

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 be applied depending on the regional grid to which a proposed project activity will connect in Indonesia:

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

Table 1 Grid emission factor Case 1 and Case 2

National/regional grid name	Emission factor for Case 1 (tCO ₂ /MWh)	Emission factor for Case 2 (tCO ₂ /MWh)
Jamali	0.616	0.533
Sumatra	0.477	0.477
Batam	0.664	0.533
Tanjung Pinang, Tanjung Balai Karimun, Tanjung Batu, Kelong, Ladan, Letung, Midai, P Buru, Ranai, Sedanau, Serasan, Tarempa	0.555	0.533
Bangka, Belitung, S Nasik, Seliu	0.553	0.533
Khatulistiwa,	0.532	0.532
Barito	0.666	0.533
Mahakam	0.527	0.527
Tarakan	0.493	0.493
Sulutgo	0.325	0.325
Sulselbar	0.320	0.320
Kendari, Bau Bau, Kolaka, Lambuya, Wangi Wangi, Raha	0.593	0.533
Palu Parigi	0.517	0.517
Lombok, Bima, Sumbawa	0.561	0.533
Kupang, Ende, Maumere, Waingapu	0.507	0.507
Ambon, Tual, Namlea	0.533	0.533
Tobelo, Ternate Tidore	0.532	0.532
Jayapura, Timika, Genyem	0.523	0.523
Sorong	0.525	0.525

- An emission factor of **0.533 tCO₂/MWh** is applied, for renewable energy system (s) in a proposed project activity which is connected to an internal grid only connecting to an isolated grid and/or a captive power generator (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 48 electricity interconnection systems or grids as shown in Figure 1, which cover 34 provinces as shown in Table 2.



Figure 1. Map of Indonesian grids¹

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

Table 2 Interconnection systems and provinces covered

Interconnection System	Provinces/area 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	
3. Batam	Batam Island	
4. Tanjung Pinang	Riau Islands	
5. Tanjung Balai Karimun		
6. Tanjung Batu		
7. Kelong		
8. Ladan		
9. Letung		
10. Midai		
11. P Buru		
12. Ranai		
13. Sedanau		
14. Serasan		
15. Tarempa		
16. Bangka		Bangka-Belitung
17. Belitung		
18. S Nasik		
19. Seliu	West Kalimantan	
20. Khatulistiwa		
21. Barito		
22. Mahakam		
23. Tarakan		
24. Sulutgo		
25. Suselbar		
26. Kendari		South and Central Kalimantan
27. Bau Bau		
28. Kolaka		
29. Lambuya		
30. Wangi Wangi		
31. Raha		
32. Palu Parigi	East Kalimantan	
33. Lombok	North Kalimantan	
34. Bima	North Sulawesi and Gorontalo	
35. Sumbawa	South and West Sulawesi	
36. Kupang	Southeast Sulawesi	
37. Ende		
38. Maumere		
39. Waingapu		
40. Ambon		
41. Tual	Central Sulawesi	
42. Namlea	West Nusa Tenggara	
43. Tobelo		
44. Ternate Tidore		
45. Jayapura	East Nusa Tenggara	
46. Timika		
47. Genyem		
48. Sorong		
	Maluku	
	North Maluku	
	Papua	
	West Papua	

(Data source: Directorate General of Electricity, Ministry of Energy and Mineral Resources, Indonesia, 2017)

There are six types of primary energy used for electricity generation in Indonesia, namely, coal, oil and diesel, natural gas, hydro, geothermal, and solar power². The share of electricity generated from 2013 to 2015 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)	2013	2014	2015
Coal	75	84	85
Oil (HSD, IDO, MFO) and diesel	30	65	71
Natural gas	41	11	6
Hydro	13	11	10
Geothermal	4.3	4.3	4.4
Solar power	0.01	0.01	0.01
Total	164	175	176

*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 hydro power project³. 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. Based on this assumption, the Government of Indonesia published emissions factor of each regional grid (Appendix 2).

2. Calculation of emission factors of the national/regional grids

In order to identify the emission factors of 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. In calculating the emission factors of each fossil fuel power generation, the best heat efficiencies among currently operational plants in Indonesia are applied.

The most efficient coal-fired power plants and gas-fired power plants currently operational in Indonesia are identified in Table 4 and the best heat efficiencies are 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

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.

achieved yet by the world's leading diesel generator, is applied due to the data limitation⁴.

Table 4 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) ⁵	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:

$$\begin{aligned} & \text{Emission factor of fossil fuel power plant [tCO}_2\text{/MWh]} \\ & = (\text{Emission factor of fuel source [kgCO}_2\text{/TJ]} \times 10^{-3} \times 0.0036 [\text{TJ/MWh}] / (\text{Heat efficiency (LHV) [\%]} / 100) \end{aligned}$$

Applying the emission factors of coal, gas and diesel combustion, which are 92,800 kgCO₂/TJ, 54,300 kgCO₂/TJ and 72,600 kgCO₂/TJ, respectively, derived from “2006 IPCC Guidelines for National Greenhouse Gas Inventories, 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 at **0.795 tCO₂/MWh** for coal-fired power plants, **0.320 tCO₂/MWh** for gas-fired power plants and **0.533 tCO₂/MWh** for diesel-fired power plants.

Using the data of electricity generation including LCMR resources (Appendix 1) and the conservative emission factors of each power source, operating margins of each national/regional grid are obtained, as follows:

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

Where:

EF_{RE,j} = The reference emission factor of regional grid *j* [tCO₂/MWh]

EF_{*i*} = Conservative emission factor of power plant type *i* [tCO₂/MWh]

EG_{*i,j*} = Electricity generated and delivered to the regional grid from power plant type *i* including LCMR resources in grid *j* during 2013-2015 [MWh]

As a result, the emission factor of each national/regional grid is calculated and shown in column “Emission

⁴ The approved JCM methodologies (BD_AM002, CR_AM001, KE_AM002, KH_AM002, MN_AM003, PW_AM001 and MV_AM001, VN_AM007) also applied this value.

⁵ https://www.toshiba.co.jp/tech/review/2008/09/63_09pdf/a03.pdf

factor for Case 1 (tCO₂/MWh)” of Table 1, to be applied for renewable energy system(s) in a proposed project activity which is directly connected, or connected via an internal grid not connecting to either an isolated grid or a captive power generator, to a national/regional grid. Those values are lower than the 2015 emission factors of the respective national/regional grids published by the Government of Indonesia (Appendix 2). Therefore, net emission reductions will be ensured by applying the emission factors 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:

$$\begin{aligned} & \text{Emission factor of diesel power plant [tCO}_2\text{/MWh]} \\ &= (\text{CO}_2 \text{ emission factor of diesel oil [kgCO}_2\text{/TJ]} \times 10^{-3} \times 0.0036 [\text{TJ/MWh}] / (\text{Heat efficiency (LHV) [\%]}/100) \end{aligned}$$

Applying the default value of the emission factor of diesel combustion which is 72,600 kgCO₂/TJ derived from “2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 2, stationary combustion”, together with the heat efficiency of 49%, the emission factor of an isolated grid and/or captive power generator is calculated at **0.533 tCO₂/MWh**.

4. Selection of the calculated emission factors

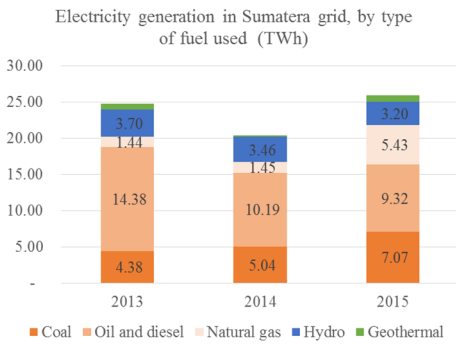
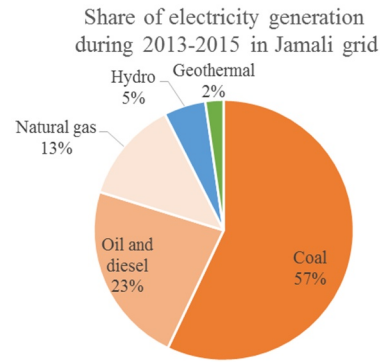
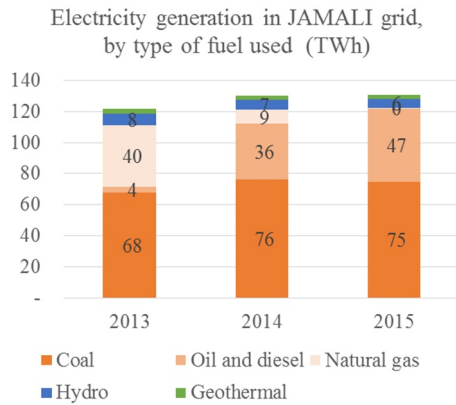
In case the renewable energy system(s) in a proposed project activity is directly connected, or connected via an internal grid not connecting to either an isolated grid or a captive power generator, to a national/regional grid (Case 1), the value of operating margin including LCMR resources, using the 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 Case 1 (tCO₂/MWh)” of Table 1.

In case that the renewable energy system(s) in a proposed project activity is connected to an internal grid connecting to both a national/regional grid and an isolated grid and/or a captive power generator (Case 2), the lower values between “Emission factor for Case 1 (tCO₂/MWh)” of Table 1 and the conservative emission factor of diesel-fired power plant of 0.533 tCO₂/MWh are applied. The emission factors to be applied are shown in column “Emission factor for Case 2 (tCO₂/MWh)” of Table 1.

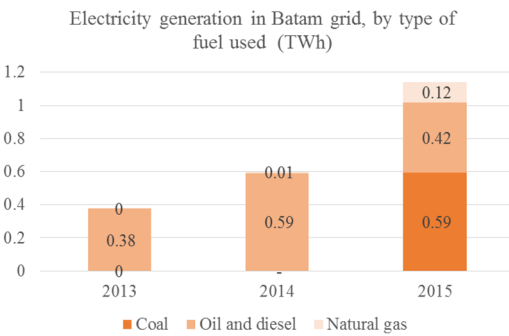
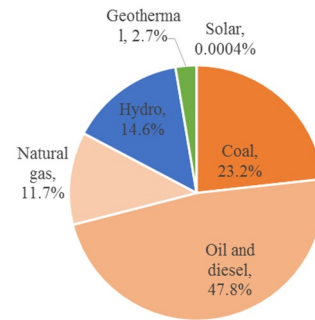
In case that the renewable energy system(s) in a proposed project activity is only connected to an internal

grid connecting to an isolated grid and/or a captive power generator (Case 3), the emission factor of 0.533 tCO₂/MWh is applied.

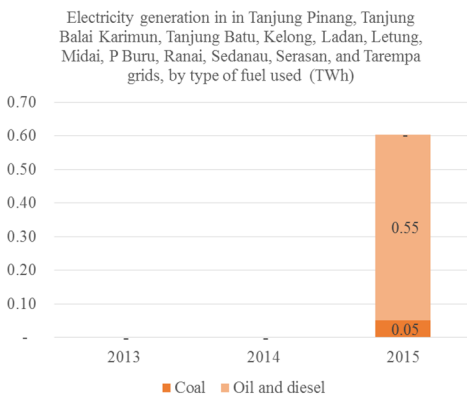
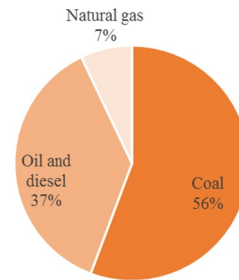
Appendix I Electric power source mix of each regional grid



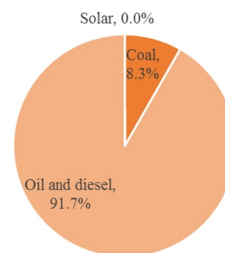
Share of electricity generation during 2013-2015 in Sumatera grid



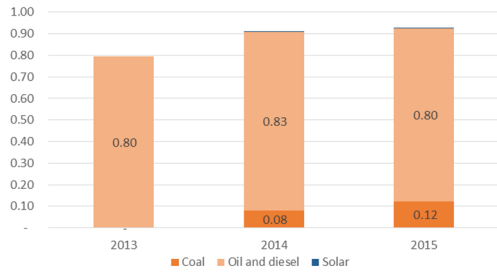
Share of electricity generation during 2013-2015 in Batam grid



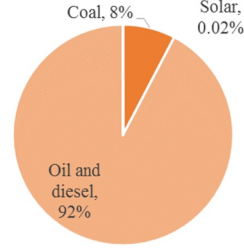
Share of electricity generation during 2013-2015 in Tanjung Pinang, Tanjung Balai Karimun, Tanjung Batu, Kelong, Ladan, Letung, Midai, P Buru, Ranai, Sedanau, Serasan, and Tarempa grids



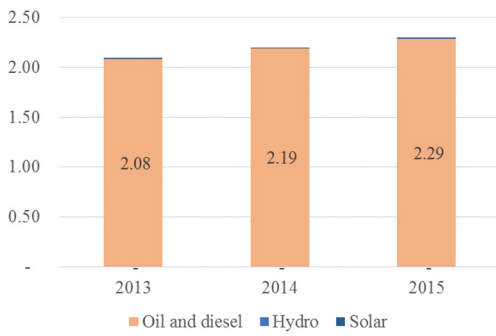
Electricity generation in Bangka, Belitung, S Nasik, and Seliu grids, by type of fuel used (TWh)



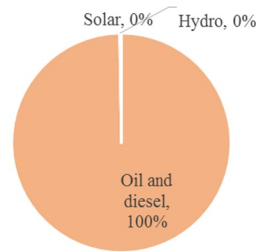
Share of electricity generation during 2013-2015 in Bangka, Belitung, S Nasik, and Seliu grids



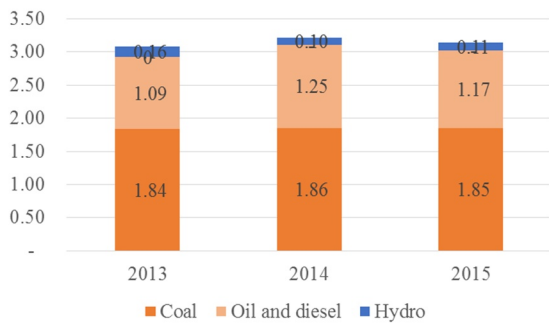
Electricity generation in Khatulistiwa grid, by type of fuel used (TWh)



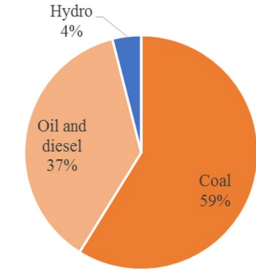
Share of electricity generation during 2013-2015 in Khatulistiwa grid



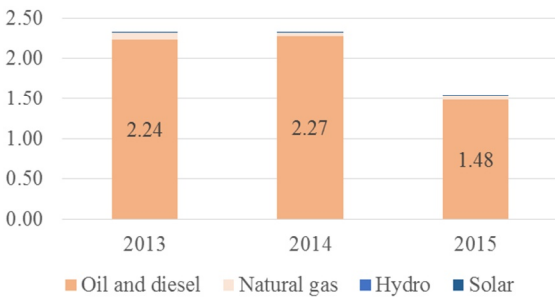
Electricity generation in Barito grid, by type of fuel used (TWh)



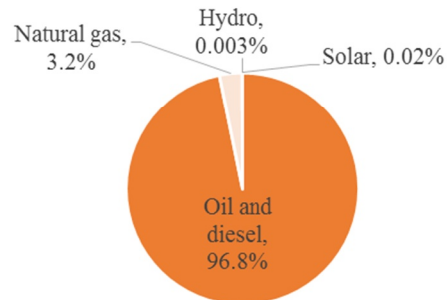
Share of electricity generation during 2013-2015 in Barito grid

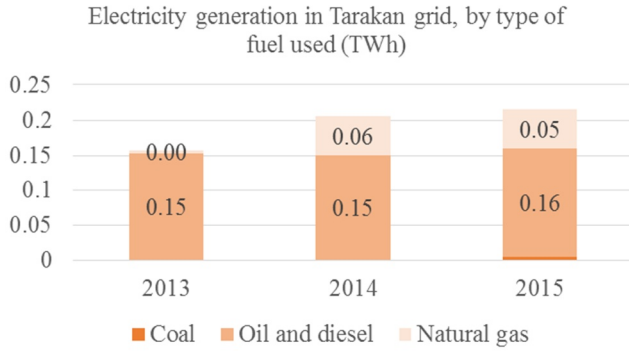


Electricity generation in Mahakam grid, by type of fuel used (TWh)

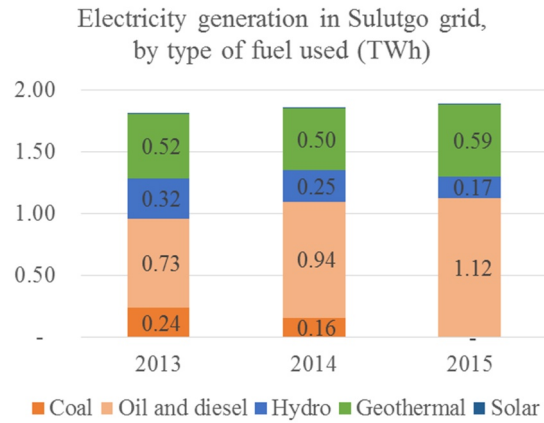
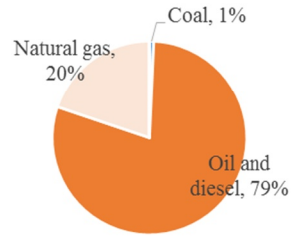


Share of electricity generation during 2013-2015 in Mahakam grid

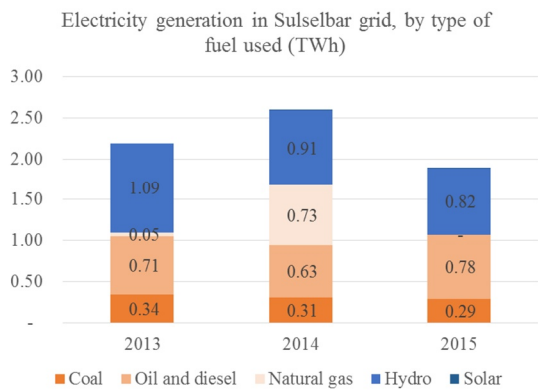
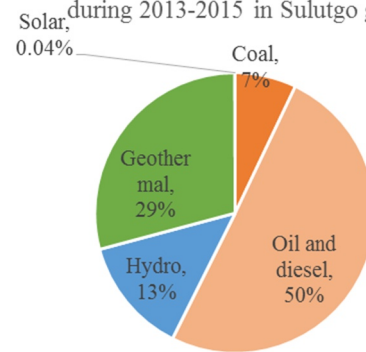




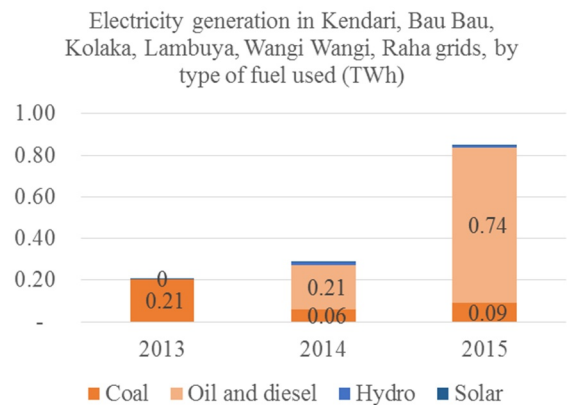
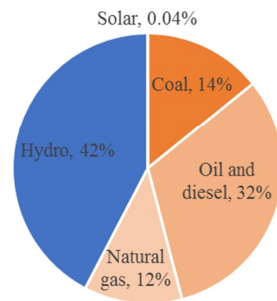
Share of electricity generation during 2013-2015 in Tarakan grid



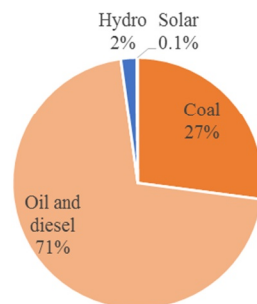
Share of electricity generation during 2013-2015 in Sulutgo grid



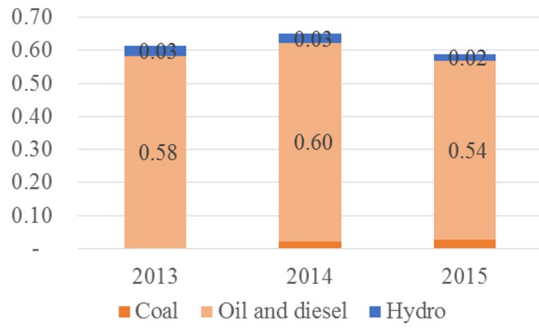
Share of electricity generation during 2013-2015 in Sulselbar grid



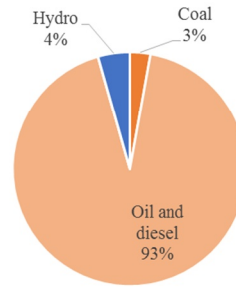
Share of electricity generation during 2013-2015 in Kendari, Bau Bau, Kolaka, Lambuya, Wangi Wangi, Raha grids



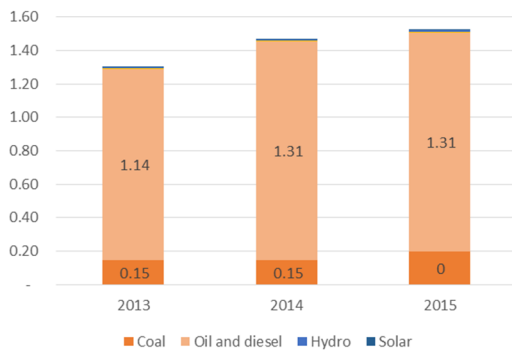
Electricity generation in Palu Parigi grid, by type of fuel used (TWh)



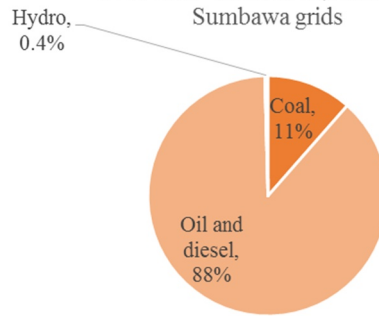
Share of electricity generation during 2013-2015 in Palu Parigi grid



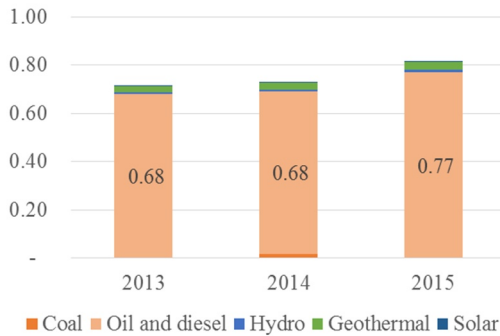
Electricity generation in Lombok, Bima, and Sumbawa grids, by type of fuel used (TWh)



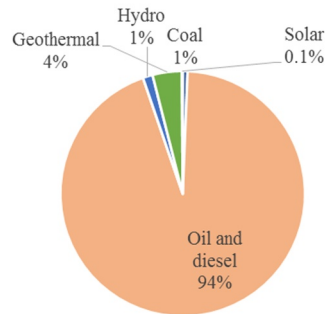
Share of electricity generation during 2013-2015 in Lombok, Bima, and Sumbawa grids



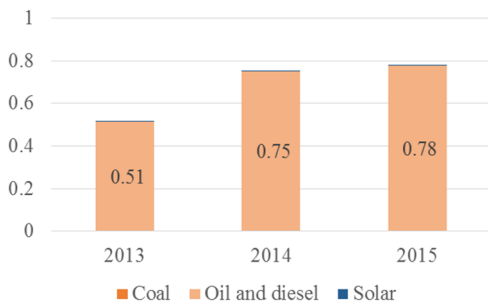
Electricity generation in Kupang, Ende, Maumere, and Waingapu grids, by type of fuel used (TWh)



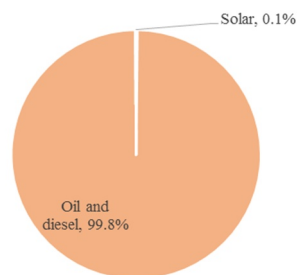
Share of electricity during 2013-2015 in Kupang, Ende, Maumere, and Waingapu grids

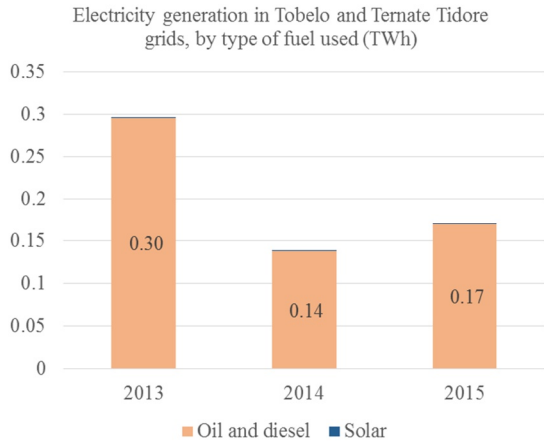


Electricity generation in Ambon, Tual, and Masohi grids by type of fuel used (TWh)

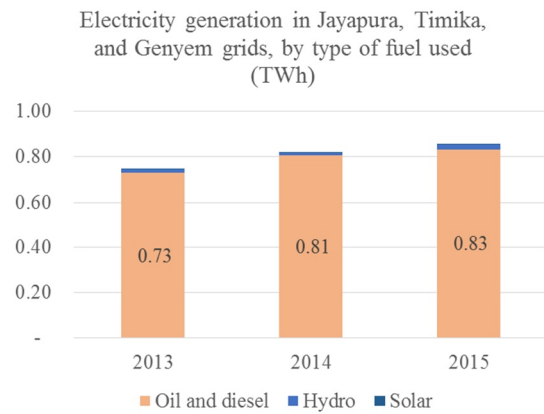
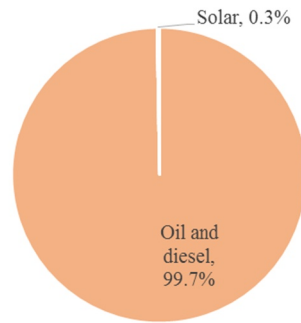


Share of electricity generation during 2013-2015 in Ambon, Tual, and Masohi grids

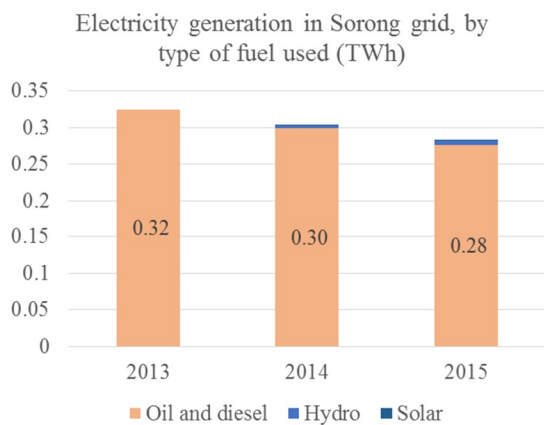
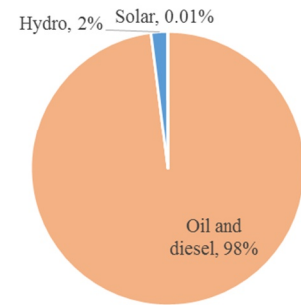




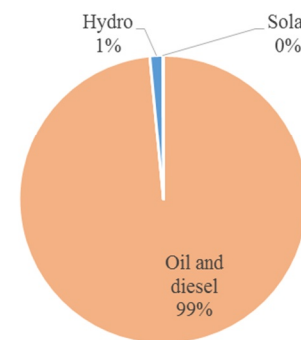
Share of electricity generation during 2013-2015 in Tobelo and Ternate Tidore grids



Share of electricity generation during 2013-2015 in Jayapura, Timika, and Genyem grids



Share of electricity generation during 2013-2015 in Sorong grid



(Data source: Directorate General of Electricity, Ministry of Energy and Mineral Resources, 2016)

Appendix 2 Emission factors of grids published by the Government of Indonesia (2015)

No.	Interconnection of Electric Power Systems	Emission Factor (tCO ₂ /MWh)
1	Jamali	0.903
2	Sumatera	0.855
3	Batam	0.953
4	Tanjung Pinang	0.805
5	Tanjung Balai Karimun	1.092
6	Tanjung Batu	0.734
7	Kelong	0.946
8	Ladan	0.820
9	Letung	0.770
10	Midai	0.771
11	P Buru	0.988
12	Ranai	0.718
13	Sedanau	0.811
14	Serasan	0.743
15	Tarempa	0.735
16	Bangka	0.807
17	Belitung	0.733
18	S Nasik	0.800
19	Seliu	1.077
20	Khatulistiwa	0.721
21	Barito	1.512
22	Mahakam	0.760
23	Tarakan	0.625
24	Sulutgo	0.715

No.	Interconnection of Electric Power Systems	Emission Factor (tCO ₂ /MWh)
25	Sulselbar	0.714
26	Kendari	0.903
27	Bau Bau	0.841
28	Kolaka	0.743
29	Lambuya	0.795
30	Wangi Wangi	0.755
31	Raha	0.733
32	Palu Parigi	1.001
33	Lombok	0.793
34	Bima	0.718
35	Sumbawa	0.634
36	Kupang	0.722
37	Ende	0.710
38	Maumere	0.741
39	Waingapu	0.760
40	Ambon	0.769
41	Tual	0.712
42	Namlea	0.724
43	Tobelo	0.734
44	Ternate Tidore	0.724
45	Jayapura	0.787
46	Timika	0.751
47	Genyem	0.006
48	Sorong	0.779

(Data source: Directorate General of Electricity, Ministry of Energy and Mineral Resources, Indonesia, 2017)