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 CO2/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 (tCO_2/MWh)	$ktCO_2$
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 (tCO_2/MWh)	$ktCO_2$
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 (tCO_2/MWh)	$ktCO_2$
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 (tCO_2/MWh)	$ktCO_2$
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.