: Sabah Forest Industries Sdn. Bhd. (Table 4.4)

1. Sabah Forest Industries (SFI) is one of Malaysia's largest timber growers and wood processors. It manages a forest estate totalling 288,000 hectares, pulp and paper manufacturing facilities, and an integrated timber complex consisting of a saw mill and a veneer and plywood factory.
2. The SFI is Malaysia's only integrated pulp and paper manufacturer. Recent modifications to its pulp mill have doubled its capacity to 240,000 bone dry tons of pulp per year. Half of this is manufactured into writing and printing paper for domestic and international markets and the other half is exported as market pulp.
3. The majority owner of SFI is Ballarpur Industries Limited, which in turn is part of the Avantha Group of companies.

Table 4.4. Background of Sabah Forest Industries Sdn. Bhd. in Sipitang, Sabah

Licensee and Location of Installation	Energy Source	Licensed Capacity (MW)	Generated Electricity (GWh)
Sabah Forest Industries Sdn Bhd Mukim Kg. Sebubuh Daerah Sipitang	Wood waste	79.5	52.6

GWh = gigawatt-hour, MW = megawatt.

Source: Performance and Statistical Information on Electricity Supply Industry in Malaysia 2015.

Model Case 3: BASF Petronas Chemical Sdn Bhd (Table 4.5)

1. BASF PETRONAS Chemicals celebrated its 20th anniversary in 2017. The company has grown in leaps and bounds since its inception in August 1997.
2. It is a smart joint venture partnership between BASF of Germany, one of the world's largest chemical companies, and PETRONAS, Malaysia's fully integrated oil and gas multinational, under its subsidiary PETRONAS Chemicals Group.
3. With an initial investment of RM3.4 billion (US$1.00 = RM3.90), this partnership brought together a vast amount of experience, innovation, cutting-edge technology, and an abundance of strategically located high-quality resources. The second wave of investments include the RM1.5 billion (about US$500 million) Integrated Aroma Ingredients Complex and production facilities for highly reactive polyisobutylene (HR-PIB), which are expected to come on-stream in 2017 whereas the 2-ethylhexanoic acid plant started up successfully in late 2016.
4. Today, operating from one of the largest Verbund (Integrated) chemical sites in Asia- Pacific, BASF PETRONAS Chemicals has become a leading chemical company, producing and marketing chemical products, which are ever-present and highly essential in consumers' daily lives.

Table 4.5. Background of BASF Petronas Chemicals Sdn. Bhd. In Kuantan, Pahang

Licensee and Location of Installation	Energy Source	Licensed Capacity (MW)	Generated Electricity (GWh)
BASF PETRONAS Chemicals Sdn Bhd Lot 139, Kawasan Perindustrian Gebeng 26080 Kuantan Pahang	Natural Gas	27.4	29.31

GWh = gigawatt-hour, MW = megawatt.

Source: Performance and Statistical Information on Electricity Supply Industry in Malaysia 2015.

Model Case 4: Gas District Cooling (Putrajaya) (GDCP) Sdn Bhd (Table 4.6)

1. GDCP Sdn Bhd was incorporated in 1997.
2. Its principal activities are generation and sale of chilled water for air-conditioning of buildings in Putrajaya.
3. It is 100% owned by Putrajaya Holdings Sdn Bhd.
4. GDCP business operation is governed by a 22-year concession agreement with the government.
5. Currently, the GDCP operates six district cooling plants in Putrajaya, serving mainly government buildings and facilities.

6. Every customer enters a sale and purchase agreement before chilled water is supplied to their respective development project.

Table 4.6. Background of Gas District Cooling (Putrajaya) Sdn. Bhd. In Putrajaya

Licensee and Location of Installation	Energy Source	Licensed Capacity (MW)	Generated Electricity (GWh)
Gas District Cooling (Putrajaya) Sdn Bhd Plot 2U1 Putrajaya Precinct 2 Wilayah Persekutuan Putrajaya	Natural Gas	10.74	23.51

GWh = gigawatt-hour, MW = megawatt.
Source: Energy Commission of Malaysia (2015).

Overview of the Feed-in Tariff System in Malaysia

Malaysia's feed-in tariff (FiT) system obliges distribution licensees to buy from feed-in approval holders the electricity produced from renewable resources (renewable energy) and using the FiT rate, as set by the Ministry, through the Sustainable Energy Development Authority (SEDA). The distribution licensees will pay for renewable energy supplied to the electricity grid for a specific duration (Table 4.7).

By guaranteeing access to the grid and setting a favourable price per unit of renewable energy, the FiT mechanism would ensure that renewable energy becomes a viable and sound long-term investment for companies and individuals.

Key terminologies in FiT:

1. Distribution licensees: Companies holding the licence to distribute electricity (e.g. Tenaga Nasional Berhad, Sabah Electricity Sdn. Bhd., NUR Generation).
2. Feed-in approval holder: An individual or company who holds a feed-in approval certificate issued by the Sustainable Energy Development Authority Malaysia. The holder is eligible to sell renewable energy at the FiT rate.
3. FiT rate: Fixed premium rate payable for each unit of renewable energy sold to distribution licensees. The FiT rate differs for different renewable resources and installed capacities. Bonus FiT rate applies when the criteria for bonus conditions are met.
4. Indigenous: Renewable resources must be from Malaysia and are not imported.
5. Duration: Period during which the renewable electricity could be sold to distribution licensees and paid with the FiT rate. The duration is based on the characteristics of the renewable resources and technologies. The duration is 16 years for biomass and biogas resources, and 21 years for small hydropower and solar photovoltaic (PV) technologies.

Table 4.7. Financial Support for Renewable Power Generation

Renewable Energy	Capacity	Feed-in-Tariff $ cent/kWh
Solar PV	<=4 kW	26.11
	4 kW< x <=24 kW	25.48
	24 kW < x <= 72 kW	21.78
Biomass	<=10 MW	8.79
	10 MW < x <=20 MW	8.22
	20 MW < x <= 30 MW	7.66
Biogas	1 MW < x <=4 MW	9.07
	4 MW < x <=10 MW	8.50
	10 MW < x <= 30 MW	7.94
Hydro	<=10 MW	6.84
	10 MW < x <=30 MW	6.55

kWh = kilowatt-hour, PV = photovoltaic.
Source: Sustainable Energy Development Authority (SEDA) Malaysia, 2017.

Emission Factor in Malaysia

The increase of electricity demand in Malaysia will be a major challenge for the country. This includes the sustainable, reliable, and environment-friendly future electricity supply to meet the international and national growing demand on combating climate change issues and green technology evolution.

The total carbon dioxide ($CO2$) emissions per MWh indicate the $CO2$ emissions from fossil fuels consumed for electricity generation. Thus, the emission per MWh varies a lot across countries and from year to year, depending on generation mix.

Malaysia used the latest and updated version of methodology tool to calculate the emission factor for operation margin and build margin in 2015 (Table 4.8). The result showed that the decreases in the emission factors for Peninsular Malaysia and Sarawak slightly increased for Sabah. This decrease can be due to many reasons, namely, the shutdown of a certain number of fossil fuel-fired power plants, increase in the capacity generation of hydro power and efficiency of technologies installed in the stations as well as the process of electricity transmission and distribution. The development of more fossil-fuel power units increased the emission factor.

Table 4.8. Grid Electricity Emission Factor 2015

Region	2012	2013	2014	2015	Change in % from 2012 to 2015
	t CO_2/MWh				
Peninsular Malaysia	0.741	0.742	0.694	0.680	-8,97
Sabah	0.546	0.533	0.536	0.546	No change
Sarawak	0.872	0.724	0.699	0.597	-46.0

MWh = megawatt-hour, tCO_2 = tonnes of CO_2.

Source: Malaysian Green Technology Corporation (MGTC), 2017.

Based on the emission factor of each region, the potential CO2 avoidance from DES could be calculated. In 2015, this was about 174.52 ktCO2 equivalent. From the total, 51.9% or 90.54 ktCO2 equivalent was from Peninsular Malaysia, 32.2% from Sarawak, and 15.9%, from Sabah (Table 4.9).

Table 4.9. Potential CO_2 Avoidance from DES

Region	Fuel Type	Generation (GWh)	Emission Factor (tCO2/MWh)	ktCO2
Peninsular Malaysia	Industrial process waste heat	17.99	0.680	12.23
	Empty fruit bunch	76.20	0.680	51.82
	Palm oil shell and fibre	0.45	0.680	0.31
	Palm oil mill effluent	7.14	0.680	4.86
	Wood dust	0.25	0.680	0.17
	Solar	0.12	0.680	0.08
	Hydro	5.28	0.680	3.59
	Palm oil waste	25.69	0.680	17.47
	Paddy husk	0.03	0.680	0.02
	Subtotal	**133.15**	**0.680**	**90.54**
Sabah	Empty fruit bunch	50.27	0.546	27.45
	Agricultural waste	0.61	0.546	0.33
	Subtotal	**50.88**	**0.546**	**27.78**
Sarawak	Palm Oil waste	34.66	0.597	20.69
	Wood/sawmill dust	52.56	0.597	31.38
	Others	6.91	0.597	4.13
	Subtotal	**94.13**	**0.597**	**56.20**
	Grand total	**278.16**		**174.52**

GWh = gigawatt-hour, MWh = megawatt-hour, tCO2 = tonnes of CO2 .

Source: Author's Calculation.

Cost–Benefit Analysis

Governments typically use cost–benefit analysis to evaluate the desirability of a given intervention. This tool analyses the cost effectiveness of different alternatives to see whether the benefits outweigh the costs. The aim is to gauge the efficiency of the intervention relative to the status quo. The costs and benefits of an intervention are evaluated in terms of the public's willingness to pay for the impacts (benefits) or willingness to pay to avoid them (costs) (Table 4.10).

Table 4.10. Estimated Various Type of Costs in Power Sector by Fuel Type

	Unit	Biomass	Biogas	PV	Solid Waste	Mini Hydro
Capital cost	US$$/MW	2,236,842	2,407,368	4,276,316	592,105	263,158
Fuel cost	US$/kWh	0.0322	-	-	-	-
Variable cost	US$/kWh	0.0078	0.0026	0.0061	0.0184	0.0061
Fixed cost	US$/MW	80,972	99,714	8,553	85,053	1,293
	Unit	**Gas**	**Coal**	**Hydro**	**Oil**	**Nuclear**
Capital cost	US$/MW	750,000	970,000	263,158	1,448,684	2,560,900
Fuel cost	US$/kWh	0.0225	0.037	-	0.0876	0.0095
Variable cost	US$/kWh	0.0033	0.003	0.0061	0.0071	0.0005
Fixed cost	US$/MW	13,000	20,000	1,293	10,526	42,000

kWh = kilowatt-hour, MWh = megawatt-hour, PV = photovoltaic.
Source: Author's Estimation from literature review.

The estimated costs for off-grid for DES for each case were calculated based on their respective cost elements, such as capital, fuel, variable, and fixed costs (Table 4.11). For case 1, which uses biogas as the main fuel, the estimated cost for off-grid is approximately US$2,878,974. For case 2, which uses biomass as the main fuel with a capacity of 79.5 MW, the estimated off-grid cost is US$177,478,766. As for case 3, which uses natural gas as the main fuel, the estimated off-grid cost is US$20,634,898. For case 4, which uses natural gas as the main fuel at 10.74 MW capacity, the estimated off-grid cost is US$8,398,428.

Assumptions

1. About 5% of transmission line cost was already captured under capital cost.
2. The estimated average transmission line cost is US$180,000 per kilometre.
3. Ten kilometres are required to supply electricity to the national grid from the power plant.

Table 4.11. Estimated Cost Off-Grid

	Case 1	Case 2	Case 3	Case 4
Fuel Type	**Biogas**	**Biomass**	**Natural Gas**	**Natural Gas**
Capacity (MW)	1.20	79.50	27.40	10.74
Generation (GWh)	5.74	52.60	29.31	23.51
Capital cost (US$)	2,744,400	168,937,492	19,522,500	7,652,250
Fuel cost (US$)	–	1,693,720	659,475	528,975
Variable cost (US$)	14,918	410,280	96,723	77,583
Fixed cost (US$)	119,657	6,437,274	356,200	139,620
Total Cost (US$)	**2,878,974**	**177,478,766**	**20,634,898**	**8,398,428**

GWh = gigawatt-hour, MW = megawatt.

Source: Author's Calculation.

With the same parameter data for each case, the estimated total cost was calculated for the on-grid condition (Table 4.12). This is just an analysis to see the difference between off grid and on grid of the total cost for DES. For case 1, the cost for on-grid is about US$4,678,974, 62.5% higher than the estimated cost for off-grid. For case 2, the total cost for on-grid is about US$179,278,766, only 1.0 % more than off-grid. For case 3, the cost for on-grid is about US$22,434,898, 8.7 % higher than the off-grid condition. Finally, for case 4, the total cost for on-grid is about US$10,198,428, about 21.4% higher than for off-grid.

Table 4.12. Estimated Cost On-Grid

	Case 1	Case 2	Case 3	Case 4
Fuel Type	**Biogas**	**Biomass**	**Natural Gas**	**Natural Gas**
Capacity (MW)	1.2	79.5	27.4	10.74
Generation (GWh)	5.7376	52.6	29.31	23.51
Capital cost (US$)	4,544,400	170,737,492	21,322,500	9,452,250
Fuel cost (US$)	–	1,693,720	659,475	528,975
Variable cost (US$)	14,918	410,280	96,723	77,583
Fixed cost (US$)	119,657	6,437,274	356,200	139,620
Total cost (US$)	**4,678,974**	**179,278,766**	**22,434,898**	**10,198,428**

GWh = gigawatt-hour, MW = megawatt.

Source: Author's Calculation.

Current Policy

No specific policy on DES exists in Malaysia. However, some programmes created by the government support the rural electrification activities. The Rural Electricity Supply Programme includes a grid connection method, alternative methods such as hybrid solar and hydro micro, and installation of streetlights in villages to ensure the sufficiency, guarantee, and reliability of electricity supply to the people especially in rural areas.

The Akaun Amanah Industri Bekalan Elektrik (AAIBE) or Malaysian Electricity Supply Industries Trust Account (MESITA) was formed under Section 9 (3) of the Financial Procedure Act 1957, by means of a trust deed on 1 January 1997. It was officially launched in July 1997. The contributors to the fund are the power-generating companies, i.e. Tenaga Nasional Berhad Generation Sdn. Bhd. and independent power producers (IPPs) in Peninsular Malaysia comprising Genting Sanyen Power Sdn Bhd, Port Dickson Power Bhd, Powertek Bhd, Segari Energy Venture Sdn, and YTL Power Generation Sdn Bhd. Their contribution is voluntary, and they contribute 1% of their electricity sales (of their total annual audited turnover) to the Peninsular Grid or the transmission network to the fund.

Future Development of DES

Future installed capacity by type of energy sources

Table 4.13. Future Installed Capacity by Energy Sources in MW

	2020	2030	2040	2050
Hydro	5,967	8,510	8,543	8,543
Natural Gas	14,439	24,837	37,667	51,467
Coal	13,067	18,511	29,311	43,311
Diesel / MFO	1,309	1,137	1,197	1,197
Biomass	867	888	916	916
Solar	1,349	2,619	2,679	2,679
Biogas	189	194	194	194
Others	39	39	39	39
Total	**37,226**	**56,735**	**80,546**	**108,346**

MFO = Medium Fuel Oil.

Source: Results generated from LEAP Software, 2018.

The estimated future installed capacity by type of energy source was calculated based on information from the latest power development plan for the country (Table 4.13).

By 2050, the total installed capacity in the country is expected to be at 108,346 MW. In 2050, about 48% of power-generating capacity will be from natural gas, followed by coal at 40%. The capacity will be from renewable energy such as hydro (8%), solar (2%), and biomass (1%).

Based on estimated future installed capacity, DES for Malaysia for the same period was estimated based on the proportion of the share of DES in 2015 (Tables 4.14 to 4.17).

Table 4.14. Estimated Future DES Installed Capacity and Generation for 2020

Region	Fuel Type	Installed Capacity (MW)	Generation (GWh)
Peninsular Malaysia	Natural gas	378.98	769.45
	Industrial process waste heat	11.55	18.08
	Diesel	356.17	9.87
	Empty fruit bunch	300.94	76.60
	Palm oil shell and fibre	5.41	0.45
	Palm oil mill effluent	8.24	12.12
	Wood dust	4.16	0.25
	Solar	5.96	0.72
	Hydro	2.22	5.51
	Palm oil waste	17.99	25.82
	Paddy husk	25.13	0.03
	Subtotal	**1,116.76**	**918.91**
Sabah	Empty fruit bunch	11.18	50.53
	Agricultural waste	6.53	0.61
	Diesel	8.53	150.56
	Subtotal	**26.25**	**201.70**
Sarawak	Natural gas	99.43	440.41
	Diesel	8.53	5.67
	Palm oil waste	20.00	34.84
	Wood/sawmill dust	24.02	52.83
	Others	5.05	6.91
	Subtotal	**157.04**	**540.66**
	Grand total	**1,300.04**	**1,661.28**

GWh = gigawatt-hour, MW = megawatt.

Source: Author's calculation

Table 4.15. Estimated Future DES Installed Capacity and Generation for 2030

Region	Fuel Type	Installed Capacity (MW)	Generation (GWh)
Peninsular Malaysia	Natural gas	651.89	1,323.56
	Industrial process waste heat	11.83	18.52
	Diesel	309.37	8.57
	Empty fruit bunch	308.23	78.45
	Palm oil shell and fibre	5.54	0.46
	Palm oil mill effluent	8.45	12.45
	Wood dust	4.26	0.26
	Solar	11.57	1.39
	Hydro	3.17	7.86
	Palm oil waste	18.43	26.45
	Paddy husk	25.74	0.03
	Subtotal	**1,358.50**	**1,478.00**
Sabah	Empty fruit bunch	11.45	51.76
	Agricultural waste	6.69	0.63
	Diesel	7.41	130.77
	Subtotal	**25.55**	**183.16**
Sarawak	Natural gas	171.03	757.56
	Diesel	7.41	4.92
	Palm oil waste	20.49	35.68
	Wood/sawmill dust	24.61	54.11
	Others	5.05	6.91
	Subtotal	**228.59**	**859.20**
	Grand total	**1,612.64**	**2,520.36**

GWh = gigawatt-hour, MW = megawatt.

Source: Author's calculation.

Table 4.16. Estimated Future DES Installed Capacity and Generation for 2040

Region	Fuel Type	Installed Capacity (MW)	Generation (GWh)
Peninsular Malaysia	Natural gas	988.64	2,007.26
	Industrial process waste heat	12.20	19.11
	Diesel	325.70	9.03
	Empty fruit bunch	317.95	80.93
	Palm oil shell and fibre	5.71	0.48
	Palm oil mill effluent	8.45	12.45
	Wood dust	4.40	0.27
	Solar	11.84	1.42
	Hydro	3.18	7.89
	Palm oil waste	19.01	27.28
	Paddy husk	26.55	0.03
	Subtotal	**1,723.64**	**2,166.14**
Sabah	Empty fruit bunch	11.81	53.39
	Agricultural waste	6.90	0.65
	Diesel	7.80	137.67
	Subtotal	**26.52**	**191.71**
Sarawak	Natural gas	259.38	1,148.90
	Diesel	7.80	5.18
	Palm oil waste	21.13	36.81
	Wood/sawmill dust	25.38	55.82
	Others	5.05	6.91
	Subtotal	**318.75**	**1,253.62**
	Grand total	**2,068.90**	**3,611.47**

GWh = gigawatt-hour, MW = megawatt.

Source: Author's calculation.

Table 4.17. Estimated Future DES Installed Capacity and Generation for 2050

Region	Fuel Type	Installed Capacity (MW)	Generation (GWh)
Peninsular Malaysia	Natural gas	1,350.85	2,742.66
	Industrial process waste heat	12.20	19.11
	Diesel	325.70	9.03
	Empty fruit bunch	317.95	80.93
	Palm oil shell and fibre	5.71	0.48
	Palm oil mill effluent	8.45	12.45
	Wood dust	4.40	0.27
	Solar	11.84	1.42
	Hydro	3.18	7.89
	Palm oil waste	19.01	27.28
	Paddy husk	26.55	0.03
	Subtotal	**2,085.85**	**2,901.54**
Sabah	Empty fruit bunch	11.81	53.39
	Agricultural waste	6.90	0.65
	Diesel	7.80	137.67
	Subtotal	**26.52**	**191.71**
Sarawak	Natural gas	354.40	1,569.82
	Diesel	7.80	5.18
	Palm oil waste	21.13	36.81
	Wood/sawmill dust	25.38	55.82
	Others	5.05	6.91
	Subtotal	**413.77**	**1,674.54**
	Grand total	**2,526.14**	**4,767.79**

GWh = gigawatt-hour, MW = megawatt.

Source: Author's Calculation.

In 2020, the projected future DES installed capacity is about 1,300 MW. The potential total electricity generation for DES is about 1,661 GWh. For 2030, the installed capacity for DES is about 1,613 MW with potential electricity generation around 2,520 GWh. In 2040, the installed capacity for DES is estimated at 2,069 MW with potential electricity generation about 3,611 GWh. The estimated installed capacity for DES in 2050 is 2,526 MW with potential electricity generation around 4,768 GWh.

Projected Potential CO2 Avoidance from DES in 2020, 2030, 2040, and 2050 [level 1]

Based on estimation of DES in 2020, 2030, 2040, and 2050, we can calculate the projected potential CO2 avoidance. Tables 4.18 to 4.21 show the results for each period.

Table 4.18. Projected Potential CO_2 Avoidance from DES for 2020

Region	Fuel Type	Generation (GWh)	Emission Factor (tCO2/MWh)	ktCO2
Peninsular	Industrial process waste heat	18.08	0.680	12.30
	Empty fruit bunch	76.60	0.680	52.09
	Palm oil shell and fibre	0.45	0.680	0.31
	Palm oil mill effluent	12.12	0.680	8.24
	Wood dust	0.25	0.680	0.17
	Solar	0.72	0.680	0.49
	Hydro	5.51	0.680	3.75
	Palm oil waste	25.82	0.680	17.56
	Paddy husk	0.03	0.680	0.02
	Subtotal	**139.59**	**0.680**	**94.92**
Sabah	Empty fruit bunch	50.53	0.546	27.59
	Agricultural waste	0.61	0.546	0.33
	Subtotal	**51.15**	**0.546**	**27.93**
Sarawak	Palm oil waste	34.84	0.597	20.80
	Wood/sawmill dust	52.83	0.597	31.54
	Others	6.91	0.597	4.13
	Subtotal	**94.59**	**0.597**	**56.47**
	Grand total	**285.32**		**179.31**

GWh = gigawatt-hour, $ktCO_2$ = kilotonnes of CO_2, MW = megawatt, MWh = megawatt-hour, tCO_2 = tonnes of CO_2 .
Source: Author Calculation.

Table 4.19. Projected Potential CO_2 Avoidance from DES for 2030

Region	Fuel Type	Generation (GWh)	Emission Factor (tCO2/MWh)	ktCO2
Peninsular	Industrial process waste heat	18.52	0.680	12.59
	Empty fruit bunch	78.45	0.680	53.35
	Palm oil shell and fibre	0.46	0.680	0.32
	Palm oil mill effluent	12.45	0.680	8.46
	Wood dust	0.26	0.680	0.18
	Solar	1.39	0.680	0.94
	Hydro	7.86	0.680	5.35
	Palm oil waste	26.45	0.680	17.99
	Paddy husk	0.03	0.680	0.02
	Subtotal	**145.87**	**0.680**	**99.19**
Sabah	Empty fruit bunch	51.76	0.546	28.26
	Agricultural waste	0.63	0.546	0.34
	Subtotal	**52.38**	**0.546**	**28.60**
Sarawak	Palm oil waste	35.68	0.597	21.30
	Wood/sawmill dust	54.11	0.597	32.31
	Others	6.91	0.597	4.13
	Subtotal	**96.71**	**0.597**	**57.74**
	Grand total	**294.96**		**185.53**

GWh = gigawatt-hour, $ktCO_2$ = kilotonnes of CO_2, MW = megawatt, MWh = megawatt-hour, tCO_2 = tonnes of CO_2 .
Source: Author Calculation.

Table 4.20. Projected Potential CO_2 Avoidance from DES for 2040

Region	Fuel Type	Generation (GWh)	Emission Factor (tCO2/MWh)	ktCO2
Peninsular	Industrial process waste heat	19.11	0.680	12.99
	Empty fruit bunch	80.93	0.680	55.03
	Palm oil shell and fibre	0.48	0.680	0.32
	Palm oil mill effluent	12.45	0.680	8.46
	Wood dust	0.27	0.680	0.18
	Solar	1.42	0.680	0.97
	Hydro	7.89	0.680	5.37
	Palm oil waste	27.28	0.680	18.55
	Paddy husk	0.03	0.680	0.02
	Subtotal	**149.85**	**0.680**	**101.90**
Sabah	Empty fruit bunch	53.39	0.546	29.15
	Agricultural waste	0.65	0.546	0.35
	Subtotal	**54.04**	**0.546**	**29.50**
Sarawak	Palm oil waste	36.81	0.597	21.98
	Wood/sawmill dust	55.82	0.597	33.32
	Others	6.91	0.597	4.13
	Subtotal	**99.54**	**0.597**	**59.43**
	Grand total	**303.42**		**190.83**

GWh = gigawatt-hour, $ktCO_2$ = kilotonnes of CO_2, MW = megawatt, MWh = megawatt-hour, tCO_2 = tonnes of CO_2 .
Source: Author Calculation.

Table 4.21. Projected Potential CO_2 Avoidance from DES for 2050

Region	Fuel Type	Generation (GWh)	Emission Factor (tCO2/MWh)	ktCO2
Peninsular	Industrial process waste heat	19.11	0.680	12.99
	Empty fruit bunch	80.93	0.680	55.03
	Palm oil shell and fibre	0.48	0.680	0.32
	Palm oil mill effluent	12.45	0.680	8.46
	Wood dust	0.27	0.680	0.18
	Solar	1.42	0.680	0.97
	Hydro	7.89	0.680	5.37
	Palm oil waste	27.28	0.680	18.55
	Paddy husk	0.03	0.680	0.02
	Subtotal	**149.85**	**0.680**	**101.90**
Sabah	Empty fruit bunch	53.39	0.546	29.15
	Agricultural waste	0.65	0.546	0.35
	Subtotal	**54.04**	**0.546**	**29.50**
Sarawak	Palm oil waste	36.81	0.597	21.98
	Wood/sawmill dust	55.82	0.597	33.32
	Others	6.91	0.597	4.13
	Subtotal	**99.54**	**0.597**	**59.43**
	Grand total	**303.42**		**190.83**

GWh = gigawatt-hour, $ktCO_2$ = kilotonnes of CO_2, MW = megawatt, MWh = megawatt-hour, tCO_2 = tonnes of CO_2 .
Source: Author Calculation.

In 2020, the projected potential CO2 avoidance for DES will be about 179.31 ktCO2 equivalent and in 2030 the potential CO2 avoidance for DES will increase to 185.53 ktCO2 equivalent. The potential projected CO2 avoidance for DES in 2040 is expected to increase to 190.83 ktCO2 equivalent. By 2050, the projected potential CO2 avoidance from DES will be 190.83 ktCO2 equivalent.

Table 4.22. Estimated Cost Between Off Grid and On Grid for DES in 2020

2020				Off-Grid					On-Grid				
Region	Fuel Type	Installed Capacity (MW)	Generation (GWh)	Capital Cost (US$)	Fuel Cost (US$)	Variable Cost (US$)	Fixed Cost (US$)	Total Cost (US$)	Capital Cost (US$)	Fuel Cost (US$)	Variable Cost (US$)	Fixed Cost (US$)	Total Cost (US$)
Peninsular Malaysia	Natural gas	378.98	769.45	284,234,135.47	17,312,639.61	2,539,187.14	4,926,725.01	309,012,687.24	286,034,135.47	17,312,639.61	2,539,187.14	4,926,725.01	310,812,687.24
	Industrial process waste heat	11.55	18.08	25,853.408.40	582,300.32	141,054.11	935,222.38	27,493,985.21	27,635,408.40	582,300.32	141,054.11	935,222.38	29,293,985.21
	Diesel	356.17	9.87	515,984,660.66	864,802.25	70,092.42	3,749,095.41	520,668,650.75	517,784,660.66	864,802.25	70,092.42	3,749,095.41	522,468,650.75
	Empty fruit bunch	300.94	76.60	673,159,666.26	2,466,441.60	597,461.01	24,367,874.22	700,591,443.09	674,959,666.26	2,466,441.60	597,461.01	24,367,874.22	702,391,443.09
	Palm oil shell and fibre	5.41	0.45	12,096,997.14	14,565.60	3,528.31	437,902.21	12,552,993.26	13,896,997.14	14,565.60	3,528.31	437,902.21	14,352,993.26
	Palm oil mill effluent	8.24	12.12	19,826,719.47	0	31,523,77	539,260.25	20,397,503.49	21,626,719.47	-	31,523.77	539,260.25	22,197,503,49
	Wood dust	4.16	0.25	9,308,841.67	8,092.00	1,960.17	336,973.08	9,655,866.92	11,108,841.67	8,092.00	1,960.17	336,937.08	11,455,866.92
	Solar	5.96	0.72	25,491,605.32	0	4,363.54	50,985.40	25,546,954.26	27,291,605.32	-	4,363.54	50,985.40	27,346,954.26
	Hydro	2.22	5.51	585,130.05	0	33,621.72	2,874.98	621,626.75	2,385,130.05	-	33,621.72	2,874.98	2,421,626.75
	Palm oil waste	17.99	25.82	40,248,373.39	831,533.92	201,427.47	1,456,960.88	42,738,295.66	42,048,373.39	831,533.92	201,427.47	1,456,960.88	44,538,295.66
	Paddy husk	25.13	0.03	56,212,812.00	971.04	235.22	2,034,861.57	58,248,879.83	58.012,821.00	971.04	235.22	2,034,861.57	60,048,879.83
	Subtotal	**1,116.76**	**918.91**	**1,662,984,349.83**	**22,081,346.34**	**3,624,454.90**	**38.838,735.38**	**1,727,528,886.45**	**1,682,784,349.83**	**22,081,346.34**	**3,624,454.90**	**38,838,735.38**	**1,747,328,886.45**
Sabah	Empty fruit bunch	11.18	50.53	25,003,458.78	1,627,139.36	394,151.77	905,106.42	27,929,856.33	26,803,458.78	1,627,139.36	394.151.77	905,106.42	29,729,856.33
	Agricultural waste	6.53	0.61	14,615,331.12	19,744.48	4,782.82	529.064.01	15,168.922.43	16,415,331.12	19,744.48	4,782.82	529,064.01	16,968,922.43
	Diesel	8.53	150.56	12,362,011.27	13,188,676.19	1,068,945.22	88,821.20	26.709.453.87	14,162,011.27	13,188,676.19	1,068.945.22	89,821.20	28,509,453.87
	Subtotal	**26.25**	**201.70**	**51,980,801.61**	**14,835,560.03**	**1,467,879.81**	**1,523,991.63**	**69,808,232.63**	**57,380,801.16**	**14,835,560.03**	**1,467,879,81**	**1,523,991.63**	**75,208,232.63**
Sarawak	Natural gas	99.43	440.41	74,570,567.02	9,909,225.61	1,453,353.09	1,292,556.50	87,225,702.21	76,370,567.02	9,909,225.61	1,453,353.09	1,292,556.50	89,025,702.21
	Diesel	8.53	5.67	12,362,011.27	496,518.47	40,242.94	59,661.57	12,958,434.24	14,162,011.27	496,518.47	40,242.94	59,661.57	14,758,434.24
	Palm oil waste	20.00	34.84	44,745,398.35	1,121,874.88	271,758.51	1,619,749.81	47,758,781.55	46,545,398.35	1,121,874.88	271,758.51	1,619,749.81	49,558,781.55
	Wood/sawmill dust	24.02	52.83	53,739,448.27	1,701,262.08	412,106.96	1,945,327.66	57,798,144,97	55,539,448.27	1,701,262.08	412,106.96	1,945,327.66	59,598,144.97
	Others	5.05	6.91	11,296,052.10	222,502.00	53,898.00	408,908.60	11,981,360.70	13,096,052.10	222,502.00	53,898.00	408,908.60	13,781,360.70
	Subtotal	**157.04**	**540.66**	**196,713,477.02**	**13,451,383.04**	**2,231,359.50**	**5,326,204.13**	**217,722,423.68**	**205,713,447.02**	**13,451,383.04**	**2,231,359.50**	**5,326,204.13**	**226,772,423.68**
	Grand total	**1,300.04**	**1,661.28**	**1,911,678,628.01**	**50,368,289.41**	**7,323,694.21**	**45,688,931.13**	**2,015,059,542.77**	**1,945,878,628.01**	**50,368,289.41**	**7,323,694.21**	**45,688,931.13**	**2,049,259,542.77**

Source: Author’s calculation.

Table 4.23. Estimated Cost Between Off Grid and On Grid for DES in 2030

2030				Off-Grid					On-Grid				
Region	Fuel Type	Installed Capacity (MW)	Generation (GWh)	Capital Cost (US$)	Fuel Cost (US$)	Variable Cost (US$)	Fixed Cost (US$)	Total Cost (US$)	Capital Cost (US$)	Fuel Cost (USD)	Variable Cost (US$)	Fixed Cost (US$)	Total Cost (US$)
Peninsular Malaysia	Natural gas	651.89	1,323.56	488,920,508.53	29,780,042.25	4,367,739.53	8,474,622.15	531,542,912.45	490,720,508.53	29,780,042.25	4,367,739.53	8,474,622.15	533,342,912.45
	Industrial process waste heat	11.83	18.52	26,461,179.53	596,404.48	144,470.65	957,874.82	28,159,929.48	28,261,179.53	596,404.48	144,470.65	957,874.82	29,959,929.48
	Diesel	309.37	8.57	448,185,301.13	751,168.95	60,882.42	3,256,471.72	452,253,824.22	449,985,301.13	751,168.95	60,882.42	3,256,471.72	454,053,824.22
	Empty fruit bunch	308.23	78.45	689,464,571.67	2,526,182.40	611,932.38	24,958,099,54	717,560,786.00	691,264,571,67	2,526,182.40	611,932.38	24,958,099.54	719,360,786.00
	Palm oil shell and fibre	5.54	0.46	12,390,003.99	14,918.40	3,613.77	448,508,84	12,857,045.00	14,190,235.86	14,918.40	3,613.77	448,508.84	14,657,045.00
	Palm oil mill effluent	8.45	12.45	20,351,235.86	0	32,357.74	552,321.92	20,935,915.51	22,151,235.86	-	32,357.74	552,321.92	22,735,915.51
	Wood dust	4.26	0.26	9,534,315.34	8,288.00	2,007.65	345,135.05	9,889,746.05	11,334,315.34	8,288.00	2,007.65	345,135.05	11,689,746.05
	Solar	11.57	1.39	49,490,373.86	0	8,471.53	98,985.01	49,597,830.40	51,290,373.86	-	8,471.53	98,985.01	51,397,830.40
	Hydro	3.17	7.86	834,499.20	0	47,950.54	4,100.23	886,549.96	2,634,499.20	-	47,950.54	4,100.23	2,686,549.96
	Palm oil waste	18.43	26.45	41,223,247.49	851,674.88	206,306.34	1,492,250.59	43,773,479.30	43,023,247.49	851,674.88	206,306.34	1,492,250.59	45,573,479.30
	Paddy husk	25.74	0.03	57,574,368.00	994.56	240.92	2,084,148.87	59,659,752.35	59,374,368.00	994.56	240.92	2,084,148.87	61,459,752.35
	Subtotal	**1,358.50**	**1,478.00**	**1,844,429,604.60**	**34,529,673.92**	**5,485,973.47**	**42,672,518.73**	**1,927,117,770.72**	**1,864,229,604.60**	**34,529,673.92**	**5,485,973.47**	**42,672,518.78**	**1,946,917,770.72**
Sabah	Empty fruit bunch	11,45	51.76	25,609,078.89	1,666,551.04	403,698.70	927,029.42	28,606,358.04	27,409,078.89	1,666,551.04	403,698.70	927,029.42	30.406.358.04
	Agricultural waste	6.69	0.63	14,969,335.68	20,222.04	4,898.67	541,878.71	15,536,335.78	16,769,335.68	20,222.72	4,898.67	541,878.71	17,336,335.78
	Diesel	7.41	130.77	10,737,667.54	11,455,710.33	928,487.94	78,018.71	23,199,884.68	12,537,667.54	11,455,710.33	928,487.94	78,018.87	24,999,884.68
	Subtotal	**25.55**	**183.16**	**51,316,082.11**	**13,142,484.09**	**1,337,085.31**	**1,546,926.99**	**67,342,578.50**	**56,716,082,11**	**13,142,484.09**	**1,337,085.31**	**1,546,926.99**	**72,742,578.50**
Sarawak	Natural gas	171.03	757.56	128,271,291.17	17,045,185.70	2,499,960.57	2,223,369.05	150,039,806.49	130.071.291.17	17,045,185.70	2,499,960.57	2,223,369.05	151,839,806.49
	Diesel	7.41	4.92	10,737,667.54	431,376.93	34,955.09	51,822.16	11,255,721.72	12,537,667.54	431,276.93	34,955.09	51,822.16	13,005,721.72
	Palm oil waste	20.49	35.68	45,829,196.93	1,149,048.32	278.340.90	1,658,982.50	48,915,568.65	47,629,196.93	1,149,048.32	278,340.90	1,658,982.50	50,715,568.65
	Wood/sawmill dust	24.61	54.11	55,041,095.81	1,742,469.12	422,088.79	1,992,446.32	59,198,100.04	56,841,095.81	1,742,469.12	422,088.79	1,992,446.32	60,998,100.04
	Others	5.05	6.91	11,296,052.10	222,502.00	53,898.00	408,908.60	11,981,360.70	13,096,052.10	222,502.00	53,898.00	408,908.60	13,781,360.70
	Subtotal	**228.59**	**859.20**	**251,175,303.54**	**20,590,482.08**	**3,289,243.35**	**6,335,528.62**	**218,390,557.60**	**260,175,303.54**	**20,590,482.08**	**3,289,243.35**	**6,335,528.62**	**290,390,557.60**
	Grand total	**1,612.64**	**2,520.36**	**2,146,920,990.25**	**68,262,640.09**	**10,112,302.13**	**50,554,974.35**	**2,275,850,906.82**	**2,181,120,990.25**	**68,262,640.09**	**10,112,302.13**	**50,554,974.35**	**2,310,050,906.82**

Source: Author's calculation.

Table 4.24. Estimated Cost Between Off Grid and On Grid for DES in 2040

2040				Off-Grid					On-Grid				
Region	Fuel Type	Installed Capacity (MW)	Generation (GWh)	Capital Cost (US$)	Fuel Cost (US$)	Variable Cost (US$)	Fixed Cost (US$)	Total Cost (US$)	Capital Cost (US$)	Fuel Cost (US$)	Variable Cost (US$)	Fixed Cost (US$)	Total Cost (US$)
Peninsular Malaysia	Natural gas	988.64	2,007.26	741,481,209.28	45,163,459.81	6,623,974.11	12,852,340.96	806,120,984.15	743,281,209.28	45,163,459.81	6,623,974.11	12,852,340.96	807,920,984.15
	Industrial process waste heat	12.20	19.11	27,295,541.05	615,210.03	149,026.03	988,078.08	29,047,855.19	29,905,541.05	615,210.03	149,026.03	988,078.08	30,847,855.19
	Diesel	325.70	9.03	471,836,240.50	790,808.48	64,095.21	3,428,317.20	476,119,461.38	473,636,240.50	790,808.48	64,095.21	3,428,317.20	477,919,461.38
	Empty fruit bunch	317.95	80.93	711,204,445.56	2,605,836.80	631,227.55	25,745,066.65	740,186,576.55	713,004,445.56	2,605,836.80	631,227.55	25,745,066.65	741,986,576.55
	Palm oil shell and fibre	5.71	0.48	12,780,679.80	15,388.80	3,727.72	462,651.01	13,262,447.32	14,580,679.80	15,388.80	3,727.72	462,651.01	15,062,447.32
	Palm oil mill effluent	8.45	12.45	20,351,235.86	0	32,357.74	569,737.47	20,953,331.07	22,151,235.86	-	32,357.74	569,737.47	22,753,331.07
	Wood dust	4.40	0.27	9,834,946.91	8,549.33	2,070.96	356,017.69	10,201,584.89	11,634,946.91	8,549.33	2,070.96	356,017.69	12,001,584.89
	Solar	11.84	1.42	50,624,173.95	0	8,665.61	101,252.70	50,734,092.26	52,424,173.95	-	8,665.61	101,252.70	52,534,092.26
	Hydro	3.18	7.89	837,735.21	0	48,136.48	4,116.13	889,987.82	2,637,735.21	-	48,136.48	4,116.13	2,689,987.82
	Palm oil waste	19.01	27.28	42,523,079.62	878,529.49	212,811.49	1,539,303.54	45,153,724.14	44,323,079.62	878,529.49	212,811.49	1,539,303.54	46,953,724.14
	Paddy husk	26.55	0.03	59,489,776.00	1,025.92	248.51	2,149,865.28	61,540,915.71	61,189,776.00	1,025.92	248.51	2,149,865.28	63,340,915.71
	Subtotal	**1723.64**	**2,166.14**	**2,148,159,063.71**	**50,078,808.66**	**7,776,341.41**	**48,196,746.69**	**2,254,210,960.48**	**2,167,959,063.71**	**50,078,808.66**	**7,776,341.41**	**48,196,746.69**	**2,274,010,960.48**
Sabah	Empty fruit bunch	11.81	53.39	26,416,572.36	1,719,099.95	416,427.94	956,260.07	29,508,360.32	28,216,572.36	1,719,099.95	416,427.94	956,260.07	31,308,360.32
	Agricultural waste	6.90	0.65	15,441,341.76	20,860.37	5,053.13	558,964.97	16,026,220.24	17,241,341.76	20,860.37	5,053.13	558,964.97	17,826,220.24
	Diesel	7.80	137.67	11,304,299.07	12,060,233.31	977,484.66	82,135.96	24,424,153.00	13,104,299.07	12,060,233.31	977,484.66	82,135.96	26,224,153.00
	Subtotal	**26.52**	**191.71**	**53,162,213.20**	**13,800,193.63**	**1,398,965.73**	**1,597,361.01**	**69.958,733.57**	**58,562,213.20**	**13,800,193.63**	**1,398,965.73**	**1,597,361.01**	**75,358,733.57**
Sarawak	Natural gas	259.38	1,148.90	194,532,138.52	25,850,183.59	3,791,360.26	3,371,890.40	227,545,572.78	196,332.138.52	25,850,183.59	3,791,360.26	3,371,890.40	229,345,572.78
	Diesel	7.80	5.18	11,304,299.07	454,035.61	36,799.69	54,556.84	11,849,691.22	13,104,299.07	454,035.61	36,799.69	54,556.84	13,649,691.21
	Palm oil waste	21.13	36.81	47,274,261.70	1,185,279.57	287,117.41	1,711,292.76	50,457,951.44	49,074,261.70	1,185,279.57	287,117.41	1,711,292.76	52,257,951.44
	Wood/sawmill dust	25.38	55.82	56,776,625.86	1,797,411.84	435,397.90	2,055,271.20	61,064,706.80	58,576,625.86	1,797,411.84	435,397.90	2,055,271.20	62,864,706.80
	Others	5.05	6.91	11,296,052.10	222,502.00	53,898.00	408,908.60	11,981,360.70	13,096,052.10	222,502.00	53,898.00	408,908.60	13,781,360.70
	Subtotal	**318.75**	**1,253.62**	**321,183,377.25**	**29,509,412.62**	**4,604,573.26**	**7,601,919.80**	**362,899,282.92**	**330,183,377.25**	**29,504,412.62**	**4,604,573.26**	**7,601,919.80**	**371,899,282.92**
	Grand total	**2,068.9**	**3,611.47**	**2,522,504,654.16**	**93,388,414.90**	**13,779,880.40**	**57,396,027.50**	**2,687,068,976.97**	**2,556,704,654.16**	**93,388,414.90**	**13,779,880.40**	**57,396,027.50**	**2,721,268,976,97**

Source: Author's calculation.

Table 4.25. Estimated Cost Between Off Grid and On Grid for DES in 2050

2050				Off-Grid					On-Grid				
Region	Fuel Type	Installed Capacity (MW)	Generation (GWh)	Capital Cost (US$)	Fuel Cost (US$)	Variable Cost (US$)	Fixed Cost (US$)	Total Cost (US$)	Capital Cost (US$)	Fuel Cost (US$)	Variable Cost (US$)	Fixed Cost (US$)	Total Cost (US$)
Peninsular Malaysia	Natural gas	1,350.85	2,742.66	1,013,136,522.63	61,709,926.09	9,050,789.16	17,561,033.06	1,101,458,270.94	1,104,936,522.63	61,709,926.09	9,050,789.16	17,561,033.06	1,103,258,270.94
	Industrial process waste heat	12.20	19.11	27,295,541.05	615,210.03	149,026.03	988,078.08	29,047,855.19	29,095,541.05	615,210.03	149,026.03	988,078.08	30,847,855.19
	Diesel	325.70	9.03	471,836,240.50	790,808.48	64,095.21	3,428,317.20	476,119,461.38	473,636,240.50	790,808.48	64,095.21	3,428,317.20	477,919,461.38
	Empty fruit bunch	317.95	80.93	711,204,445.56	2,605,836.80	631,227.55	25,745,066.65	740,186,576.55	713,004,445.56	2,605,836.80	631,227.55	25,745,066.65	741,986,576.55
	Palm oil shell and fibre	5.71	0.48	12,780,679.80	15,388.80	3,727.72	462,651.01	13,262,447.32	14,580,679.80	15,388.80	3,727.72	462,651.01	15,062,447.32
	Palm oil mill effluent	8.45	12.45	20,351,235.86	0	32,357.74	569,737.47	20,953,331.07	22,151,235.86	-	32,357.74	569,737.47	22,753,331.07
	Wood dust	4.40	0.27	9,834,946.91	8,549.33	2,070.96	356,017.69	10,201,548.89	11,634,946.91	8,549.33	2,070.96	356,017.69	12,001,584.89
	Solar	11.84	1.42	50,624,173.95	0	8,665.61	101,252.70	50,734,092.26	54,424,173.95	-	8665.61	101,252.70	52,534,092.26
	Hydro	3.18	7.89	837,735.21	0	48,136.48	4,116.13	889,987.82	2,637,735.21	-	48,136.48	4,116.13	2,689,987.82
	Palm oil waste	19.01	27.28	42,523,079.62	878,529.49	212,811.49	1,539,303.54	45,153,724.14	44,323,079.62	878,529.49	212,811.49	1,539,303.54	46,953,724.14
	Paddy husk	26.55	0.03	59,389,776.00	1,025.92	248.51	2,149,865.28	61,540,915.71	61,189,776.00	1,025.92	248.51	2,149,865.28	63,340,915.71
	Subtotal	**2,085.85**	**2,901.54**	**2,419,814,377.07**	**66.625,274.94**	**10,203,156.46**	**52,905,438.79**	**2,549,548,247.26**	**2,439,614,377.07**	**66,625,274.94**	**10,203,156.46**	**52,905,438.79**	**2,569,348,247.26**
Sabah	Empty fruit bunch	11.81	53.39	26,416,572.36	1,719,099.95	416,427.94	956,260.07	29,508,360.32	28,216,572.36	1,719,099.95	416,427.94	956,260.07	31,308,360.32
	Agricultural waste	6.90	0.65	15,441,341.76	20,860.37	5,053.13	558,964.97	16,026,220.24	17,241,341.76	20,860.37	5,053.13	558,964.97	17,826,220.24
	Diesel	7.80	137.67	11,304,299.07	12,060,233.31	977,484.66	82,135.96	24,424,153.00	13,104,299.07	12,060,233.31	977,484.66	82,135.96	26,224,153.00
	Subtotal	**26.52**	**191.71**	**53,162,213.20**	**13,800,193.63**	**1,398,965.73**	**1,597,361.01**	**69,958,733.57**	**58,562,213.20**	**13,800,193.63**	**1,398,965.73**	**1,597,361.01**	**75,358,733.57**
Sarawak	Natural gas	354.40	1,569.82	265,802,574.49	35,320,875.01	5,180,395.00	4,607,244.62	310,911,089.12	267,602,574.49	35,320,875.01	5,180,395.00	4,607,244.62	312,711,089.12
	Diesel	7.80	5.18	11,304,299.07	454,035.61	36,799.69	54,556.84	11,849,691.21	13,103,299.07	454,034.61	36,799.69	54,556.84	13,649,691.21
	Palm oil waste	21.13	36.81	47,274,261.70	1,185,279.57	287,117.41	1,711,292.76	50,457,951.44	49,074,261.70	1,185,279.57	287,117.41	1,711,292.76	52,257,951.44
	Wood/sawmill dust	25.38	55.82	56,776,625.86	1,797,411.84	435,397.90	2,055,271.20	61,064,706.80	58,576,625.86	1,797,411.84	435,397.90	2,055,271.20	62,864,708.80
	Others	5.05	6.91	11,296,052.10	222,502.00	55,898.00	408,908.60	11,981,360.70	13,096,052.10	222,502.00	53,898.00	408,908.60	13,781,360.70
	Subtotal	**413.77**	**1,674.54**	**392,453,813.21**	**39,980,104.03**	**5,993,608.00**	**8,837,274.02**	**446,264,799.27**	**401,453,813.21**	**39,980,104.03**	**5,993,608.00**	**8,837,274.02**	**455,264,799.27**
	Grand total	**2,526.14**	**4,767.79**	**2,865,430,403.48**	**119,405,572.60**	**17,595,730.20**	**63,340,073.82**	**3,065,771,780.10**	**2,899,630,403.48**	**119,405,572.60**	**17,595,730.20**	**63,340,073.82**	**3,099,971,780.10**

Source: Author's calculation.

Chapter 5
Distributed Energy System in the Philippines

Introduction

For a developing country like the Philippines, energy demand will constantly increase through the years with rapid urbanisation and increased economic growth and industrialisation. The aspiration of the present Duterte administration towards industrialised Philippines would necessarily require ensured sufficient energy to support and drive the country towards this direction. And whilst the country is inducing more private investment in the generation sector and pursuing distribution and transmission reinforcements to support its power requirements, it still struggles to provide stable and reliable power supply.

The country's archipelagic state remains a major constraint in strengthening the transmission and distribution infrastructures to be able to deliver power supply to end users. This limitation clearly deprives the communities in remote islands from access to electricity. Furthermore, implementation of power projects in the projected period is not guaranteed due to lengthy government processes and requirements. These are just some challenges that have prompted the Philippines to start exploring distributed energy system (DES) as a viable option to satisfy immediate electricity demands.

DES applies to all distributed generation or decentralised power system where electric power is produced and consumed locally at or near the consumers; it can either be utility or consumer owned. Off grid can be a stand-alone generation having no connection to the national grid whilst on grid is termed embedded generation[1] or self-generating generator. Several technologies that form DES both in off-grid and on-grid areas include solar photovoltaic (PV), wind, solar, hydro, biomass, geothermal, diesel, coal, gas, and waste-to-heat recovery/cogeneration.

[1] Embedded generator refers to generating units that are indirectly connected to the grid through the distribution utilities system or industrial generation facilities that are synchronised with the grid.

The advent of DES applications in the Philippines is progressively transforming the landscape of the power sector and its associated challenges. Today, DES begins to become part of the country's power system primarily for services such as emergency power, uninterruptible supply, or ancillary service. Its dynamic features have responded to the complexity of the generation, transmission, and distribution systems incited by costly investment on conventional power plants, power losses, reliability issues, and environmental concerns, amongst others. It has become an effective energy solution for areas where electricity access seems to be unachievable. This energy system made it possible for consumers to be not just mere recipients of electricity supply, but also suppliers by allowing them to generate their own electricity and export excess to the grid.

As DES continuously becomes more desirable and economical because of its scale, flexibility, and proximity to the consumers, distributed generation may eventually be on par with centralised generation in the coming years. The continued technical advancement in the electric power system offers better opportunities for distributed generation to become as important as centralised generation. The widely growing interest of the implementation of DES applications simply suggests that it will become a significant element in restructuring and modernising the country's power industry.

Methodology

On-Grid/Embedded Generations

The 2008–2015 data on power generation submitted by generation companies and distribution utilities through their monthly operations report served as the working database to assess the demand projection of on-grid DES/embedded generations by 2025 and 2040. Since the country's system operator, the National Grid Corporation of the Philippines, does not capture and monitor embedded generations, the primary data needed for projections were sourced from the monthly operations report submitted to the Department of Energy (DOE). From this, all embedded generations were obtained and disaggregated per technology.

The base case demand projection was primarily derived using an econometric model of electricity generation based on technology, with economic growth and time trend as explanatory variables. Such estimation means that a unit change in electricity generation can be explained by the behaviour of economic growth and time trend over the planning period. This historical trend was used and applied to the actual 2015 electricity generation to come up with the baseline electricity generation forecasts.

From the forecasted electricity generations that have been established, the peak demand forecasts are then obtained using the load factor approach. In this method, the forecasted electricity generation is divided by a predefined load factor. For this purpose, a high load factor of 70% is assumed in consideration of increased diversities and management of loads in industrial zones and on-grid areas resulting in relatively constant power usage.

In this methodology, identification of the additional capacity is solely dependent on the projection of electricity demand unlike in other planning processes where reserve requirements and committed capacities are also considered. To determine the annual deficit per type of power plant, the peak demand forecast was subtracted from the existing dependable capacity as of December 2015. The resulting value is the required or necessary DES capacity to meet future demand. A negative result indicates that the existing capacity still has a surplus capacity for that specific period.

Off-Grid Generation

To illustrate a holistic picture of DES profile for off-grid generation, this study captured the respective off-grid areas under the coverage franchise areas of grid-connected electric cooperatives.

This study used the following information to determine the future capacity of DES in off-grid areas: (i) 2015 data of DES installed capacity and electricity generated, and (ii) off-grid electricity demand projections for planning horizon 2025 and 2040.

The main source of information is the 2016 individual distribution development plan (DDP) of off-grid electric cooperatives as submitted to and approved by the DOE. The DDP is a 10-year plan prepared annually by all distribution utilities for managing their distribution systems and ensuring continuous, reliable, and affordable electricity service to its customers through identification of infrastructure requirements and timely procurement of power supply agreements. The 2016 DDP has a baseline year of 2015 (actual) and projections from 2016 to 2025, utilising various forecasting models. For this study, the electricity demand projections were extended to 2040 to capture long-term demand and the corresponding additional capacity requirements in off-grid areas.

To identify the required DES capacities by 2025 and 2040, the current installed capacities were subtracted from the projected electricity demand on a per-technology basis. The resulting figure then provides for the required additional DES capacities, if the existing capacities fall short of the projected demand for the planning period. On the other hand, if the existing installed capacities are still sufficient to meet the 2025 and 2040 electricity demand, this indicates that no additional capacities are required for that outlook period.

On top of these, new DES technologies such as wind and geothermal energy sources were likewise accounted, with the understanding that these new technologies will essentially form part of the future DES energy mix. These new DES technologies are firm capacities that are electric cooperatives programmed in their power supply expansion plan.

Current Situation of Distributed Energy System

On-Grid/Embedded Generation

This section concentrates on the current situation of embedded generation in the country. Included in the discussions are the existing installed capacities per type of energy source and its substantial merits to the power sector, the present policies and opportunities to promote the use of distributed generation, and its share to the overall generation capacity to support enhancement of energy security.

Installed Capacity and Power Generation

As of 2015, the country's total installed capacity of embedded generation operating in industrial zones and on-grid areas was recorded at 609 megawatts (MW) with a total power generation of 1,292,700 megawatt-hours (MWh)[2] (Table 5.1). In this period, oil-based/diesel power plants with an equivalent installed capacity of 346.59 MW dominated embedded generation. This is attributed to the influx of embedded diesel power plants in Mindanao since 2012 as part of the government's proposed actions to augment the power crisis in the region. The renewable energy sources also had a significant contribution in the country's embedded generation with 159.77 MW, followed by combined heat and power (CHP) or industrial cogeneration, providing a considerable share of 103 MW. Meanwhile, there has been no record yet of coal-fired and geothermal power plants being utilised in the form of DES since they are widely used in centralised power as base load supply.

[2] Embedded generations included in the 2015 data of the Department of Energy (DOE) that are presently grid-connected, non-operational, and decommissioned have been excluded to isolate the effects of such occurrences.

Table 5.1. Total DES Installed Capacity and Gross Power Generation (On grid), 2015

Applications	Current/Existing Capacity	
	MW	MWh
Solar PV	16.60	21,732
Wind	54.00	53,947
Biomass/biogas	9.40	23,561
Micro hydro	79.77	367,944
Geothermal	0.00	0
Diesel generator	346.59	561,785
Thermal power (coal, slurry, fuel oil, others)	0.00	0
CHP incl. heat recovery facility	103.00	263,731
Other generators		
Total	**609.00**	**1,292,700**

CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour, PV = photovoltaic.
Source: Philippine DOE (2015).

Merits of Embedded Generation

Deployment and use of DESs in industrial zones and on-grid areas deliver substantial merits to both consumers and distribution utilities. Since most economic activities are centred in urbanised areas, ensured sufficient supply is very critical in all aspects for the continuous operation of cities, businesses, and homes. It is in this circumstance that majority of the embedded units installed today serve as backup especially during peak hours. Since application of renewable technologies is very site-specific, most units installed in these areas are diesel power plants.

In 2015, the DOE and Energy Regulatory Commission introduced the Interruptible Load Program (ILP) in Luzon in anticipation of the tight power supply during the summer period. In this mechanism, business customers of a distribution utility voluntarily disconnect themselves off the grid especially during peak demand period. Participating customers will be incentivised should they use their own embedded stand-by generation during power supply deficit. The ILP in some ways illustrated the practicality and helpfulness of embedded generations in today's power industry.

Embedded generation significantly contributes to reducing peak power requirements. This has benefited distribution utilities just like the power distributor giant Manila Electric Company (MERALCO), most of whose franchise areas are growing load centres. MERALCO provides financial incentives to customer owners of embedded units to make them available to electric system operators during peak demand periods. In Mindanao, electric cooperatives and distribution utilities have started integrating embedded generations in their networks to serve as ancillary service as the National Grid Corporation of the Philippines is not providing a contract for ancillary services. Consequently, these embedded units around the country shared their part in alleviating the line congestion being experienced and increasing the reliability of delivering power. Since the units are usually closer to the consumers, power loss is also reduced, resulting in higher efficiency and better performance of the system. Thus, the use of embedded generations is an effective solution in providing emergency power, particularly on those facilities that require highly reliable electricity.

Opportunities and Economy of DES in On-Grid Areas

In terms of economy, there are vast opportunities in the development of DES, particularly in industrial and commercial sectors situated in on-grid areas and economic zones. According to the Philippine Economic Zone Authority, 358 economic zones are operating nationwide, hosting some of the top global manufacturing and industrial companies[3]. These ecozones could be future sites for DES, particularly solar and wind farms that are expected to augment power requirements in the future.

The booming industrial and commercial field across the country denotes potential opportunities on the application of DES, especially that there is an ongoing trend of companies venturing on embedded generations to produce their own electricity for lower energy bills and increased reliability. From 2011 to 2015, the industrial and commercial sectors shares to total electricity consumption averaged 27% and 24%, respectively (Philippine DOE, 2016a). As these sectors are electricity intensive, meeting the electricity demands will require an unprecedented level of investment in fuel supply, generation, and networks. Thus, it is generally in these sectors that adoption of DES would be more beneficial in reducing electricity consumption and managing peak demands.

As the cost of DES becomes economical, it will be advantageous for some facilities and businesses requiring highly reliable electricity to install and generate their own power to

[3] http://www.peza.gov.ph/index.php/economic-zones/list-of-economic-zones

assure continuity of their operations. Since use of DES is limited to certain locations and conditions, many of the developers now are focusing on energising large commercial and industrial sectors through solar rooftops. Meanwhile, the application of cogeneration or waste heat recovery is also gaining popularity amongst the pulp and paper, refining, and manufacturing sectors.

Although application of DES is competitive with conventional generation, it is still difficult to attract investors as the government lacks concrete, transparent, and reliable policies regarding DES. Power investments are capital intensive; hence, these must be complemented with a market that is predictable and friendly to investors to enable and encourage higher penetration of embedded generations in the grid.

Energy Security Brought by Embedded Generation

Enhancing energy security has always been a major challenge the country has to deal with. Sudden power outages have dramatic implications for the country's economic activities resulting from interruption of business operations and loss of revenues. The introduction of generating power in the form of distributed generation can provide an enhanced energy security.

The Philippine DOE estimated that 3.18% of the country's overall power generation in 2015 came from embedded generation in on-grid areas and economic zones (Table 5.2). Out of this, the share of renewable sources and fossil-based power plants to the total capacity of power generation registered at 0.83% and 2.35%, respectively.

Table 5.2. Percentage Share of Installed Generating Capacity, 2015

	Installed Capacity, MW	Percentage Share
Off-grid generation	**404.50**	**2.1**
On-grid generation	**18,765.00**	**97.9**
Embedded generation	609.36	3.18
Renewable energy	159.77	0.83
Fossil based	449.59	2.35
Overall power generation	**19,169.50**	**100.00**

MW = megawatt.

Source: Philippine DOE (2016b).

CO_2 Emissions Reduction by Existing On-Grid/Embedded DES

The use of renewable energy and energy-efficient technologies such as cogeneration/CHP in producing energy has been proven to drive down carbon emissions since it reduces the need to produce electricity from carbon-intensive sources such as fossil fuels. Using the standard emission factor of 7.03 x 10-4 MT-CO2/kWh set by the US Environmental Protection Agency and the actual electricity generation for 2015, the carbon footprint offset from renewable energy and CHP was estimated at 513,833.25 MTCO2 for a total of 730,915 MWh of clean energy (Table 5.3).

Table 5.3. Total CO2 Emissions Reduction by Renewable Energy System and Combined Heat and Power (On-grid DES), 2015

Applications	Existing Dependable Capacity		CO2 Emission Reduction, MTCO2
	MW	MWh	
Solar PV	12.30	21,732	15,277.60
Wind	54.00	53,947	37,924.74
Biomass/biogas	7.88	23,561	16,563.38
Micro hydro	63.40	367,944	258,664.63
CHP incl. heat recovery facility	52.40	263,731	185,402.89
Total	**189.98**	**730,915**	**513,833.25**

CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour, MTCO2 = metric ton of CO2, PV = photovoltaic.

Note: Emission factor = 7.03 × 10-4 MTCO2/kWh.

Source: Philippine DOE (2015a).

Case Studies of DES Application for Economic Zones

This study cites two manufacturing plants using on-site power generation to describe the state and performance of embedded generation in the country.

Case Study 1: San Carlos Ecozone Negros Occidental

San Carlos Bioenergy Inc. (SCBI) is a pioneer in ethanol manufacturing in the country. In 2008, it completed the first integrated sugar cane-based ethanol and power cogeneration power plant in Asia (Zabaleta, 2012). The integrated cogeneration facility located in San Carlos City, Negros Occidental has a capacity of 8.3 MW powered by indigenous biomass resources, particularly bagasse, by-products from ethanol production.

In 2010, the SCBI signed a power supply contract with VMC Rural Electric Services Cooperative Inc. (VRESCO) for 2.4 MW–4.8 MW in excess capacity for 30 years at P2.86 per kWh, subject to regular adjustments based on inflation (Gatdula, 2010). VRESCO distributes electricity to its franchise areas covering the cities of San Carlos, Victorias, Cadiz, Sagay, and Escalante and the municipalities of E.B. Magalona, Manapla, Toboso, and Calatrava in Negros Occidental.

In terms of power generation, the SCBI generated a total of 18,134 MWh in 2015 (Table 5.4). It is committed to providing sustainable power and maintaining the environmental integrity of its surrounding areas. The generating facility of the SCBI upheld this commitment in 2013 as it played a key role in the aftermath of Typhoon Yolanda (Haiyan). The whole province of Negros Occidental had no power due to damaged power lines of the local cooperative. But in just after 2 days, the facility was able to supply the city of San Carlos with 1.5–1.7 MW of electricity for 1 week.[4] This model case of the SCBI clearly demonstrated the defining attributes and qualities of distributed generation in terms of enhancing energy security and reliability.

Table 5.4. SCBI's Installed Capacity and Power Generation, 2015

Applications	Current/Existing Capacity	
	MW	MWh
Biomass/Biogas San Carlos Bioenergy Inc. (SCBI)	8.3	18,134

MW = megawatt. MWh = megawatt-hour.
Source: Philippine DOE (2015a).

Case Study 2: United Pulp and Paper Company, Inc.

United Pulp and Paper Company, Inc. (UPPC) is the Philippines' biggest industrial paper manufacturer located in Calumpit, Bulacan and a subsidiary of the Siam Cement Group of Thailand. This plant uses 100% waste paper as raw material and is powered by a 30 MW cogeneration power plant that runs on coal, paper rejects, waste paper sludge, and biomass like corn cob and straw dust.

Formerly a bunker-fired plant facility, the Siem Cement Group started to invest in 2004 to put up a circulating fluidised bed cogeneration plant to supply the power and steam requirements of its paper mills (Cahiles-Magkilat, 2005). This is part of the plant's strategy to generate fuel savings and reduce production cost as it cost consumes a high amount of energy.

[4] http://www.rappler.com/video/reports/46278-green-revolution-san-carlos-city

The UPPC generated a total of 143,359 MWh solely for its own consumption to run its machinery to produce paper (Table 5.5). The company's decision to venture in power generation is an important motivation for many businesses on how large power consumers can translate their demand into additional power generation through on-site generation.

Table 5.5. UPPC's Installed Capacity and Power Generation, 2015

Applications	Current/Existing Capacity	
	MW	MWh
CHP incl. Heat Recovery Facility United Pulp and Paper Company, Inc. (UPPC)	30	143,359

CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour.
Source: Philippine DOE (2015a).

Current Policies for Embedded Generation

Technically, the country does not have an existing policy with respect to embedded generation. In fact, even the minimum connection and operational requirements of embedded generators in the distribution system have yet to be established and integrated with the Philippine Distribution Code.

However, there are existing support mechanisms when it comes to embedded generations from renewable energy sources. The outstanding progress on applications of DES using renewable energy technologies is the result of the government's continuous promotion and encouragement of cleaner sources of energy. Currently, the government offers incentives under the Renewable Energy Act of 2008 such as income tax holidays, 10% corporate tax rates, duty-free importation of renewable energy machinery and equipment, and 0% value-added tax on renewable energy sales and purchases. Under this law is the adoption of a feed-in-tariff (FiT) system where an eligible producer of renewable energy is entitled to a guaranteed payment of a fixed rate for each kilowatt-hour of energy it supplies to the relevant grid (ERC, 2010). In addition to this is the implementation of the net-metering scheme, a non-fiscal incentive that allows consumers to produce its own power generation using eligible renewable energy facilities and to deliver excess supplies back to the electric grid to offset their electricity consumption at 100 kW maximum.

Off-Grid Generation

This section briefly discusses the profile of DESs in off-grid areas. As of this writing, about 20 electric cooperatives are serving the off-grid areas (Table 5.6).

Table 5.6. List of Off-Grid Electric Cooperatives

Island	Off-Grid Electric Cooperative
Luzon	Batanes Electric Cooperative (BATANELCO)
	Lubang Electric Cooperative (LUBELCO)
	Occidental Mindoro Electric Cooperative (OMECO)
	Oriental Mindoro Electric Cooperative (ORMECO)
	Marinduque Electric Cooperative (MARELCO)
	Tablas Island Electric Cooperative (TIELCO)
	Romblon Electric Cooperative (ROMELCO)
	Busuanga Island Electric Cooperative (BISELCO)
	Palawan Electric Cooperative (PALECO)
	First Catanduanes Electric Cooperative (FICELCO)
	Masbate Electric Cooperative (MASELCO)
	Ticao Island Electric Cooperative (TISELCO)
Visayas	Bantayan Island Electric Cooperative (BANELCO)
	Camotes Electric Cooperative (CELCO)
	Province of Siquijor Electric Cooperative (PROSIELCO)
Mindanao	Siasi Electric Cooperative (SIASELCO)
	Sulu Electric Cooperative (SULECO)
	Basilan Electric Cooperative (BASELCO)
	Tawi-tawi Electric Cooperative (TAWELCO)
	Dinagat Island Electric Cooperative (DIELCO)

Source: Philippine Department of Energy – 2016 Distribution Development Plan.

Table 5.7 lists the on-grid electric cooperatives with off-grid areas in their service franchises.

Table 5.7. List of On-grid Electric Cooperatives with Off-grid Areas

Island	Off-Grid Electric Cooperative	
Luzon	Quezon II Electric Cooperative (QUEZELCO II)	Polillo, Panukulan, Burdeos, Patnanungan, and Jomalig, Quezon
	Aurora Electric Cooperative (AURELCO)	Dinalungan, Casiguran and Dilasag, Aurora Dinapigue, Isabela
	Batangas II Electric Cooperative (BATELEC II)	Tingloy, Batangas
	Camarines Sur IV Electric Cooperative (CASURECO IV)	Caramoan and Garchitorena, Camarines Sur
	Isabela II Electric Cooperative (ISELCO II)	Divilacan, Palanan, and Maconnacon, Isabela
	Albay Power and Energy Corporation (APEC)[5]	Rapu-Rapu, Albay
Visayas	Antique Electric Cooperative (ANTECO)	Caluya Island, Antique
	Biliran Electric Cooperative (BILECO)	Higatangan Island, Biliran
	Bohol I Electric Cooperative (BOHECO I)	Inabanga, Calape, Baclayon, Tubigon and Panglao, Bohol
	Iloilo III Electric Cooperative (ILECO III)	Gigantes Island, Iloilo
	Mactan Electric Company (MECO)	Olango Island, Lapu-Lapu City
	Northern Samar Electric Cooperative (NORSAMELCO)	Municipalities of Biri, San Antonio, Capul, San Vicente and Batag Island
	Samar I Electric Cooperative (SAMELCO I)	Municipalities of Sto. Nio , Almagro, and Tagapul-an
	Samar II Electric Cooperative (SAMELCO II)	Municipality of Zumarraga
	Southern Leyte Electric Cooperative (SOLECO)	Limasawa Island
Mindanao	Davao del Sur Electric Cooperative (DASURECO)	Balut and Saranggani Islands
	Sultan Kudarat Electric Cooperative (SUKELCO)	Lebak, Kalamansig, Sen. Ninoy Aquino, and Palimbang, Sultan Kudarat
	Surigao del Norte Electric Cooperative (SURNECO)	Hikdop Island
	Zamboanga City Electric Cooperative (ZAMCELCO)	Sacol Island

Source: Philippine Department of Energy – 2016 Distribution Development Plan.

[5] APEC is the concessionaire of the defunct Albay Electric Cooperative, Inc. (ALECO).

Existing Power Plants (Off-Grid)

As of December 2015, there were about 322 existing power plants (314 were oil based whilst 8 were micro hydro) operating as stand-alone DES in off-grid areas. By type of ownership, about 291 power facilities, mostly oil-based diesel, were state owned through the National Power Corporation – Small Power Utilities Group (NPC–SPUG). About 24 power facilities were privately owned and operated by New Power Providers. About five micro-hydro power plants were owned by distribution utilities, and two oil-based power plants were under the qualified third party (QTP)[6] programme (Table 5.8).

Table 5.8. Existing Off-Grid Power Plants by Type of Ownership, 2015

Owner	No. of Power Plants		Total
	Oil based	Micro hydro	
NPC-SPUG	290	1	291
New power providers	22	2	24
Utility-owned	–	5	5
Qualified third parties	2	–	2
Total	**314**	**8**	**322**

- = zero, NPC-SPUG = National Power Corporation – Small Power Utilities Group.
Data Source: DOE, 2015.

Installed Capacity and Gross Power Generation (Off-Grid)

As of 2015, the total installed capacity of DES operating in off-grid areas was 404.5 MW. About 392.4 MW or 97% of the installed DES capacity came from diesel generators, whilst roughly 12.2 MW or 3% were from micro-hydro power plants.

During the same period, power generation grossed 1,066,236 megawatt-hours (MWh). The bulk (96.9%) of the electricity generated came from fossil-based diesel power generators whilst a mere portion (3.1%) was sourced from renewable energy-based micro-hydro power plants (Table 5.9).

[6] QTP is created based on Section 59 of Republic Act No. 9136 or the Electric Power Industry Reform Act of 2001 or the EPIRA Law under Rule 14 of its Implementing Rules and Regulations. Said section stipulates that entities other than distribution utilities are authorised to provide electric service in remote and unviable areas that distribution utilities are unable to serve for any reason.

Table 5.9. Total DES Installed Capacity and Gross Power Generation (Off grid), 2015

Applications	Installed Capacity (MW)	Gross Generation (MWh)
Solar PV	-	-
Wind	-	-
Biomass/biogas	-	-
Micro hydro	12.15	33,335
Geothermal	-	-
Diesel generator	392.36	1,032,901
Thermal Power (coal, slurry, fuel oil, others)	-	-
CHP incl. heat recovery facility	-	-
Other generators	-	-
Total	**404.51**	**1,066,236**

- = zero, CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour, PV = photovoltaic.

Source: Philippine Department of Energy (2015b).

Merits of DES in Off-Grid Areas

The deployment of DES applications has merits, especially in off-grid areas. For one, the concept of DES as stand-alone mini-grid is practically viable in island provinces, especially when public funds are limited to finance the extension of the main transmission lines to reach the off-grid areas.

Elaborating further, the mobility of fossil-based DES technologies such as diesel power generators enables sustainable supply of energy in far-flung areas. Compared to other technologies, diesel power generators can be easily installed through modular units, and their installed capacity can be conveniently augmented at any given time.

Potential renewable energy sources such as run-of-river hydro, geothermal, biomass, wind, and solar PVs are site-specific resources that are abundantly available in rural areas. The abundance of this cleaner set of renewable sources in the off-grid areas allow for the immediate application of DES to secure the electricity supply of remote communities.

Opportunities and Economy of DES in Off-Grid Areas

The Philippine energy sector is open for business. In fact, there is a huge potential for investment opportunities for both on-grid and off-grid infrastructure in the areas of power generation, transmission, and distribution. However, because off-grid areas have relatively smaller electricity demand compared to on grid, the private sector is reluctant to invest in DES power generation. Hence, the government implemented the Private Sector Participation (PSP) programme.

The PSP is a government programme promulgated through Department Circular No. 2004-01-001 to encourage the inflow of private capital investment to engage in missionary electrification.[7] This is pursuant to Section 3(b) of Rule 13 of the Implementing Rules and Regulations of Republic Act No. 9136 or the 'Electric Power Industry Reform Act (EPIRA) of 2001'. The section provides that NPC–SPUG shall periodically assess the requirements and prospects for bringing its functions to commercial viability on an area-by-area basis at the earliest possible time, including a programme to encourage private sector participation.

In the long run, the PSP is expected to improve the delivery of power-related services, such as efficiency and reliability of power generation, that would significantly benefit the end consumers. Consequently, the PSP aims to meet future demand growth.

Because of the lower peak demand level in off-grid areas, economies of scale in putting up DES technologies are likewise being applied. Depending on the economic activities taking place in the island grids, the size of DES varies. For instance, relatively large off-grid areas such as Palawan, Mindoro, Masbate, and Siquijor are amongst the progressive missionary areas whose installed DES capacities ideally range from above 10 MW. On the other hand, the rest of the developing islands and islets have DES capacities of less than 10 MW.

Energy Security brought by DES in Off-Grid Areas

DES applications primarily aim to attain energy security especially in off-grid areas. Table 5.10 presents the percentage share of the on-grid and off-grid installed generating capacities for 2015. As shown in the table, about 97.9% of the installed generating capacities are used for on-grid application, with merely 2.1% coming from off grid.

For on grid, 64.9% of the total installed generating capacities are fossil-based facilities comprised of oil-based, coal, and natural gas power plants, whilst renewable types of generating capacities sccpunt for a 33.0% share.

[7] Missionary electrification refers to providing basic electric services to remote or off-grid areas and ultimately bringing the operations in these areas to viable levels.

For off grid, the share of fossil-based generating capacities was only 2.1% of the total, mostly diesel. Roughly 0.1% of the off-grid capacities are sourced from renewable energy technologies.

Table 5.10. Percentage Share of Installed Generating Capacity, 2015

	Installed Generating Capacity (MW)	Percentage Share
On grid	**18,765.0**	**97.9**
Fossil based	12,435.0	64.9
Renewables	6,330.0	33.0
Off grid	**404.5**	**2.1**
Fossil based	392.4	2.0
Renewables	12.2	0.1
Total	**19,169.5**	**100.0**

MW = megawatt.

Source: Philippine DOE (2016b).

In general, off-grid capacities account for a very minimal share of the country's total installed generating capacities. Considering that small-island and isolated grids possess varied peculiarities, DES applications serve a significant purpose in ensuring energy security and sustainability in off-grid areas.

CO_2 Emissions Reduction by Existing Off-Grid DES

The increasing levels of greenhouse gas (GHG) emissions from the energy sector is widely viewed as a major contributor to global warming or climate change. Within the sector, these GHG emissions are largely attributed to the combustion of fossil fuels during the energy transformation processes. Whilst climate change has recently become an urgent and priority concern globally, the Philippines as a developing country remains a minor contributor to the world's GHG emission compared to the developed economies and other neighbouring countries.

For this study, the present and future domestic GHG emissions were duly accounted for to establish the potential advantage of reducing GHG emissions through DES, especially for off-grid areas. In estimating the GHG equivalencies, this study used the emission factor of 7.03 x 10-4 $MTCO_2$/kWh set by the United States Environmental Protection Agency (EPA).

Table 5.11 shows the 2015 electricity gross generation in off-grid areas and the potential CO_2 emissions reduction expressed in metric tons of carbon dioxide equivalent ($MTCO_2e$). For the reported period, off-grid areas recorded a total potential GHG emissions reduction of 749,563.91 MTCO2e based on the actual 1,066,236 MWh gross power generation. About 96.9% of this figure, or 726,129.40 $MTCO_2e$, can be reduced from fossil-based diesel generation. Avoided units of CO_2 emissions from renewable energy account for 23,434.51 $MTCO_2e$.

Table 5.11. CO_2 Emissions Reduction Equivalencies in DES Off-Grid Areas, 2015

Fuel Type	Gross Generation (MWh)	CO2 Emissions Reduction (MTCO2e)
Fossil-based (diesel)	1,032,901	726,129.40
Renewable Energy (micro hydro)	33,335	23,434.51
Total	**1,066,236**	**749,563.91**

$MTCO_2e$ = metric tons carbon dioxide equivalent, MWh = megawatt-hour.

Note: CO_2 emissions reduction was calculated using the US Environmental Protection Agency's emission factor of 7.03 x 10-4 $MTCO_2$/kWh.

Source: Department of Energy 2015 Gross Generation, 2015.

Cost–Benefit Analysis of On-Grid and Off-Grid Areas

Another envisioned advantage of utilising DES is to provide affordable energy. However, this vision is rather contrary in the case of the Philippines. To support this statement, the DOE conducted a cost–benefit analysis comparing the cost of providing electricity in the main grid against the off grid.

With reference to the 2015 data on electricity tariff (Table 5.12), the national average power rate in the main grid is ₱8.8029/kWh or US$0.1767.[8] This was computed by taking the average electricity tariff of the on-grid electric cooperatives (US$0.1890/kWh) and the public investor-owned utilities (US$0.1644/kWh). On the other hand, the national average electricity tariff in off-grid areas as of December 2015 is ₱10.7396/kWh or US$0.2156/kWh.[9]

For both main grid and off grid, the national average effective electricity rates are composed of the (i) generation charge; (ii) system loss charge; (iii) distribution, supply, and metering charges; (iv) subsidy charges;[10] (v) other charges;[11] and (vi) government charges (universal charge, and value added tax).

[8] Foreign exchange rate used: US$1 = ₱49.8126 (Reference: Bangko Sentral ng Pilipinas (BSP), accessed 30 May 2017).
[9] Including the cash incentive for renewable energy in off-grid areas; excluding the feed-in-tariff allowance.
[10] Includes lifeline and Senior Citizen's discount.
[11] Includes loan condonation, PEMC–SPA charges, over/under recovery and interclass cross subsidy.

Table 5.12. Comparative Effective Electricity Rates, 2015

Fuel Type	Average Electricity Rate	
	(₱/kWh)	(US$/kWh)
Main Grid Average Electricity Rate	**8.8029**	**0.1767**
On-grid electric cooperatives	9.4147	0.1890
Private investor–owned utilities	8.1912	0.1644
Off-grid Electric Cooperatives	**10.7396**	**0.2156**
Variance (Off grid – On grid)	**1.9367**	**0.0389**

kWh = kilowatt-hour.
Source: Philippine DOE (2015c).

As a result of the cost–benefit analysis, off-grid power rates are deemed higher by US$0.0389 compared to the power rates in the main grid.

Case Studies of DES Application for Off-Grid Areas

This section discusses two model cases where off-grid DES is being applied: the Romblon Electric Cooperative, Inc. (ROMELCO) and the Basilan Electric Cooperative, Inc. (BASELCO) that serve as distribution utilities in the provinces of Romblon and Basilan, respectively.

Case Study 1: Romblon Electric Cooperative, Inc.

The province of Romblon is in the MIMAROPA[12] region. It is composed of about 20 major and smaller islands scattered across the centre of the Philippine archipelago. The biggest is Tablas Island comprising nine municipalities (San Agustin, Calatrava, San Andres, Odiongan, Ferrol, Santa Fe, Looc, Alcantara, and Santa Maria); Sibuyan Island with three municipalities (Magdiwang, Cajidiocan, and San Fernando); and Romblon Island, the capital town, is an island municipality located in the middle of the islands. Four other major islands are the municipalities of Corcuera, Banton, Concepcion, and San Jose.

Romblon is primarily an agricultural province with most economic activities evolving in the basic sectors such as agriculture and livestock raising, marginal fishing, and small-scale mining activities with aggregates as the major product. Basically, major activities in the province are focused on the fishing and tourism industries, and crop production.

[12] MIMAROPA is an administrative region in the Philippines comprising the provinces of Mindoro, Marinduque, Romblon, and Palawan.

Two distribution utilities cater to the power requirements of the province: (i) Tablas Island Electric Cooperative, Inc. (TIELCO) serving the franchise area of Tablas Island, and (ii) ROMELCO, serving the rest of the island municipalities. This case study focuses only on the areas under the ROMELCO franchise.

As of end 2015, ROMELCO's power-generating facilities had an installed capacity of 8.38 MW. By type of power source, 7.48 MW come from diesel generators operated by NPC-SPUG and 0.9 MW are sourced from Cantingas micro-hydro power plant owned by the utility. The 2015 system peak demand of ROMELCO reached 3.07 MW whilst gross power generation was registered at 16,913 MWh (Table 5.13).

Table 5.13. ROMELCO's Installed Capacity and Gross Power Generation, 2015

Applications	Installed Capacity (MW)	Percentage Share (MWh)
Solar PV	-	-
Wind	-	-
Biomass/biogas	-	-
Micro hydro	0.9	4,879
Geothermal	-	-
Diesel generator	7.48	12,034
Thermal Power (coal, slurry, fuel oil, others)	-	-
CHP incl. heat recovery facility	-	-
Other generators	-	-
Total	**8.38**	**16,913**

- = zero, CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour, PV = photovoltaic.
Source: ROMELCO (2016).

Case Study 2: Basilan Electric Cooperative, Inc.

In terms of gross provincial income, Basilan is a third-class island province located in the Autonomous Region in Muslim Mindanao. It is the largest island situated in the northernmost of the major islands of the Sulu archipelago.

The province is subdivided into 11 municipalities – Akbar, Al-Barka, Hadji Mohammad Ajul, Hadji Muhtamad, Lantawan, Maluso, Sumisip, Tabuan-Lasa, Tipo-Tipo, Tuburan, Ungkaya Pukan – and two cities – Isabela City, a component city, and Lamitan City, the capital.

Agriculture is the main source of livelihood with major products that include coconut (primarily copra), rubber, coffee, black pepper, and African palm oil. Other crops are palay, corn, cacao, and cassava.

Unlike Romblon, the power requirements of Basilan are being catered by its sole distribution utility, BASELCO. Basilan also belongs to the BASULTA area (Basilan, Sulu, and Tawi-Tawi), which is one of the large clusters of off-grid area in Mindanao.

In 2015, Basilan's installed generating capacity totalled 14.03 MW. The bulk of the power supply (95.2%) was sourced from diesel-based facilities owned and operated by NPC-SPUG, with the remaining power capacity (4.8%) from utility-owned Kumalarang micro-hydro power plant. During the same period, system peak demand was recorded at 8.3 MW whilst total electricity generated was at 39,370 MWh (Table 5.14).

Table 5.14. BASELCO's Installed Capacity and Gross Power Generation, 2015

Applications	Installed Capacity (MW)	Percentage Share (MWh)
Solar PV	-	-
Wind	-	-
Biomass/biogas	-	-
Micro hydro	0.67	579
Geothermal	-	-
Diesel generator	13.36	38,791
Thermal Power (coal, slurry, fuel oil, others)	-	-
CHP incl. heat recovery facility	-	-
Other generators	-	-
Total	**14.03**	**39,370**

= , CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour, PV = photovoltaic.

(-) means zero.

Source: BASELCO Distribution Development Plan, 2016.

Current Policies for DES in Off-Grid Areas

a. *Universal Charge for Missionary Electrification (UCME)*

Since it is costlier to generate electricity in off-grid areas compared to the main grid, the government implemented a subsidy programme through the universal charge for missionary electrification. UCME is a policy mechanism created under

Rule 13 of the Implementing Rules and Regulations of Electric Power Industry Reform Act. Its sales revenue is a main funding source of NPC–SPUG to support the delivery of electricity services. More importantly, it cushions the impact of high generation costs in far-flung areas. The mechanism is expressed in peso per kilowatt-hour that is applied and charged to all electricity consumers of the country. The 2015 average UCME charge is US$0.0074/kWh.

b. Feed-in-Tariff

Republic Act No. 9513 or the 'Renewable Energy Act of 2008' articulated the government's thrust to promote the development, utilisation, and commercialisation of renewable energy resources to shift towards a low-carbon future. To realise this thrust, the renewable energy law provided for policy mechanisms to encourage and accelerate the development and utilisation of cleaner energy sources.

Amongst the major incentives provided under the Renewable Energy Act is the feed-in-tariff (FiT). FiT refers to a renewable energy policy that offers guaranteed payments on a fixed rate per kilowatt-hour for emerging renewable energy sources, excluding any generation for own use. The implementation of the FiT system aims to:

- allow renewable energy developers to recover their investments and provide them with internationally acceptable return on investment during the FiT period;
- accelerate the development of emerging/competitive renewable energy technologies; and
- not unduly burden the consumers with heavy pass-on charges.

To further safeguard consumer interest, the FiT system was accompanied by a corresponding installation target per type of renewable energy resource. Installation targets are the renewable energy-rated capacities per technology projected based on the awarded renewable energy service contracts for a given period as certified by the government through DOE. The installation targets aim to pre-determine the impact of the FiT rates at a given period and the maximum penetration of renewable energy capacities to the grid. Table 5.15 summarises the current FiT rates and installation targets per renewable energy technology.

Table 5.15. Approved Feed-in Tariff Rates and Installation Target (as of June 2017)

RE Technology	Approved Rates (US$/kWh)	Percentage Share (MWh)
Run-of-river hydro	0.1184	250
Biomass	0.1331	250
Wind	0.1486	400
Solar	0.1943	500

kWh = kilowatt-hour, MW = megawatt.

Source: ERC Resolution No. 10, series of 2012; ERC Resolution No. 1, series of 2017.

At present, the FiT system is only applicable and can be availed of by prospective developers of renewable energy in the main grid. To guarantee that the FiT system would be practicable to all electricity consumers, the National Renewable Energy Board, the Department of Energy, and the Energy Regulatory Commission, in consultation with energy stakeholders, periodically conducts a review.

c. *Cash Incentive for Renewable Energy Developers in Off-Grid Areas*

As the government finds it very challenging to entice private investment for the development of renewable energy in off-grid areas, it likewise put in place a cash incentive mechanism.

As provided under Chapter VII General Incentives and Section 15(h) of the renewable energy law or Republic Act 9513, a renewable energy developer 'shall be entitled to a cash generation-based incentive per kilowatt-hour rate generated, equivalent to fifty percent (50%) of the universal charge for power needed to service missionary areas where it operates the same, to be chargeable against the universal charge for missionary electrification'. In 2015, the cash incentive for renewable energy developers was US$0.000034/kWh.

d. *Competitive Selection Process in Securing Power Supply Agreements*

In June 2015, DOE issued Department Circular No. 2015-06-0008, mandating all distribution utilities to undergo a competitive selection process in securing power supply agreements with generation companies. The foremost objective of the policy is to reinforce good governance and instil a transparent process amongst distribution utilities in managing, negotiating, and procuring long-term power supply contracts. Correspondingly, the policy issuance enables a level-playing field and facilitates fair competition amongst generation companies that redound benefits to electricity consumers through reliable, adequate, and least-cost supply of electricity.

Development of Distributed Energy System

There is a great possibility that the future of power system is DES. This is becoming increasingly clear as demonstrated by the growing presence of stand-alone and on-site generations, advances in applications and new technologies, and the changing preference of consumers. In this section, the additional required capacities of DES per type of energy source for 2025 and 2040 will be identified. Determining the future power requirements is crucial as it will entail additional investments in meeting future demand.

On-Grid/Embedded Generation

2025 Outlook

Table 5.16 shows that the aggregated existing dependable capacity of 508.28 MW for embedded generation is theoretically sufficient to meet the projected demand of 457.71 MW by 2025 as denoted by an excess capacity of 50.57 MW. This is attributed to the huge presence of embedded diesel generators as it still has the surplus capacity of 93 MW in 2025.

However, considering that most of these units are stand-alone generations and that transfer of power is not readily possible, the excess capacity of diesel generators is not guaranteed to offset any deficiency of supply of other DES technologies to include the 1.52 MW for solar, 2.97 MW for biomass, 13.66 MW for hydro, and 24.28 MW for CHP. With this analysis, these technologies will have a shortfall of 42.43 MW in total by 2025.

Similarly, energy demand for embedded generations is estimated to double from its total generation of 1,292,700 MWh in 2015 to 2,529,921 MWh by 2040. This can be translated to an additional required energy of 1,237,221 MWh for the same period.

Table 5.16. Projected DES Required Capacity and Energy Demand by 2025 (On grid)

Fuel Type	Existing Dependable Capacity, 2015		2025			
	MW	MWh	Peak Demand, MW	Required Capacity, MW	Energy Demand, MWh	Required Energy, MWh
Solar PV	12.30	21,732	13.82	1.52	84,732	63,000
Wind	54.00	53,947	54.00	-	53,947	-
Biomass/biogas	7.88	23,561	10.85	2.97	66,560	42,999
Micro hydro	63.40	367,944	77.06	13.66	472,544	104,600
Geothermal	-	-	-	-	-	-
Diesel generator	318.30	561,785	225.30	(93.0)	1,381,917	820,132
Thermal power (coal, slurry, fuel oil, others)	-	-	-	-	-	-
CHP incl. heat recovery facility	52.40	263,731	76.68	24.28	470,221	206,490
Total	**508.28**	**1,292,700**	**457.71**	**(50.57)**	**2,529,921**	**1,237,221**

CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour, PV = photovoltaic.

Note: Required Capacity and Energy Demand by 2025 is based on author's calculation.

Source: Philippine DOE (2015a).

2040 Outlook

Demand is forecasted to significantly increase from 2015 to 2040. Total peak demand is projected to reach 908.11 MW by 2040, requiring an additional capacity of 298.75 MW (Table 5.17). The need for additional capacities to support the expected demand comprises 17.36 MW for solar, 11.2 MW for biomass, 46 MW for hydro, 140.77 MW for diesel, and 83.42 MW for CHP.

Likewise, energy demand will continue to grow to about 4,671,609 MWh by 2040 from power generation of 1,292,700 MWh in 2015. This denotes an additional energy requirement of 3,378,909 MWh within the 25-year period. The future demand of the case models that practice the DES applications using on-site generation was likewise determined.

Projected CO2 Emissions Reduction by Future On-Grid/Embedded DES

Table 5.18 shows the cumulative CO2 emission reduction by the renewable energy system and CHP for on-grid DES from 2015 to 2040. In this approach, the computed

Table 5.17. Projected DES Required Capacity and Energy Demand by 2040 (On grid)

Fuel Type	Existing Dependable Capacity, 2015		2040			
	MW	MWh	Peak Demand, MW	Required Capacity, MW	Energy Demand, MWh	Required Energy, MWh
Solar PV	12.30	21,732	29.66	17.36	181,893	160,161
Wind	54.00	53,947	54.00	-	53,947	-
Biomass/biogas	7.88	23,561	19.08	11.20	117,017	93,456
Micro hydro	63.40	367,944	109.40	46.00	670,871	302,927
Geothermal	-	-	-	-	-	-
Diesel generator	318.30	561,785	459.07	140.77	2,815,035	2,253,250
Thermal power (coal, slurry, fuel oil, others)	-	-	-	-	-	-
CHP incl. heat recovery facility	52.40	263,731	135.82	83.42	832,846	569,115
Total	**508.28**	**1,292,700**	**807.03**	**298.75**	**4,671,609**	**3,378,909**

CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour, PV = photovoltaic. (-) means zero

Note: Required Capacity and Energy Demand by 2040 is based on author's calculation.

Source: Philippine DOE (2015a).

annual emission reduction of 513,833 MTCO2 for 2015 (Table 3) was used as the baseline for the annual CO2 emission reduction. In reference to this, renewable energy and CHP are expected to avoid total carbon emissions of at least 5,652,165.70 MTCO2 for 10 years, starting in 2015. Likewise, for a crediting period of 25 years (2015–2040), the total CO2 emission reduction is estimated to be at least 13,359,664 MTCO2. The computed CO2 emission reductions for 2025 and 2040 are minimum since the annual electricity production from renewable energy and CHP re assumed to be the same in 2015–2040 and that annual emission reduction for the entire crediting period is constant.

Case Study 1: San Carlos Ecozone Negros Occidental

The existing capacity of SCBI is forecasted to be insufficient to meet future demand. Based on projected demand, there will be a need of 1.31 MW by 2025 as its peak demand will reach 8.31 MW from its dependable capacity of 7 MW in 2015. Similarly, for 2040, it will need an additional capacity of 6.74 MW as peak demand is expected to be 13.74 MW. These additional capacities are necessary to support the SCBI's own-use

Table 5.18. Projected CO_2 Emission Reduction by Renewable Energy System and Combined Heat and Power (On-Grid DES)

RE Technology	Projected CO_2 Emission Reduction, $MTCO_2$
2015	513,833.25
2016	1,027,666.49
2017	1,541,499.74
2018	2,055,332.98
2019	2,569,166.23
2020	3,082,999.47
:	:
2025	**5,652,165.70**
:	**:**
2040	**13,359,664.37**

Note: CO_2 emissions reduction was calculated using US Environmental Protection Agency's emission factor of 7.03 x 10-4 $MTCO_2$/kWh

consumption for running its facilities and to comply with its power supply contract to VRESCO.

In terms of energy demand, the additional required energy by 2025 and 2040 is about 32,816 MWh and 66,103 MWh, respectively (Table 5.19).

Case Study 2: United Pulp and Paper Company, Inc.

UPPC's future demand is estimated at 0.25 MW additional capacity by 2025 whilst in 2040, its required capacity is projected at 0.58 MW (Table 5.20). Noticeably, there is a slight increase on the projected power requirements of the company. This may be attributed to the constant number of units of their machinery being used for the past years especially since the forecasted demand was primarily derived from their actual power generation with time trend as independent variable. Also, large plant facilities like the UPPC strictly practice load management to have constant power usage for more efficient use of electricity. Thus, the company's decision to expand and increase its machinery will result in a surge in its future demand.

Table 5.19. SCBI's Projected Energy and Capacity Requirements, 2025 and 2040

Applications	2015		2025				2040			
	Dependable Capacity (MW)	Energy Production (MWh)	Peak Demand, MW	Energy Demand (MWh)	Required Capacity (MW)	Required Energy (MWh)	Peak Demand, MW	Energy Demand (MWh)	Required Capacity (MW)	Required Energy (MWh)
	(a)	(b)	(c)	(d)	(c – a)	(d – b)	(e)	(f)	(e – a)	(f – b)
Biomass/ biogas San Carlos Bioenergy Inc. (SCBI)	7.0	18,134	8.31	50,950	1.31	32,816	13.74	84,237	6.74	66,103

CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour, PV = photovoltaic.

Note: Required Capacity and Energy Demand by 2025 is based on author's calculation.

Source: Philippine DOE (2015a).

Table 5.20. UPPC's Projected Energy and Capacity Requirements, 2025 and 2040

Applications	2015		2025				2040			
	Dependable Capacity (MW)	Energy Production (MWh)	Peak Demand, MW	Energy Demand (MWh)	Required Capacity (MW)	Required Energy (MWh)	Peak Demand, MW	Energy Demand (MWh)	Required Capacity (MW)	Required Energy (MWh)
	(a)	(b)	(c)	(d)	(c – a)	(d – b)	(e)	(f)	(e – a)	(f – b)
CHP incl. Heat Recovery Facility United Pulp and Paper Company, Inc. (UPPC)	24.0	143,359	24.15	148,096	0.15	4,737	24.58	150,741	0.58	7,382

MW = megawatt, MWh = megawatt-hour.

Note: Required Capacity and Energy Demand by 2025 and 2040 is based on author's calculation.

Source: Philippine DOE (2015a).

Envisaged Policy for Embedded Generation

As mentioned above, the country does not have a holistic policy that captures embedded generation. A well-defined treatment of embedded generation in the power market system is needed. DOE should consider self-generation as an effective energy solution that will be substantial and easy to implement in the future. Some of the self-generating industries in the country are ready to deliver power to the grid; however, the mechanism to do so is still not in place. Stating these specific concerns, it is essential to formulate and implement policy on embedded generation to provide the direction for embedded generators. Opening opportunities for embedded generations will enable DES to penetrate the power sector and compete in the market.

Off Grid

This section briefly discusses the future development of DESs in small-island and isolated grids. Specifically, the discussion highlights the projected energy (in MWh) and capacities (in MW) of DES for 2025 and 2040, respectively, capturing the additional requirements for the medium and long term. It also considers new power generation technologies that are projected to form part of the future DES capacity mix, and briefly discusses avoidance of GHG emissions.

On a per technology basis, Table 5.21 presents the total peak and energy demand as well as the corresponding additional capacity requirements of the off-grid areas by 2025 and 2040.

2025 Outlook

For the 2025 outlook, the off-grid system peak demand is projected at 813.2 MW. Considering the existing 2015 installed capacity of 404.5 MW, an additional 408.7 MW (excluding reserve capacities) is seen as necessary to meet the overall power requirement for the period.

Per type of technology, diesel-based capacities need to be augmented by 371.5 MW whilst micro hydro, by 11.14 MW. On the other hand, aside from new capacities from micro hydro, additional firm capacities for new renewable energy sources, such as wind and geothermal, are foreseen at 6.0 MW and 20.0 MW, respectively. The entry of these new renewable energy capacities were accounted for from the power supply expansion plan of the Oriental Mindoro Electric Cooperative, Inc. Said capacities are programmed to commercially operate by 2017.

Table 5.21. Projected DES Required Capacity and Energy (Off Grid)

Fuel Type	2015			2040		
	Peak Demand, MW	Required Capacity, MW	Required Energy, MWh	Peak Demand, MW	Required Capacity, MW	Required Energy, MWh
Solar PV	-	-	-	-	-	-
Wind	6.00	6.00	66,000	6.00	6.00	66,000
Biomass/biogas	-	-	-	-	-	-
Micro hydro	23.29	11.14	103,162	23.29	11.14	103,162
Geothermal	20.00	20.00	161,184	20.00	20.00	161,184
Diesel generator	763.90	371.54	525,372	1,276.31	883.95	2,076,962
Thermal power (coal, slurry, fuel oil, others)	-	-	-	-	-	-
CHP incl. heat recovery facility	-	-	-	-	-	-
Other generators	-	-	-	-	-	-
Total	**813.19**	**408.68**	**855,718**	**1,325.60**	**921.09**	**2,407,308**

CHP = combined heat and power, MW = megawatt, MWh = megawatt-hour, PV = photovoltaic.

(-) means zero

Note: Required Capacity and Energy Demand by 2025 and 2040 is based on author's calculation.

Source: Individual Distribution Development Plan of Electric Cooperatives (2016).

Total energy demand by 2025 is estimated at 1,921,954 MWh. Since the 2015 existing power plants have a net energy production of 1,066,236 MWh, the required energy for 2025 is 855,718 MWh.

Oil-based power generation will continue to dominate the energy demand at 61.4%, whilst renewable energy generation's share is expected to be 38.6%.

2040 Outlook

In 2040, off-grid system peak demand is forecasted to reach 1,325.6 MW. Subtracting the 2015 existing capacity of 404.5 MW, the required additional capacity for the period is around 921.1 MW.

Per plant type, 883.95 MW of additional capacity is required for diesel-based generators to meet demand. Except for micro-hydro power plants, renewable energy–based capacities, particularly wind and geothermal, have fixed energy and peak demand considering that these renewable sources have been commissioned at their maximum potential capacities.

On the other hand, total energy demand by 2040 was projected at 3,473,544 MWh. To meet this energy requirement, an additional 2,407,308 MWh should be generated on top of the net energy production of 1,066,236 MWh in 2015. The bulk of the required energy is seen to come from diesel-based technology.

Projected CO2 Emissions Reduction by Future Off-Grid DES

Table 5.22 illustrates the projected GHG emissions reduction equivalencies for the 2025 and 2040 planning horizons.

As projected, by year 2025 there will be a total of 1,351,134 MTCO2e GHG emissions reduction equivalencies given a forecasted energy demand of 1,921,954 MWh. Out of this figure, about 1,095,466 MTCO2e is foreseen to be avoided from fossil-based diesel generation. On the other hand, for the incoming set of cleaner technologies, such as hydro, wind, and geothermal energies, the potential GHG emissions reduction is expected to be 255,668 MTCO2e.

Come 2040, the almost-doubling energy demand projected at 3,473,544 MWh is expected to yield GHG emissions reduction equivalencies of up to 2,441,901 MTCO2e. Fossil-based diesel generation is projected to contribute 2,186,234 MTCO2e or a roughly 89.5% share of GHG emissions potential avoidance. Potential GHG emissions reduction from renewable energy are estimated to be a mere 10.5%.

Table 5.22. Projected CO_2 Emissions Reduction Equivalencies in DES Off-grid Areas, 2025 and 2040

Fuel Type	2015		2040	
	Energy Demand, (MWh)	CO_2 Emissions Reductions ($MTCO_2e$)	Energy Demand, (MWh)	CO_2 Emissions Reductions ($MTCO_2e$)
Fossil-based (diesel)	1,558,273	1,095,466	3,109,863	2,186,234
Renewable Energy (micro hydro)	363,681	255,668	363,681	255,668
Total	**1,921,954**	**1,351,134**	**3,473,544**	**2,441,901**

MTCO2e = metric tons carbon dioxide equivalent, MWh = megawatt-hour.

Note: CO2 emissions reduction was calculated using the US Environmental Protection Agency emission factor of 7.03 x 10-4 MTCO2/kWh.

Source: Author's calculation.

Case Study 1: Romblon Electric Cooperative, Inc.

Table 5.23 shows the 2025 and 2040 energy and peak demand projections of ROMELCO based on its 2016 Distribution Development Plan. It also highlights the baseline data for the installed capacity and the net electricity production in 2015. Furthermore, the table presents the corresponding additional energy and capacity requirements for 2025 and 2040.

Total peak demand was projected to reach 4.66 MW by 2025. It was nearly shared equally by micro-hydro and diesel power applications, posted at 2.35 MW and 2.31 MW, respectively. Per fuel type, micro-hydro capacities will require an additional 1.45 MW from its existing 0.9 MW installed capacity in 2015. The current installed capacity of diesel power plants at 8.38 MW is sufficient to cover the 2.31 MW demand for diesel.

ROMELCO's energy demand for 2025 was forecasted at 26,004 MWh. Considering the 2015 net energy production of 16,913 MWh, the additional energy requirement for the period is 9,091 MWh.

For the 2040 outlook period, ROMELCO's expected peak demand of 7.02 MW will almost catch up with the existing supply of 8.38 MW, leaving an excess capacity of 1.36 MW. Although capacity requirements for micro hydro is still pegged at 1.45 MW, the required energy has significantly increased to 13,179 MWh compared to the 2025 energy requirement of 5,826 MWh. Existing diesel-based capacities should still be adequate by 2040, whilst energy requirements are expected to increase to 14,446 MWh, four times the 2025 demand level.

Case Study 2: Basilan Electric Cooperative, Inc.

Based on the demand and supply projections of BASELCO, the existing installed capacity of 14.03 MW and net energy production of 39,370 MWh in 2015 already falls short by 1.80 MW and 12,618 MWh, respectively, in 2025. Although there is a minimal excess in micro-hydro capacity at 0.03 MW, most of the capacity and energy requirement is expected to come from diesel-based technology.

By 2040, the almost doubling of peak demand is notable at 26.70 MW from its 2025 demand level of 15.83 MW, considering the economic growth of the area. To fill this gap, an additional 13.31 MW of diesel-based capacity is necessary.

Towards the long-term period, peak and energy demand for micro-hydro technology was similarly fixed at 0.64 MW and 600 MWh, respectively, having no capacity augmentation plan programmed by BASELCO for its Kumalarang micro-hydro power plant (Table 5.24).

Table 5.23. ROMELCO's Projected Energy and Capacity Requirements, 2025 and 2040

Applications	2015		2025				2040			
	Installed Capacity (MW)	Net Energy Production (MWh)	Peak Demand, MW	Energy Demand (MWh)	Required Capacity (MW)	Required Energy (MWh)	Peak Demand, MW	Energy Demand (MWh)	Required Capacity (MW)	Required Energy (MWh)
	(a)	(b)	(c)	(d)	(c – a)	(d – b)	(e)	(f)	(e – a)	(f – b)
Micro hydro	0.9	4,879	2.35	10,705	1.45	5,826	2.35	18,058	1.45	13,179
Diesel	7.48	12,034	2.31	15,299	(5.17)	3,265	4.67	26,480	(2.81)	14,446
Total	**8.38**	**16,913**	**4.66**	**26,004**	**(3.72)**	**9,091**	**7.02**	**44,538**	**(1.36)**	**27,625**

MW = megawatt, MWh = megawatt-hour.

Note: Required Capacity and Energy Demand by 2025 and 2040 is based on author's calculation.

Source: ROMELCO (2016).

Table 5.24. BASELCO's Projected Energy and Capacity Requirements, 2025 and 2040

Applications	2015		2025				2040			
	Installed Capacity (MW)	Net Energy Production (MWh)	Peak Demand, MW	Energy Demand (MWh)	Required Capacity (MW)	Required Energy (MWh)	Peak Demand, MW	Energy Demand (MWh)	Required Capacity (MW)	Required Energy (MWh)
	(a)	(b)	(c)	(d)	(c – a)	(d – b)	(e)	(f)	(e – a)	(f – b)
Micro hydro	0.67	579	0.64	600	(0.03)	21	0.64	600	(0.03)	21
Diesel	13.36	38,791	15.19	51,388	1.83	12,597	26.70	91,685	13.34	52,894
Total	**14.03**	**39,370**	**15.83**	**51,988**	**1.80**	**12,618**	**27.34**	**92,285**	**13.31**	**52,915**

MW = megawatt, MWh = megawatt-hour.

Note: Required Capacity and Energy Demand by 2025 and 2040 is based on author's calculation.

Source: BASELCO (2016).

Envisaged Policies for Off-Grid DES

This section enumerates envisaged policies and support mechanisms to further promote the development of DES in off-grid areas.

Additional Incentives

Whilst the FiT system is applicable to on-grid renewable energy developers, the government is looking at relinquishing the FiT system because the mechanism is becoming a burden to electricity consumers as an added cost to the electricity bill. As a policy recommendation, now that the investment costs for putting up renewable energy systems have significantly gone down and are at par with other conventional technologies, the FiT system applied in the off-grid is one considerable policy measure envisioned to encourage private sector interest in developing renewable energy resources.

Power Capacity Portfolio

As a priority thrust in the main grid, the government embarked on a national policy towards institutionalising a 70–20–10 percentage sharing of the baseload, mid-merit, and peaking load categories as well as reserve capacity requirement equivalent to 25% of the total peak demand. Whilst the existing profile of DES in off-grid areas is notably dominated by diesel-based technologies, diversification of the capacity mix – coupled with an appropriate power capacity portfolio such as the one being instituted in the main grid – will unquestionably strengthen the adequacy, reliability, and affordability of electricity supply.

Energy Resiliency Policy

The Philippines, most especially its remote communities, have become more vulnerable to various forms of natural and man-induced disasters and calamities in the advent of climate change. For this reason, the government has drafted a policy measure that will extensively strengthen the resiliency of the energy infrastructure, be it on grid or off grid. This initiative is visualised to reinforce the energy infrastructure to withstand the impacts of uncontrollable disruptive events.

Chapter 6
Distributed Energy System in Thailand

Thailand's Electricity Supply Industry Structure

Thailand is one of the best known developing countries in ASEAN. With a population of about 70 million, its need for electricity is gradually increasing. The country's electricity market is the wholesale market, which is the same as that of many developing countries. However, the wholesale electricity market in Thailand is regulated by the government and related organisations such as the Department of Alternative Energy Development and Efficiency, Energy Policy and Planning Office (EPPO), and the Ministry of Energy, Energy Regulatory Commission. The Electricity Generating Authority of Thailand (EGAT) produces and transmits electricity and the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA) distribute it. Most of the distributed energy systems (DESs), known as small power producers (SPPs) and very small power producers (VSPPs), are connected to the distribution system of PEA and MEA. The transmission system in Thailand already covers 99% of residential areas (Figure 6.1).

Thailand's Electricity Situation

In 2016, per EGAT records, the net peak demand of Thailand of 30,973 MW occurred on Wednesday, 11 May 2016, at 14:00, higher than that in 2015 by 2,890 MW or 10.3%. Its 2016 total net energy demand was 196,868 GWh higher than that in 2015 by 7,347 GWh or 3.9%. The highest electricity consumption comes from the industrial sector (42%), followed by the residential sector (24%), the business sector (19%), and other sector (15%). The country's electricity consumption in 2016 grew as expected because of Thailand's economic growth of 3.2%.

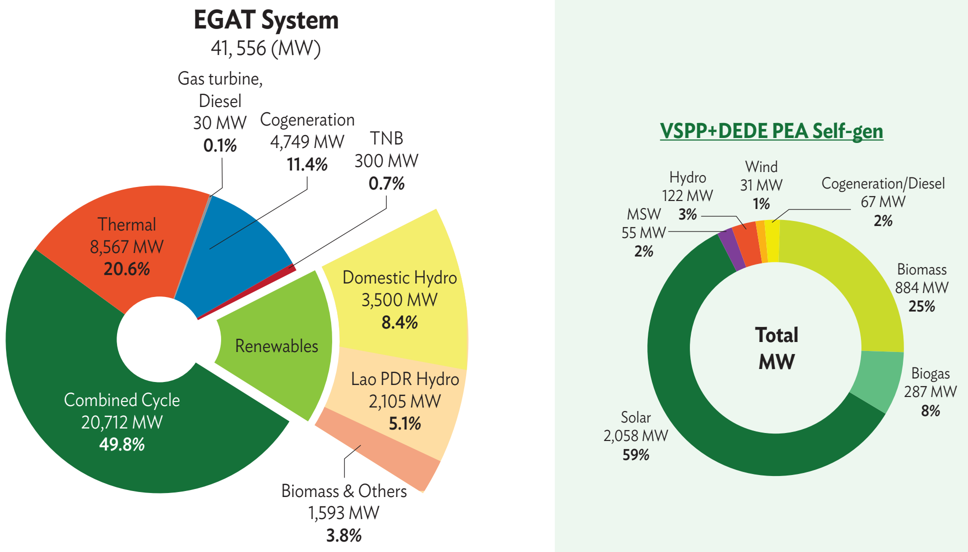
In 2016, its net power capacity amounted to 45,065 MW, comprising combined cycle power plant of 20,712 MW (49.8%), thermal power plant of 8,567 MW (20.6%), renewable energy of 7,196 MW (17.3%), cogeneration of 4,749 MW (11.4%), gas turbine and diesel power plants of 30 MW (0.1%), and power exchanges between

Thailand and Malaysia of 300 MW (0.7%). Figure 6.2 shows that Thailand's power system includes power generated by non-firm SPPs and VSPPs. It also shows the contract capacity on Thailand power system by power plant type in 2016.

Figure 6.1: Thailand National Power Grid

Source: GENI (2016).

Figure 6. 2. Contact Capacity on Thailand Power System by Power Plant Type, 2016



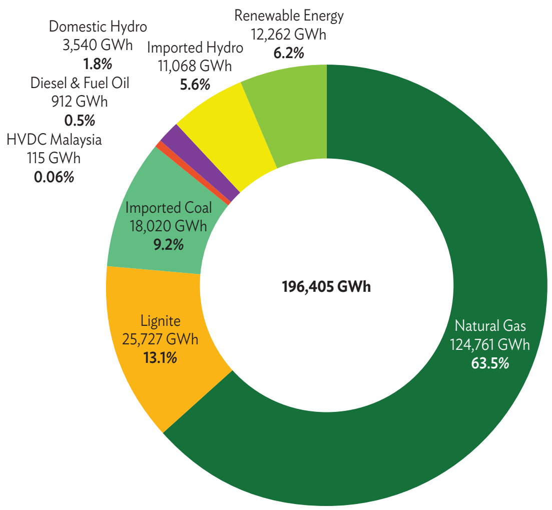
Thailand System	45,065 MW
- EGAT System	41,556 MW
- VSPP + DEDE PEA Self-gen	3,509 MW

DEDE = Department of Alternative Energy Development and Efficiency, EGAT = Electricity Generating Authority of Thailand, MW = megawatt, PEA = Provincial Electricity Authority, VSPP = very small power producer.

Source: MOE (2015).

In terms of fuel consumption for electricity generation in 2016, natural gas had the highest share in Thailand's generated power of about 63.5%, followed by lignite and import coal (22.3%), renewable energy comprising all types of renewable energy and hydropower from both neighbouring countries and domestic hydropower (13.7%), and others (0.5%). Figure 6.3 shows the energy generation by fuel type in 2016.

Figure 6.3. Energy Generation by Fuel Type, 2016



GWh = gigawatt-hour, HVDC = high voltage direct current.
Source: MOE (2015).

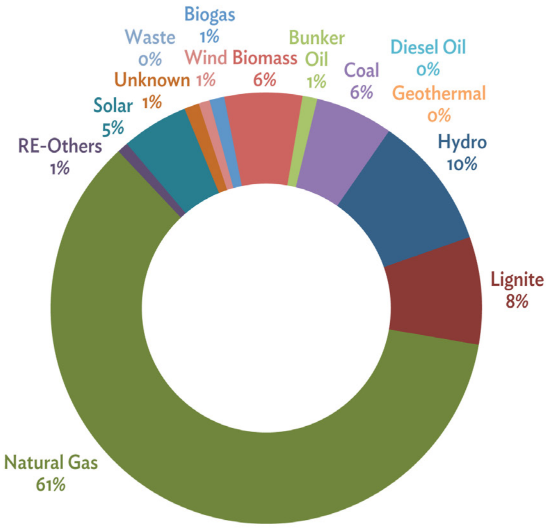
Current Situation of Thailand's Distributed Energy System

Thailand's total generation installed capacity, as of March 2017, was about 55,600 MW. (The total capacity reported is the total generation installed capacity including independent power systems. Thus, the number in this report is higher than other official national power development plans (PDPs) which excludes the independent power systems). The main fuel used for Thailand's electricity generation is natural gas. The installed capacity of natural gas–fired power plants is about 62%; of coal-fired power plants, 7.7%; bunker oil and diesel oil power plants, 1%; of hydro power plants, 8%; and of renewable energy, 13.1% (Figure 6.4). Main proportions in renewable energy capacity are biomass and solar photovoltaic (PV), which are estimated to be 5.7% and 4.9% of total capacity, respectively.

Existing Policies to Promote Distributed Energy Systems

The Royal Thai government, like many other countries, is concerned about promoting renewable energy. However, power generation costs from some renewable energy resources are still higher than those of conventional energy resources, such as coal, natural gas, and hydro, while renewable energy has been promoted to address global

Figure 6.4. Proportion of Installed Capacity by Fuel Type



Source: MOE (2015).

warming and climate change issues. Thus, the Thai government has been exerting efforts to reduce carbon dioxide (CO2) emission by gradually promoting renewable power into the power system. The government has been pushing forward the Alternative Energy Development Plan (AEDP), Figure 6.5, for Thailand to become a low-carbon society.

In the past, to attract investors, the Adder System[1] was applied to encourage renewable power generation. Nowadays, the Feed-in Tariff (FiT) mechanism is being implemented to reflect the real cost of generating renewable power and to specify the time frame of purchasing. The plan intended to encourage waste (garbage), biomass, and biogas power generation as the priority. According to the plan, the potential of generating power from waste is 500 MW. However, the potential power generation from biomass would be 2,500 MW. The policies of the Ministry of Agriculture and Cooperatives (Thailand) to increase the plantation area of sugar cane and palm, as well as to raise productivity of cassava from 3.5 to 7 tons per Rai (or 0.4 Acre) per year, could provide feedstock for biomass power generation up to the capacity of 1,500 MW. In addition, area by area zoning and limited power generation capacity measures were adopted to prevent challenges from the previous plan. Technology improvement is expected to build the competitiveness of renewable energy over that of conventional energy,

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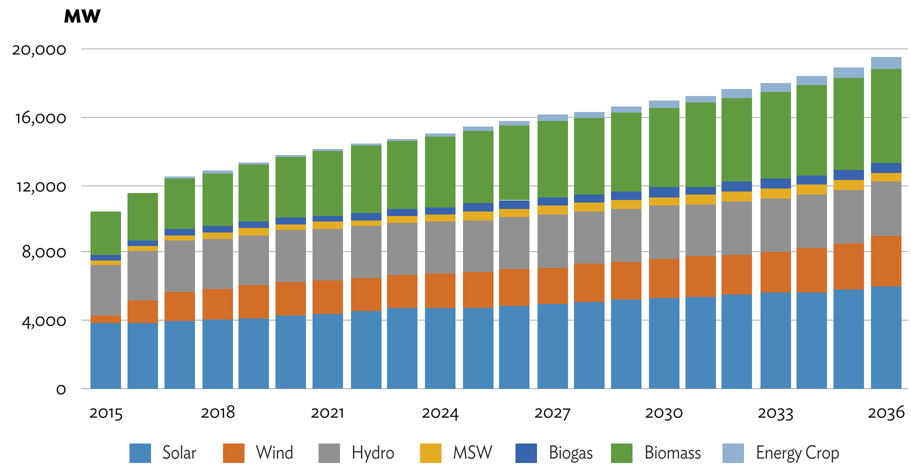
1 The Thai government has applied the premium model of feed-in tariff (FIT), or generally called 'Adder' since 2007. The premium rates and support duration will be differentiated by renewable energy type. Power utilities will buy electricity from producers at a rate equal to the base tariff, plus the wholesale fixed tariff and Adder. The Adder will be passed on to consumers in the form of the retail fixed tariff. Therefore, in no case will the electricity tariff burden on the people will increase due to the duplication of revenue of producers, except the base tariff is reviewed by including the retail fixed tariff.

especially liquefied natural gas. The main target of the AEDP is to increase the portion of renewable energy generation from 8% to 20% of the total power requirement in 2036, which accounts for a total of 19,684.4 MW.

According to the plan, SPPs and VSPPs, which can be accounted as DES, will be included in the plan. The estimated capacity of the future DES will later be discussed.

Figure 6.5. Alternative Energy Development Plan

Type	Solar	Wind	Hydro	MSW	Biogas	Biomass	Energy Crop	Total
End of 2014	1,298.5	224.5	3,048.4	65.7	311.5	2,541.8	-	7,490.4
End of 2036	6,000	3,002	3,282.4	500	600	5,570	680	19,634.4



MSW = Municipal Solid Waste, MW = megawatt

Source: EGAT (2017).

Table 6.1. The Current Renewable Energy Tariff

Technology	Feed-in-Tariff (FiT) ($ cent/kWh)
Solar PV	11.44
Wind Power	16.83
Biomass	11.77
Biogas	10.44
Micro hydro	13.6
Geothermal	N/A

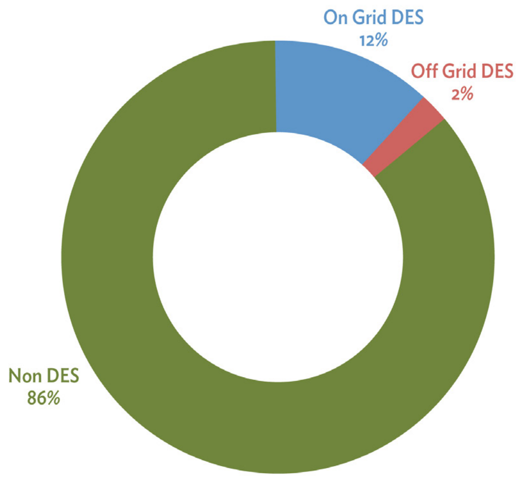
kWh = kilowatt-hour, PV = photovoltaic.

Source: EGAT, 2017.

Estimation of Current DES Status both On Grid and Off Grid

According to the assumptions of studies by the Economic Research Institute for ASEAN and East Asia (ERIA), the solar farm, solar PV, and small hydro under 50 MW are accounted for as DES. Coal, gas, geothermal, solar thermal, waste incineration plants, and biomass thermal plants under 100 MW are likewise accounted for as DES. The current installed capacity status estimates the total DES capacity (both on grid and off grid) calculated based on the above DES definition to be 7,500 MW. Therefore, DES makes up about 14% of total capacity (Figure 6.6).

Figure 6.6. Current Proportion of DES Capacity to Total Thailand Capacity

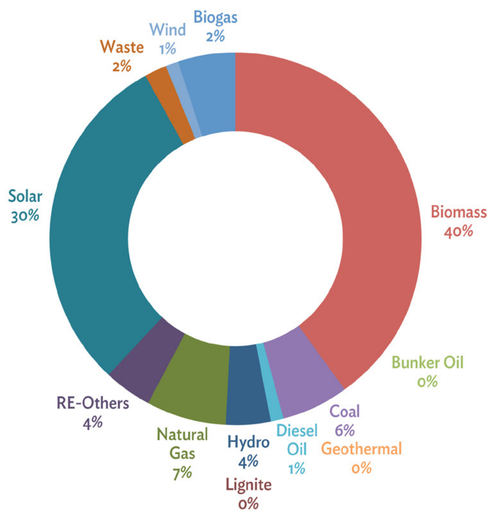


DES = Distributed Energy System.

Source: Authors' estimation.

ERIA's definition of off-grid is slightly different from the one this study. In this study, off-grid power plants are those that are not connected as a supply to the main national grid (EGAT grid) but those connected to the national grid to use the national grid as back-up. In this case, we define it as independent power system and it is accounted as off-grid. Also, the off-grid power plants in this study are those connected to the independent distribution grid (PEA and MEA that are not connected to the main national grid). The independent distribution grids are used on islands and in some rural areas. Hence, based on the definition of off-grid in this report, off-grid DES installed capacity is about 940 MW, which is about 2% of the total installed capacity of Thailand. Obviously, from the total of 14% DES, the on-grid DES is estimated to be 6,570 MW, which is 12% of the total capacity of Thailand. From 7,500 MW of DES-installed capacity, the renewable DES–installed capacity is about 6,500 MW or 86% of installed DES capacity. The renewable- installed capacity is 12% of Thailand's total capacity. The major fuel types contributing to DES capacity are biomass (40%) and solar (30%) (Figure 6.7). Biomass and solar currently play a major role in DES since the government has promoted biomass and solar in the 2010 AEDP.

Figure 6.7. Current Proportion of DES Capacity by Fuel Type



Source: Authors' estimation.

Areas that use on-grid and off-grid DES

Most of Thailand's DESs are connected on grid. The off-grid capacity of DES is only about 13% of total DES capacity in Thailand. Most of the 940 MW of the off-grid DES capacity (about 870 MW) is being used in industrial areas. Only 55 MW is used in remote residential areas, which include deep forest and remote mountainous villages.

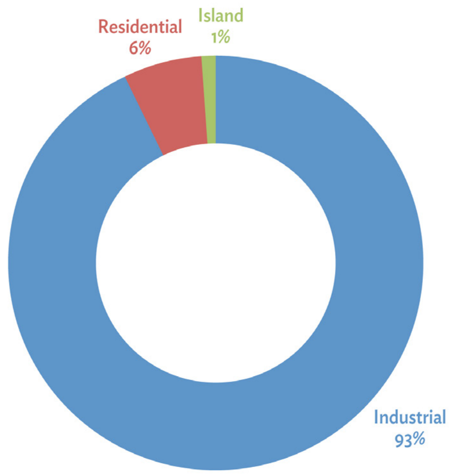
The rest, approximately 15 MW, is used on islands. Therefore, about 93% of off-grid DES capacity is used in industrial areas, about 6% is used in remote residential areas, and about 1% is used on islands (Figure 6.8).

Diversity, security, and CO2 reduction

Currently, DES in Thailand, which consists of many types of fuel in the generation mix, is one factor that increases the diversity of the total fuel mix in the country's generation capacity. Since most of the fuel used is natural gas, which is more than 60% of the total, the increase of biomass and solar in DES helps reduce the use of natural gas and results in the diversity of fuel mix. However, DESs in Thailand are not only for diversity and security but also for reducing electricity cost in industrial areas, for the return on investment of the government's promotion of FiT, and for the electricity need in some remote areas and islands.

The energy generated by solar, wind, and hydro from DES in Thailand is about 5.34 million MWh. Thus, CO_2 reduction using the factor of 7.30x10-4 metric tons CO_2/kWh is about 3,760 million metric tons CO_2 per year.

Figure 6.8. Off-grid Electricity Area



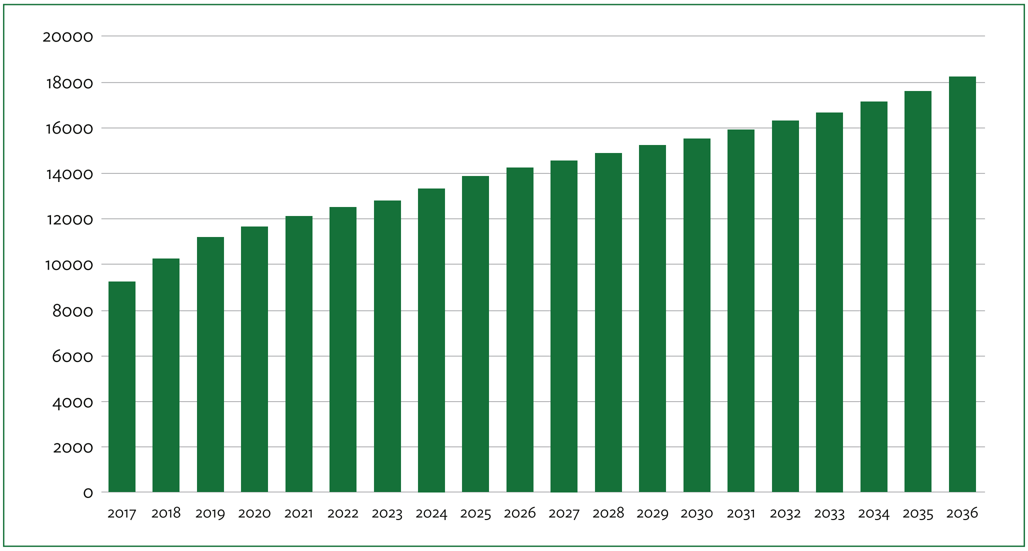
Source: Authors' estimation.

Estimation of Future DES in Thailand and Its Growth Opportunity

The government had already promoted renewables in its past PDPs. It continues to promote renewables into the system. Therefore, DES in Thailand tends to grow every year. The proportion of DES is expected to increase from 14% at 2017 to 23% at 2036. Figure 6.9 shows the estimated DES capacity according to the PDP.

Until 2036, the government's policy is to increase DES, including SPPs and VSPPs and renewables more than 10,000 MW, especially focusing on solar and biomass due to their potential. The government also has a policy to subsidise the cost of renewables using FiT. Thus, there are still a lot of opportunities to invest in DES in Thailand according to the policies. Yet, there is almost no room to increase electricity coverage in Thailand since it is already 99%. Therefore, on-grid DES is expected to grow much more than off-grid DES in the near future, according to the PDP. However, if the levelised off-grid DES electricity cost is lower than the retail electricity price provided by MEA and PEA, the off-grid capacity might skyrocket in the future.

Figure 6.9. Estimated DES Capacity in Thailand, 2017–2036



DES = Distributed Energy System.
Source: Authors' estimation.

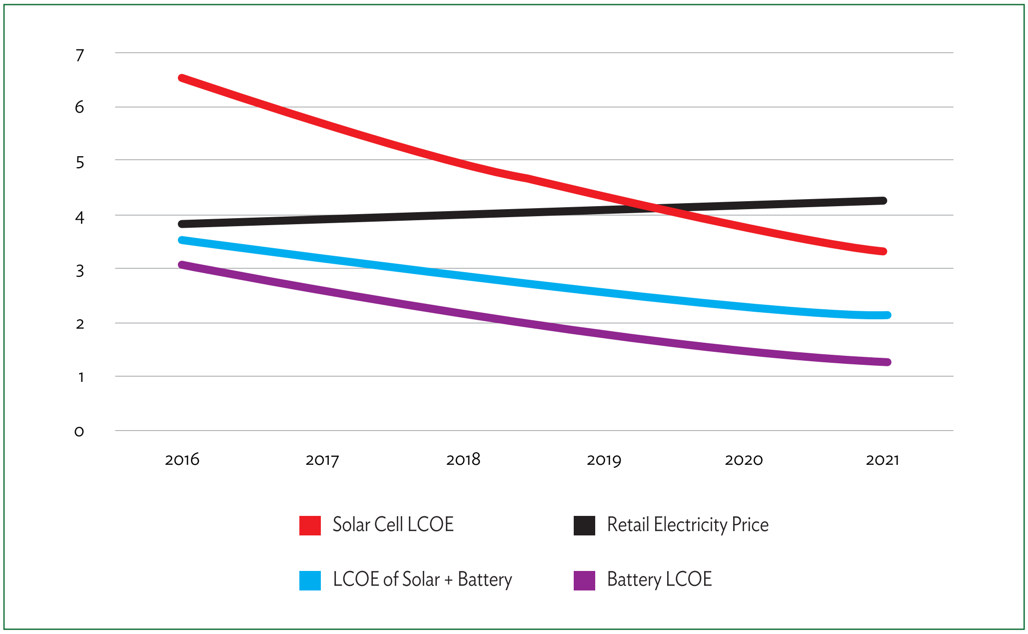
Until 2036, the government's policy is to increase DES, including SPPs and VSPPs and renewables by more than 10,000 MW, especially focusing on solar and biomass due to their potential. The government also has a policy to subsidise the cost of renewables using FiT. Thus, there are still a lot of opportunities to invest in DES in Thailand according to the policies. Yet, there is almost no room to increase electricity coverage in Thailand since it is already 99%. Therefore, on-grid DES is expected to grow much more than off-grid DES in the near future, according to the PDP. However, if the levelised off-grid DES electricity cost is lower than the retail electricity price provided by MEA and PEA, the off-grid capacity might skyrocket in the future.

Current cost of on-grid and off-grid, estimation of future cost of wind and solar compared with the retail electricity price in Thailand

Today, the cost of large-scale electricity production in Thailand is still lower than the levelised DES electricity cost. Large-scale utility power plants provided by EGAT offer reasonably low prices for consumers; thus, DES cost in Thailand is still not competitive. In the case of unsubsidised DES cost through FiT, the national grid cost plus the provided electricity cost in most remote areas is still lower than the DES off-grid cost.

The levelised cost of electricity (LCOE) of wind and solar is dropping sharply, and battery cost is decreasing annually. Hence, if future DES cost is anticipated to be lower than the retail electricity price, then DES will rapidly grow. The LCOE of solar and wind is expected to go below 1.5 baht (B)/kWh in 2036 (Source: Bloomberg new energy finance); battery capital expenditure cost is also expected to fall below 10 million B/MWh before 2022 (Seba, 2014). According to these assumptions, the residential self-generation electricity cost will be lower than the retail electricity price in 2022. Figure 6.10 compares the price of solar cell combined with that of battery electricity and the retail electricity price in Thailand when using 10 kWh/day.

Figure 6.10. Comparison of Estimated Price of Electricity in Thailand



LCOE = levelised cost of electricity.
Source: Authors' estimation.

In conclusion, current DESs in Thailand are mainly used in the private industrial section and investment in accordance with Thai government policy. The main types of DES being promoted in the country are solar and biomass. The on-grid DES in Thailand is expected to grow in the near future. DES is estimated to grow at 10,000 MW. However, the off-grid DES demand can skyrocket when the price of self-generation electricity falls below that of the electricity retail price.

Thailand's DES Policy

The new Cabinet formed in 2014 initiated the direction of Thailand's Energy 4.0. The Ministry of Energy of Thailand focused Energy 4.0 on the Thailand Integrated Energy Blueprint to drive the country's energy innovation and continue the desire of King Rama IX to strengthen families and communities.

The Energy Policy on the Electricity Sector (Energy 4.0) is shown in Figure 6.11. To enhance the power sector, the Ministry of Energy has set policies related to DES in two areas:

1. unbalanced fuel diversification and unstable renewable generation, and
2. centralisation of generation and distribution systems with high investment in transmission system.

Case Study on Thailand's Smart Grid Projects

The pilot programme included in the expedition plan of the Ministry of Energy, administration by the Energy Planning and Policy Office comprises three pilot projects:

1. Mae Hong Son smart grid, Muang district, Mae Hong Son province, operated by EGAT,
2. Micro Grid project in Mae Sariang district, Mae Hong Son province, operated by PEA.
3. Smart Grid project in Pattaya area Chonburi province, operated by PEA.

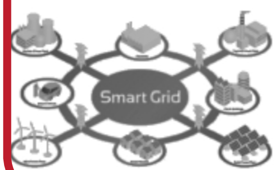
The Pilot Project of Mae Hong Son Smart Grid, Muang District, Mae Hong Son Province

The province of Mae Hong Son is preserved forest. It is the only province in Thailand where the electricity transmission system of EGAT is not accessible. Currently, electricity in the Mae Hong Son area is generated from various energy sources. Some of the electricity has to be distributed from the PEA's power distribution system through densely forested areas; Mae Hong Son province then has frequent power failures due to falling trees. Reliability and quality of electricity are important issues to be addressed in this area.

As a result, EGAT developed a smart grid as a pilot project in the Muang District of Mae Hong Son Province to make the power system in the district more stable. Mae Hong Son is considered appropriate for the implementation of the pilot programme. Because of the location of the project, it is possible to control and operate the system together with the PEA Micro Grid System at Mae Sariang.

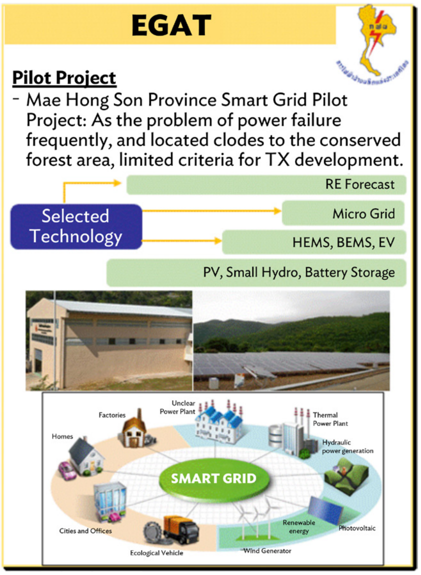
EGAT has an approved budget of B720 million for the project. To accelerate the smart grid operation, immediate action modifications have been made to the project, which covers smart grid technology and extends to a broader scope. An additional budget of B361 million has been proposed, leading to a total budget of B1.081 billion for this project.

Figure 6.11. Energy Policy on the Electricity Sector (Energy 4.0)

	Presently	Key Measures 2017-2018	Target 2036
To Enhance Power Sector	Unbalanced fuel diversification and unstable RE generation	• RE Generation Plan by Region • Firm RE & Energy Storage System • More Transmission System for RE	• Less Natural Gas in Gen. Mix (from 64% to 37%) • More RE (from 8% to 20%) • More Coal (from 18% to 23%) • More Power Import (from 10% to 20%)
To Enhance Power Sector	Not Full Capacity of Generation & Transmission System Utilization	• Power Pool Market for old and high potential power plants • Merit Order (with less constraints) • Power Purchase from Neighboring Countries	• ASAN Hub on Electricity • Competitive electricity tariff to ASEAN Countries
To Enhance Power Sector	Inefficient Use of Electricity	• Change/Use High Efficient Equipment • Block Grant/Matching Fund (Gov't Hospitals) • HEPs / MEPs • Building Code • ESCO	• Energy Saving by 89,000 GWh • Not to Construct New Power Plants 10,000 MW (equivalently)
To Enhance Power Sector	Centralised of Generation & Distribution System with High Investment of TX System	• Decentralised Generation System (Distributed Generation: DG) • Micro Gris Pilot Projects	• Decentralised Power System • Less Investment in Tx System • Smart Power System • Smart Grid
	INNOVATION 	• **Micro Grid** • **SMART Energy Management** • **SMART Grid**	• **Energy Storage System** • **SPP Hybrid Firm/VSPP Firm** • **Next Generation of Renewable**

Source: Authors' estimation.

Figure 6.12. The Pilot Project of Mae Hong Son Smart Grid of EGAT



BEMS = Building Energy Management System, EGAT = Electricity Generating Authority of Thailand, EV = electric vehicles, HEMS = Household Energy Management System, PV = Photovoltaic, TX = transmission system.
Source: EGAT (2017).

The Pilot Project of Micro Grid, Mae Sariang District, Mae Hong Son Province

The power system in Mae Sariang district, Mae Hong Son province, is supplied from Hod substation, which is about 110 kilometres away, and through the forest (Figure 6.13). These areas are those where electricity is generated from several sources, such as the PEA's diesel power plant, the small hydropower plant of the Department of Alternative Energy Development and Efficiency (DEDE), the solar power plant of VSPPs, diesel emergency generators of large consumers, etc. However, these power sources have unstable and inadequate generation capacity, resulting in poor power quality and causing frequent power failure

PEA has conducted a pilot project in this area to study and develop the micro-grid controller for planning and operating power systems with various types and sizes of power generation. With highly unstable generation of renewable energy, to maximise the potential of the power system to increase its security, and to ensure reliability and overall power quality as a whole.

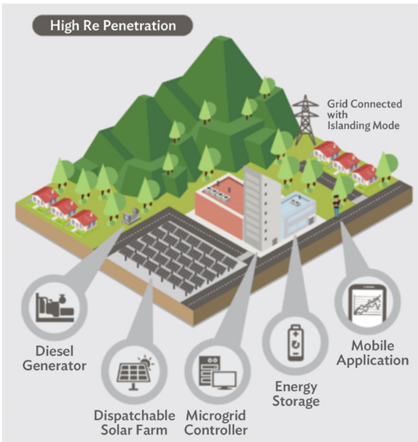
At present, PEA has an approved budget of B265 million. To accelerate the concrete smart grid operation, as part of the short-term expediting programme, the details of the project including smart grid technology and the broader scope of operations have been expanded. An additional budget of B582 million has been proposed, leading to a total budget of B847 million for this PEA project.

The Pilot Project of Smart Grid in Pattaya City Area, Chonburi Province

The smart grid project in Pattaya City Area, Chonburi Province, is the first smart grid project of PEA. The Pattaya area was selected because it was considered appropriate and 'ready' in many aspects. It has major cities with high electricity demand, wide distribution of power consumers (residential, office buildings, hotels, businesses, and industrial sectors), and integrated communication and technologies. Pattaya City also has a policy to develop into a smart city, so it is appropriate to demonstrate new technologies; the infrastructure of the communication system is quite ready in that area.

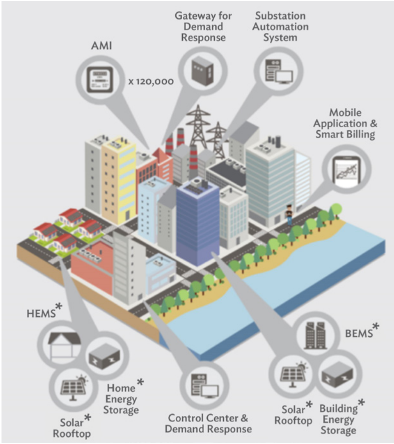
Presently, PEA has an approved budget of B1,069 million. To accelerate the concrete operation of the smart grid, as part of the short-term expediting programme, the details of the project including smart grid technology and additional operations have been expanded. An additional budget of B439 million has been proposed, leading to a total budget of B1.508 billion for this PEA project.

Figure 6.13. The Pilot Project of Micro Grid, Mae Sariang District, Mae Hong Son Province, PEA



Source: Energy Policy and Planning Office (2017).

Figure 6.14. The Pilot Project of Smart Grid in Pattaya City Area, Chonburi Province, PEA



Source: Energy Policy and Planning Office (2017).

Chapter 7
Conclusions and Policy Implications

ASEAN

The ASEAN primary energy supply is projected to increase from 592 Mtoe in 2013 to 1,697 Mtoe in 2040, representing more than threefold increases during this period. This increase in energy demand will put pressure on energy security, access, and price. Thus, the study of distributed energy system (DES) is explored as part of the energy system that could promote energy access more efficiently at lower costs. The study found that DES is a modern small power generation system that is flexible in providing electricity to end users more effectively due to lower investment cost and easier handling compared with large national power plants and grids. If it is to be widely deployed, DES could also help to 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 applied. Thailand's small power producers (SPPs) and very small power producers (VSSPs) have been widely used and their current share of 17.4% in the power generation mix in 2014 is expected to increase significantly.

At the ASEAN level, the idea of transboundary grids is being promoted in the ASEAN Power Grid. This grid is expected to make a major contribution to maximising ASEAN's benefit in avoiding the cost of power generation. However, it is expensive and it may take years to realise the connectivity. In contrast, DES can overcome cost constraints that typically inhibit the development of large capital projects and transmission and distribution lines. Thus, DES will be widely used. The modern grid system is also expected to handle the integration of DES into the grid system. DES could be a stand-alone power generation or connected to the power grid. So, its application is also very suitable for mountainous terrain, islands, and remote rural areas.

The study also estimated the DES-related renewable capacity and needed investment at the ASEAN level. The estimated power generation from combined renewable energy such as wind, solar photovoltaic (PV), geothermal, hydropower, and biomass in ASEAN will increase significantly from the business-as-usual scenario (BAU) to the alternative policy scenario (APS); it also implies investment opportunities in this sector. Investment opportunities by 2040 in BAU for combined solar, wind, biomass, hydropower, and geothermal are estimated at US$34 billion, and in the APS at US$56 billion. Amongst DES-related renewable investment opportunities, those for solar and geothermal power are expected to double from BAU to the 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 reduced CO2 emission. The study estimates that BAU would lead to a reduction of 46.1 million metric tons of CO2 emission and that the APS could lead to a reduction of 64.6 million metric ton of CO2.

Indonesia

DES can be implemented in regions like Indonesia where grid-connected electricity supply is unavailable or uneconomically viable. It can be implemented in Indonesia to support the electrification faster than by waiting for supply from a grid connection. DES is cost competitive compared with current diesel power plants. As DES projects use local energy resources, and are not necessarily technology intensive, these projects may also increase the involvement of local people in the construction and maintenance of the system. This may create jobs in the region.

As the potential of DES is huge in Indonesia, its development can be even faster with the participation of local governments, for example by providing free land for the sites of DES projects. To optimise the development of DES projects and ensure their sustainability, government support – such as tax incentives, longer term low-interest loans, and a streamlined licensing process – is needed. Good electricity tariffs for DES that take account of production costs and reasonable margins are also needed.

Malaysia

The implementation of DES is very important for the security of supply, especially for remote areas where the connectivity is far from the grid. To ensure the stability of electricity supply without disruption, equipment and other requirements for electricity generation should be properly installed and completed. DES is now the potential solution for this problem. Installing the transmission or distribution line to the national grid from remote areas is costlier. By using existing natural resources, such as biomass or biogas, DES can also reduce greenhouse gas (GHG) emissions.

Through DES, rural areas can achieve an electrification rate of 100%. Providing this basic amenity will help generate income for the economy. DES will also help boost tourism on several of Malaysia's islands. With some remote islands in the country located far from the national grid system, the implementation of DES will be a great solution.
Public and private funds are needed to ensure the success of DES' implementation. Government can offer attractive incentives to attract local and international investors.

Philippines

Evidently, the underlying principles of DES present substantial potentials that correspond to the current setting of the Philippine electric power industry, either through on-site embedded generation or stand-alone off-grid systems.

As the government aspires to bring inclusive economic development to the grassroots level, the concept of DES applications undeniably portrays an integral role in ensuring the security of energy supply in the flourishing economic and industrial zones of the country and, more importantly, of the remote communities.

Government has recognised that the deployment of DES applications is an alternative platform to complement centralised and decentralised electrification initiatives.

Harnessing the full potential of the cleaner set of fuels such as renewables is admittedly an effective mitigating measure to drastically reduce GHG emissions. This in the long run is foreseen to counter the adverse impacts of climate change. To take full advantage of this benefit, the country should pursue the development and increased use of indigenous renewable energy sources that are abundant in rural locations. But strong policy support and mechanisms from the government are imperative.

Fundamentally, DES applications are intended to provide an affordable and reasonable source of electricity. But because the private sector lacks confidence to invest in the off-grid generation business, the national government assumes responsibility for bringing the necessary electricity services to spur local economic development. To sustain the operations of DES in off-grid communities, government subsidises the costs of generating power. In turn, DESs have become costly compared with grid-connected power systems.

Moving forward, the Department of Energy, the government arm overseeing the local energy sector, has come up with the following initiatives to foster the development of and promote DESs in the country. Amongst others, the government is inclined to:

- Conduct studies that will strengthen the existing DESs.
- Declare and include future DESs as energy projects of national significance.
- Regularly update the Missionary Electrification Development Plan.
- Pursue and intensify the private sector participation programme.
- Accelerate the promotion, utilisation, and development of renewable energy as DESs.
- Explore emerging technologies that may be considered DESs.
- Develop and propose regulatory instruments that will open favourable opportunities to prospective private investors.
- Periodically review and assess existing policies, programmes, and mechanisms that will safeguard the interest of both public consumers and private investors.
- Pursue envisaged policies that are practicable and applicable to DESs.
- Study and implement a subsidy graduation programme for DES.
- Refurbish, rehabilitate, and upgrade old DES operated by the state-owned National Power Corporation – Small Power Utilities Group of the (NPC–SPUG).

Thailand

DES has been widely applied in Thailand through small power producers (SPPs) and very small power producers (VSPPs). The current share of DES in Thailand is about 17.4% of the power generation mix, and its share and capacity will increase significantly in the future. Thailand's experience could provide the best example for other ASEAN countries to use DES to respond to increasing energy demand.

DESs in Thailand are mainly used in the private industrial sector and investment in accordance with the government's policy on subsidy. DESs in Thailand mainly promote solar and biomass. The on-grid DES of the country is expected to grow in the near future. Per the current policy on DES, about 10,000 MW DES growth is expected. However, off-grid DES demand could skyrocket when the price of self-generated electricity is lower than that of retailed electricity.

The new Cabinet provided the direction of Energy 4.0. To accommodate the government's policy, the Ministry of Energy has kept the Energy 4.0 policy focused on the Thailand Integrated Energy Blueprint to drive energy innovation and given King Rama IX's desire to strengthen families and communities. To enhance the power sector, the Ministry of Energy has set policies on DES in two areas – for places that experienced unbalanced fuel diversification and unstable renewable generation, and for places where the centralised generation and distribution system was faced with high investment in the transmission system.

Policy Implications for DES in ASEAN

DES offers emerging ASEAN countries one of the best options in responding to increasing energy demand and providing energy access to remote rural, mountainous, and island areas, and economic zones as stand-alone generator or combined with the grid system. The promotion of DES is crucial, but DES will need careful policy support if it is to deploy renewable energy. Basically, the policies will work around reducing upfront investment costs of DES-related renewable generation. Those friendly policies are the required top-down renewable energy targets such as renewable portfolio standards and other policies; fiscal incentives such as exemptions from taxes (value added, fuel, income, import and export, and local taxes); and accelerated depreciation through premium tariff rates such as a feed-in tariff. ASEAN could consider the introduction of carbon tax in the future. Banking institutions will need to enlarge their role and policy to finance DES-related renewable energy and find mechanisms to minimise risks, and to increase the profitability aspects of DES-related renewable investments. DES-related investment opportunities are large, and will provide jobs and many business opportunities to people and communities. DES is one of the modern generation systems and its deployment will also help address national energy security.

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