Additional information on calculating the emission factors of Indonesia for the JCM

In order to secure net emission reductions in the methodology, the following emission factors will apply depending on the regional grid to which a proposed project activity will connect in Indonesia:

- Table 1 summarises the applied emission factors for the PV system(s) in a proposed project activity, which is directly connected, or connected via an internal grid not connecting to a captive power generator, to a regional grid (PV Case 1)
- Table 1 also summarises the applied emission factors for the PV system(s) in a proposed project activity, which is connected to an internal grid connecting to both a regional grid and a captive power generator (PV Case 2).

Table 1 Grid emission factor PV Case 1 and Case 2

Regional grid name	Emission factor for PV Case 1 (tCO_2/MWh)	Emission factor for PV Case 2 (tCO_2/MWh)
Jamali grid	0.590	0.533
Sumatra grid	0.483	0.483
Batam grid	0.627	0.533
Khatulistiwa, Barito	0.600	0.533
Mahakam grid	0.522	0.522
Sulawesi Island grids (Sulselrabar, Sulawesi Tenggara - Kendari, Bau Bau, Kolaka, Lambuya, Wangi Wangi, Raha, Suluttenggo)	0.353	0.353
Lombok, Bima, Sumbawa grids	0.551	0.533
Kupang. Ende, Maumere, Waingapu grids	0.515	0.515
Ambon, Tual, Masohi grids	0.533	0.533
Ternate grid	0.532	0.532

- An emission factor of **0.533 t-CO_2/MWh** is applied, in the case that the PV system (s) in a proposed project activity is only connected to an internal grid connecting to a captive power generator (PV Case 3).

Background information and emission factors calculation methods

1. Current status of electric power source mix in Indonesia

There are five major islands in Indonesia: Sumatra, Java, Kalimantan, Sulawesi, and Papua, and 26 electricity interconnection systems or grids as shown in Figure 1, which cover 31 provinces as shown in Table 2.

Figure 1. Map of Indonesian grids[1]

Table 2 Interconnection System and Provinces covered

Interconnection System	Provinces/power generation unit covered
1. Java-Madura-Bali (Jamali)	East Java, Central Java, D.I. Yogyakarta, West Java, Banten, D.K.I. Jakarta and Tangerang, Bali
2. Sumatra	Aceh, North Sumatra, West Sumatra, Riau, South Sumatra, Jambi, Bengkulu, Lampung, Bangka Belitung
3. Batam	Riau Provinces (Batam Island)
4. Tanjung Pinang	Riau Provinces (Bintan Island)
5. Khatulistiwa	West Kalimantan
6. Barito	South Kalimantan, Central Kalimantan
7. Mahakam	East Kalimantan
8. Sulselrabar	South Sulawesi, West Sulawesi, Southeast Sulawesi
9. Sulawesi Tenggara - Kendari	Southeast Sulawesi

[1] Approximate figure, based on Executive Summary – Electricity Supply Business Plan PT PLN, 2015-2024

10. Sulawesi Tenggara - Bau Bau	
11. Sulawesi Tenggara - Kolaka	
12. Sulawesi Tenggara - Lambuya	
13. Sulawesi Tenggara - Wangi Wangi	
14. Sulawesi Tenggara - Raha	
15. Suluttenggo	North Sulawesi, Central Sulawesi, Gorontalo
16. Lombok	West Nusa Tenggara
17. Bima	
18. Sumbawa	
19. Kupang	East Nusa Tenggara
20. Ende	
21. Maumere	
22. Waingapu	
23. Ambon	Maluku
24. Ternate	North Maluku
25. Tual	Maluku
26. Masohi	

There are six types of primary energy used for electricity generation in Indonesia, namely, coal, oil and diesel, natural gas, hydro, geothermal, and solar power[2]. The share of electricity generated from 2012 to 2014 by each type of primary energy is shown in Table 3. The electricity generation from hydro, geothermal, and solar power plants are deemed as low cost/must run (LCMR) power sources.

Table 3 Electricity generation by primary energy type

Electricity generation by primary energy type, PLN only (TWh)	2012	2013	2014
Coal	67	75	84
Oil (HSD, IDO, MFO) and diesel	33	30	65
Natural gas	36	41	11
Hydro	11	13	11
Geothermal	3.6	4.3	4.3
Solar power	0.00	0.01	0.01
Total	150	164	175

*There is a difference between the values listed as “Total“ and the summation of each value of “Coal”, “Oil (HSD, IDO, MFO) and diesel”, “Natural gas”, “Hydro”, “Geothermal” and “Solar power” because these values are rounded.
**Electricity generation represents a net amount which is the amount of electricity generated by a power plant that is transmitted and distributed for consumer use.

When the share of LCMR is less than 50% of the total grid generation, the operation of LCMR resources would not be affected by a newly installed power plant including a PV project[3]. Therefore, only electricity from gas-fired, coal-fired, and oil-fired power plant is taken into account for calculating the official regional grid emission factor in Indonesia. Applying this assumption, the Government of Indonesia

[2] Directorate General of Electricity, Ministry of Energy and Mineral Resources Indonesia (2015) The Book of Electricity Statistics Number 28-2015.
[3] CDM EB (2015) Tool to calculate the emission factor for an electricity system.

published emissions factor of each regional grid as of 2014[4] as shown in Table 4.

Table 4 Regional grid emission factors in 2014 published by the Government of Indonesia

No.	Interconnection of Electric Power Systems	Emission Factor (ton CO_2eq./MWh)
1	Jamali (Jawa-Madura-Bali)	0.84
2	Sumatera	0.794
3	Batam	0.975
4	Tanjung Pinang	1.03
5	Khatulistiwa	0.773
6	Barito	1.163
7	Mahakam	1.255
8	Sulselrabar	0.667
9	Sulawesi Tenggara - Kendari	0.85
10	Sulawesi Tenggara - Bau Bau	0.696
11	Sulawesi Tenggara - Kolaka	0.712
12	Sulawesi Tenggara - Lambuya	0.727
13	Sulawesi Tenggara - Wangi Wangi	0.73
14	Sulawesi Tenggara - Raha	0.721
15	Sulutenggo	0.886
16	Lombok	0.81
17	Bima	0.592
18	Sumbawa	0.644
19	Kupang	0.876
20	Ende	0.778
21	Maumere	0.626
22	Waingapu	0.861
23	Ambon	0.759
24	Ternate	0.777
25	Tual	0.744
26	Masohi	0.737

(Data source: Directorate General of Electricity, Ministry of Energy and Mineral Resources, Indonesia accessed at: http://jcm.ekon.go.id/en/index.php/content/Mzg%253D/emission_factor)

[4] JCM Indonesia website, http://jcm.ekon.go.id/en/index.php/content/Mzg%253D/emission_factor, 2016.

2. Calculation of emission factors of the regional grids

In order to identify the emission factors for the Indonesian regional electricity systems which can secure net emission reductions, the emission factors in this methodology are established by an operating margin that is calculated using emission factors of power plants including LCMR resources. To calculating the emission factors of each fossil fuel power generation, the best heat efficiency among currently operational plants in Indonesia is applied.

The most efficient coal-fired power plants and gas-fired power plants currently operational in Indonesia are identified in Table 5 and the best heat efficiency is determined as **42% and 61%**, respectively. With regard to diesel-fired power plants, the heat efficiency of **49%**, an efficiency level which has not been achieved yet by the world's leading diesel generator, is applied due to the data limitation[5].

Table 5 The best efficiency of fossil fuel power plants in Indonesia

Type of power plant	Power plant	Product	Capacity	Plant efficiency (LHV)
Coal-fired Ultra-Super Critical (USC)[6]	Lontar Coal-Fired Thermal Power Plant, Banten	GT13E2	315 MW	42%
Gas turbine combined cycle (GTCC)	Jawa-2 Combined Cycle Power Plant, Tanjung Priok	Mitsubishi Hitachi Power Systems M701F4	880 MW	61%

The emission factor of power generation by each fuel source is calculated from the plant efficiency using the following equation:

Emission factor of fossil fuel power plant [t-CO_2/MWh]
= (Emission factor of fuel source [kg-CO_2/TJ]*10^{-3}*0.0036[TJ/MWh] / (Heat efficiency (LHV) [%]/100)

Applying the emission factors for coal, gas and diesel combustion, which are 92,800 kgCO_2/TJ, 54,300 kgCO_2/TJ and 72,600 kgCO_2/TJ, respectively derived from "IPCC guideline 2006, Chapter 2, stationary combustion", together with the plant efficiency (LHV) of 42% for the coal-fired power plant, 61% for the gas-fired power plant and 49% for diesel-fired power plant, the conservative emission factors are calculated to be **0.795 t-CO_2/MWh** for coal-fired power plants, **0.320 t-CO_2/MWh** for gas-fired power plants and **0.533 t-CO_2/MWh** for diesel-fired power plants.

Using the data of electricity generation including LCMR resources and the conservative emission factors for each power source, operating margins in each regional grid are obtained, as follows:

---

5 The approved JCM methodologies (PW_AM001 and MV_AM001) also applied this value.
6 https://www.toshiba.co.jp/tech/review/2008/09/63_09pdf/a03.pdf

$$EF_{RE,j} = \frac{\sum_i EG_{i,j} \times EF_i}{\sum_i EG_{i,j}}$$

Where:

$EF_{RE,j}$ = The reference emission factor of regional grid j [tCO_2/MWh]

EF_i = Conservative emission factor of power plant type i [tCO_2/MWh]

$EG_{i,j}$ = Electricity generated and delivered to the regional grid from power plant type i including LCMR resources in grid j during 2012-2014 [MWh]

As a result, the emission factor for each regional grid which is directly connected, or connected via an internal grid not connecting to a captive power generator, to a regional grid is calculated as shown in column "Emission factor for PV Case1 (tCO_2/MWh)" of Table 1.

Those values are lower than the 2014 emission factors of the respective regional grids published by the government of Indonesia as shown in Table 4. Therefore, net emission reductions will be ensured by applying the emission factor as determined above.

3. Calculation of the emission factor of a captive power generator

To determine the emission factor of a captive power generator which normally uses a diesel generator in a conservative and simple manner, the heat efficiency of 49%, an efficiency level which has not been achieved yet by the world's leading diesel generator, is applied.

The emission factor of diesel power generation is calculated from the heat efficiency using the following equation:

Emission factor of diesel power plant [t-CO_2/MWh]
=(CO_2 emission factor of diesel oil [kg-CO_2/TJ]*10^{-3}*0.0036[TJ/MWh] / (Heat efficiency (LHV) [%]/100)

Applying the default value of the emission factor of diesel combustion which is 72,600 kgCO_2/TJ derived from "IPCC guideline 2006, Chapter 2, stationary combustion", together with the heat efficiency of 49%, the emission factor for a captive power generator is calculated to be **0.533 tCO_2/MWh**.

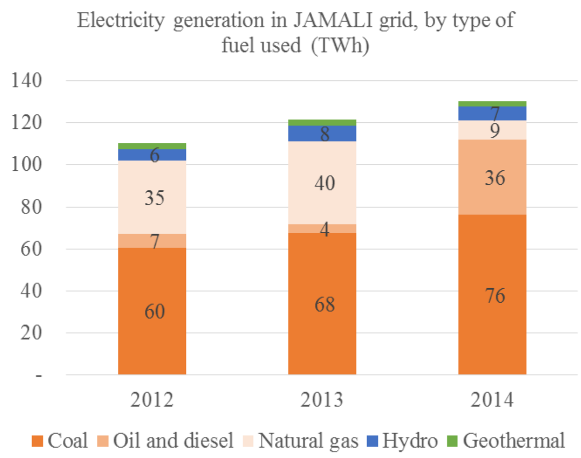
4. Selection of the calculated emission factors

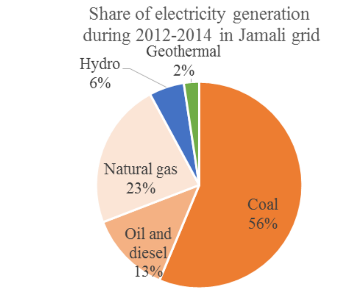
In case the PV system(s) in a proposed project activity is directly connected, or connected via an internal grid not connecting to a captive power generator, to a regional grid (PV Case 1), the value of operating margin including LCMR resources, using the best heat efficiency among currently operational plants in Indonesia in calculating emission factors of fossil fuel power plants, are applied. The emission factors to be applied are shown in column "Emission factor for PV Case 1 (t-CO_2/MWh)" of Table 1.

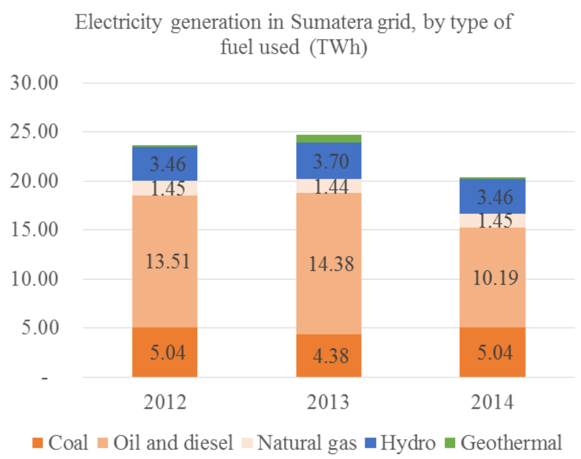
In the case the PV system(s) in a proposed project activity is connected to an internal grid connecting to both a regional grid and a captive power generator (PV Case 2), the lower values between emission factors as shown in column “Emission factor for PV Case 1 (t-CO_2/MWh)” of Table 1 and the conservative emission factors of diesel-fired power plant of 0.533 t-CO_2/MWh is applied. The emission factors to be applied are shown in column “Emission factor for PV Case 2 (t-CO_2/MWh)” of Table 1.

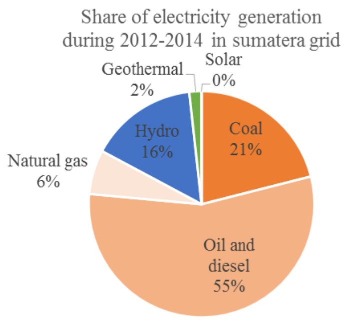
In the case that the PV system(s) in a proposed project activity is only connected to an internal grid connecting to a captive power generator (PV Case 3), **0.533 t-CO_2/MWh** is applied.

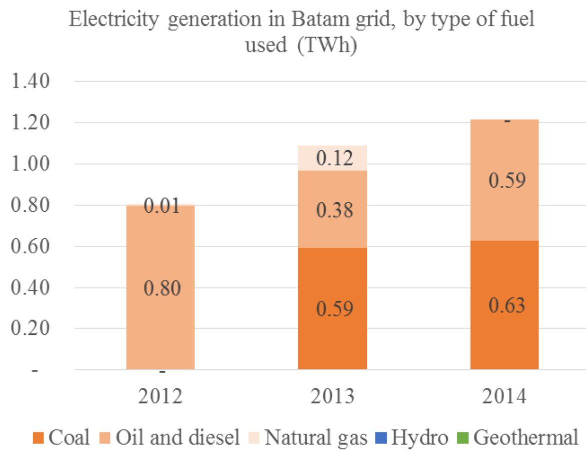
Appendix I Electric power source mix of each regional grid

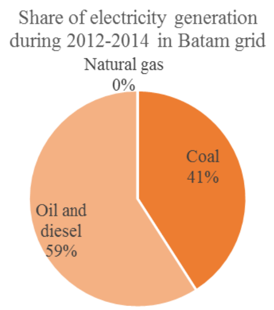


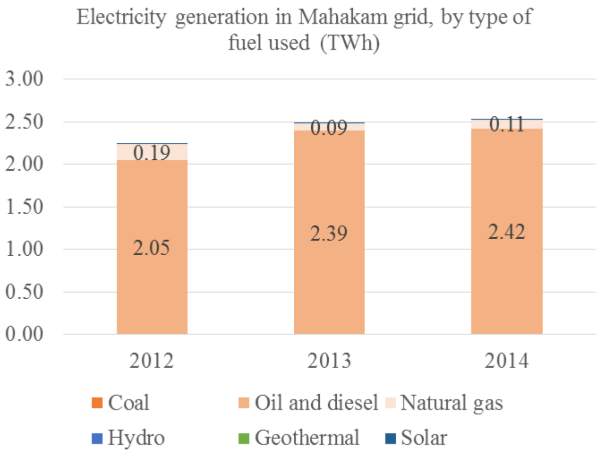


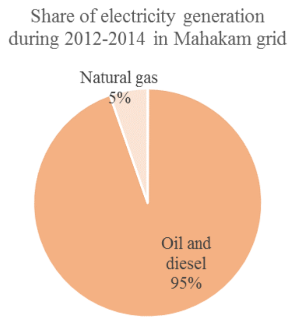


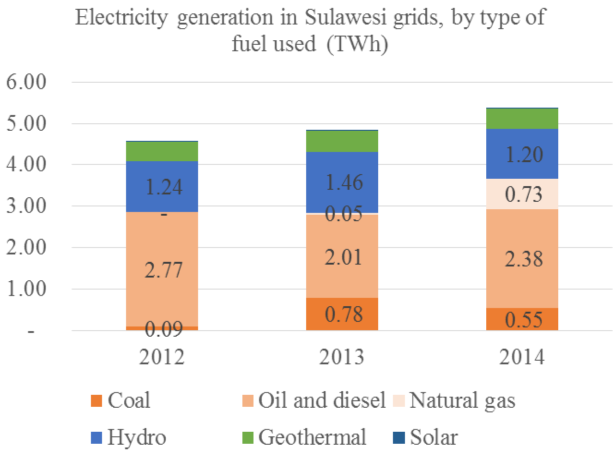


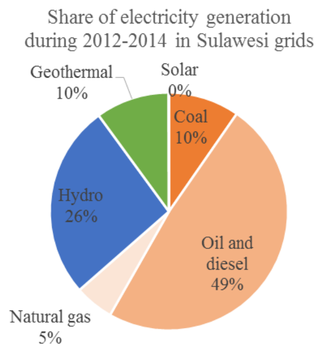


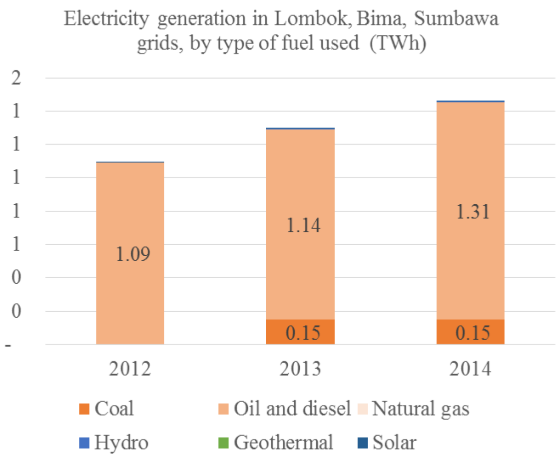


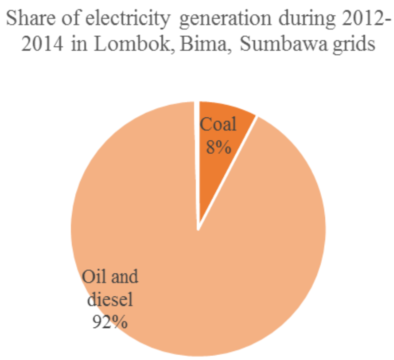

Electricity generation in Mahakam grid, by type of fuel used (TWh)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.19
2.05
0.09
2.39
0.11
2.42
2012
2013
2014
Coal
Oil and diesel
Natural gas
Hydro
Geothermal
Solar

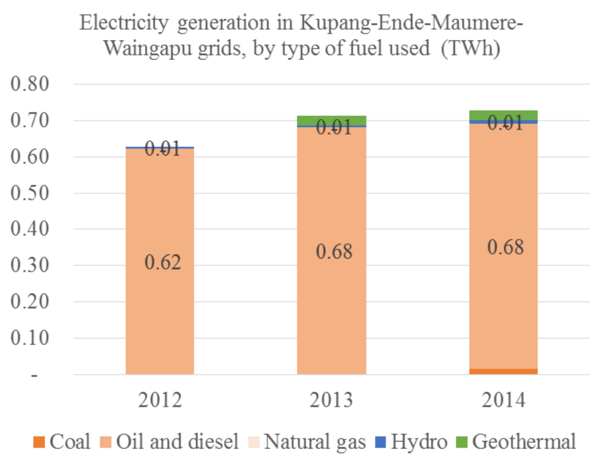

Share of electricity generation during 2012-2014 in Mahakam grid
Natural gas 5%
Oil and diesel 95%

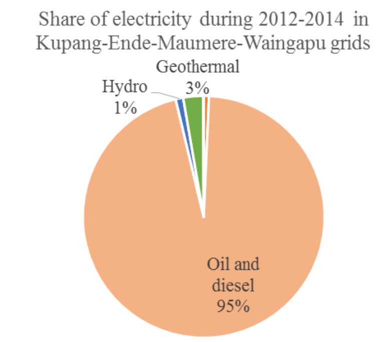

Electricity generation in Sulawesi grids, by type of fuel used (TWh)
6.00
5.00
4.00
3.00
2.00
1.00
-
1.24
-
2.77
0.09
1.46
0.05
2.01
0.78
1.20
0.73
2.38
0.55
2012
2013
2014
Coal
Oil and diesel
Natural gas
Hydro
Geothermal
Solar

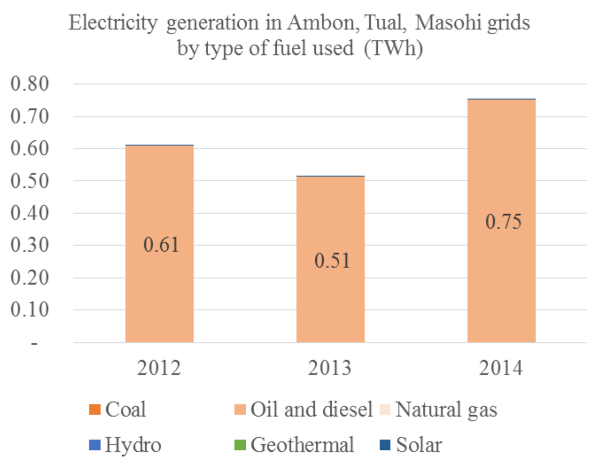

Share of electricity generation during 2012-2014 in Sulawesi grids
Geothermal 10%
Solar 0%
Coal 10%
Hydro 26%
Oil and diesel 49%
Natural gas 5%

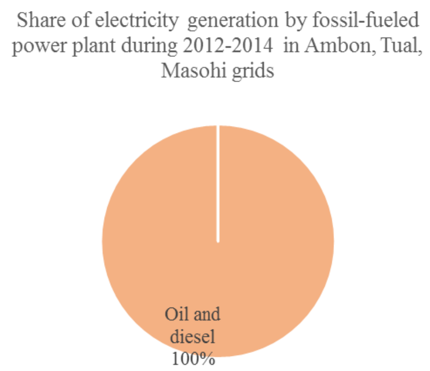

Electricity generation in Lombok, Bima, Sumbawa grids, by type of fuel used (TWh)
2
1
1
1
1
1
0
0
-
1.09
1.14
0.15
1.31
0.15
2012
2013
2014
Coal
Oil and diesel
Natural gas
Hydro
Geothermal
Solar

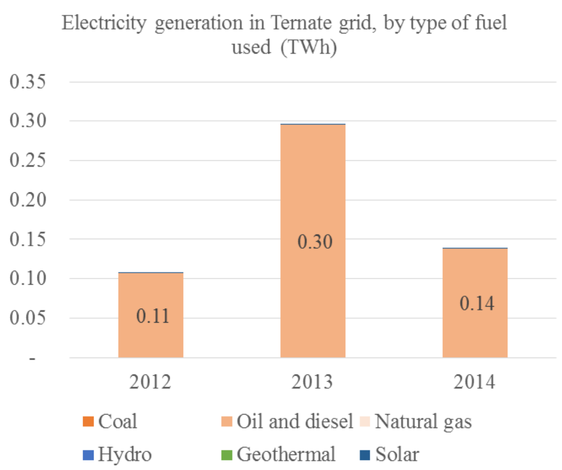

Share of electricity generation during 2012-2014 in Lombok, Bima, Sumbawa grids
Coal 8%
Oil and diesel 92%

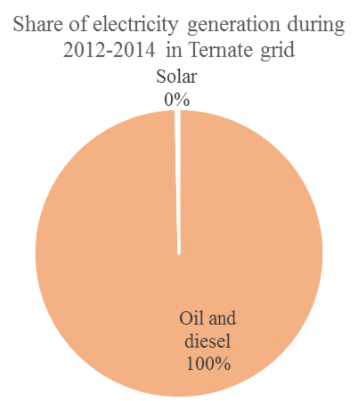

Electricity generation in Kupang-Ende-Maumere-Waingapu grids, by type of fuel used (TWh)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
-
0.01
0.62
0.01
0.68
0.01
0.68
2012
2013
2014
Coal
Oil and diesel
Natural gas
Hydro
Geothermal

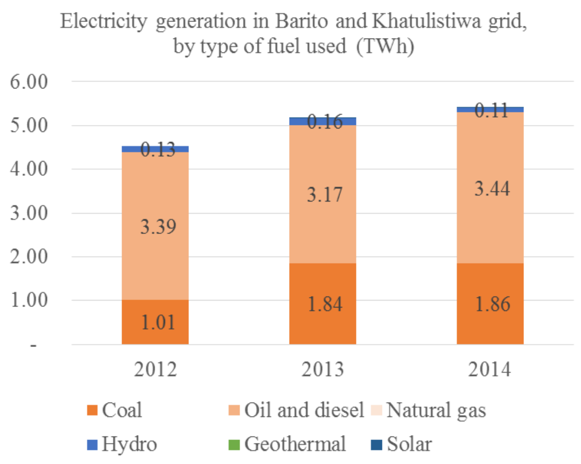

Share of electricity during 2012-2014 in Kupang-Ende-Maumere-Waingapu grids
Geothermal 3%
Hydro 1%
Oil and diesel 95%

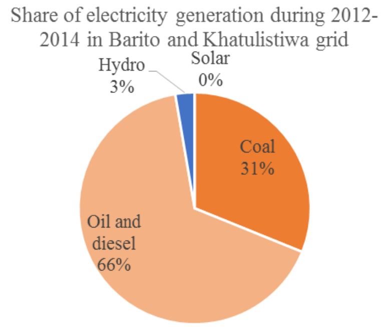

Electricity generation in Ambon, Tual, Masohi grids by type of fuel used (TWh)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
-
0.61
0.51
0.75
2012
2013
2014
Coal
Oil and diesel
Natural gas
Hydro
Geothermal
Solar


Share of electricity generation by fossil-fueled power plant during 2012-2014 in Ambon, Tual, Masohi grids
Oil and diesel 100%


Electricity generation in Ternate grid, by type of fuel used (TWh)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
-
0.11
0.30
0.14
2012
2013
2014
Coal
Oil and diesel
Natural gas
Hydro
Geothermal
Solar


Share of electricity generation during 2012-2014 in Ternate grid
Solar 0%
Oil and diesel 100%





(Data source: Directorate General of Electricity, Ministry of Energy and Mineral Resources, 2015)