

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 PV 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 (PV Case 1).
- Table 1 also summarises the emission factors to be applied for PV 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 (PV Case 2).

Table 1 Grid emission factor PV Case 1 and Case 2

National/regional grid name	Emission factor for PV Case 1 (tCO ₂ /MWh)	Emission factor for PV 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 PV 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 (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 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	
5. Tanjung Balai Karimun	
6. Tanjung Batu	
7. Kelong	
8. Ladan	
9. Letung	Riau Islands
10. Midai	
11. P Buru	
12. Ranai	
13. Sedanau	
14. Serasan	
15. Tarempa	
16. Bangka	
17. Belitung	Bangka-Belitung
18. S Nasik	
19. Seliu	
20. Khatulistiwa	West Kalimantan
21. Barito	South and Central Kalimantan
22. Mahakam	East Kalimantan
23. Tarakan	North Kalimantan
24. Sulutgo	North Sulawesi and Gorontalo
25. Sulselbar	South and West Sulawesi
26. Kendari	
27. Bau Bau	
28. Kolaka	Southeast Sulawesi
29. Lambuya	
30. Wangi Wangi	
31. Raha	
32. Palu Parigi	Central Sulawesi
33. Lombok	
34. Bima	West Nusa Tenggara
35. Sumbawa	
36. Kupang	
37. Ende	East Nusa Tenggara
38. Maumere	
39. Waingapu	
40. Ambon	
41. Tual	Maluku
42. Namlea	
43. Tobelo	
44. Ternate Tidore	North Maluku
45. Jayapura	
46. Timika	Papua
47. Genyem	
48. Sorong	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 PV 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

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.

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 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:

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

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]

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

As a result, the emission factor of each national/regional grid is calculated and shown in column “Emission factor for PV Case1 (tCO₂/MWh)” of Table 1, to be applied for PV 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:

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

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**.

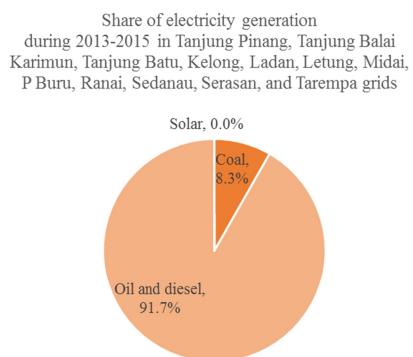
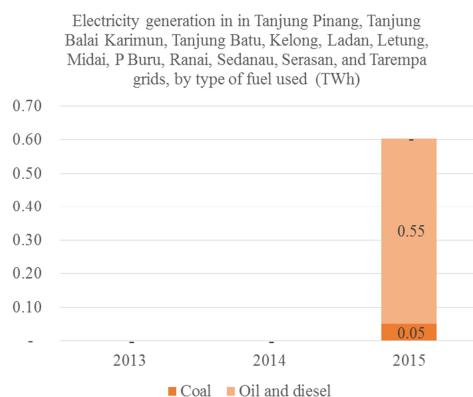
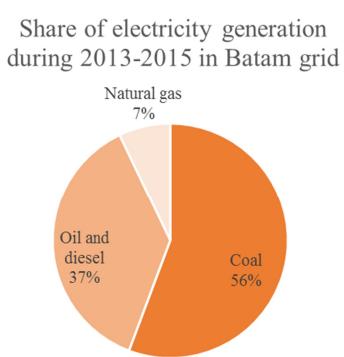
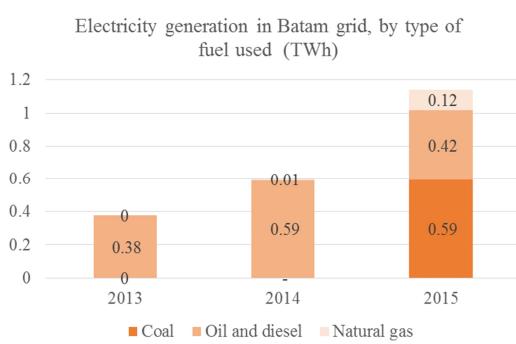
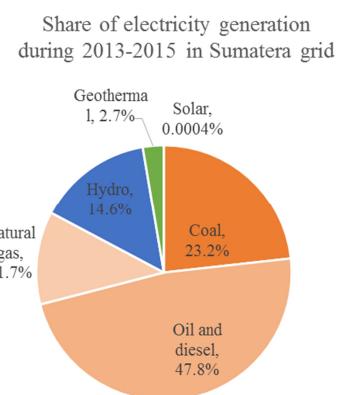
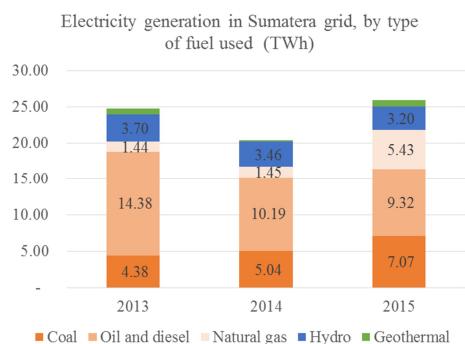
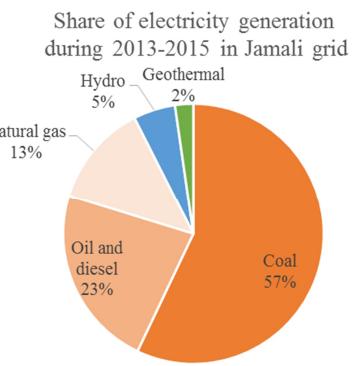
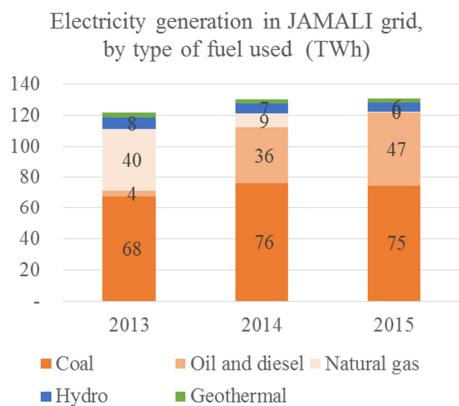
4. Selection of the calculated emission factors

In case the PV 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 (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 (tCO₂/MWh)” of Table 1.

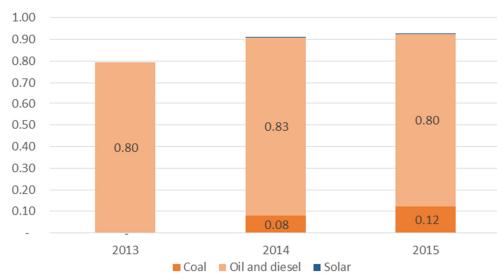
In case that the PV system(s) in a proposed project activity is connected to an internal grid connecting to both a national/regional grid and an isolated grid and/or a captive power generator (PV Case 2), the lower values between “Emission factor for PV Case 1 (tCO₂/MWh)” of Table 1 and the conservative 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 PV Case 2 (tCO₂/MWh)” of Table 1.

In case that the PV 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 (PV Case 3), the emission factor of 0.533 tCO₂/MWh is applied.

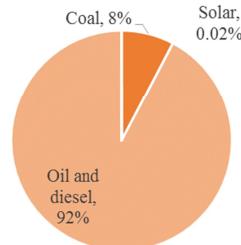
Appendix I Electric power source mix of each regional grid



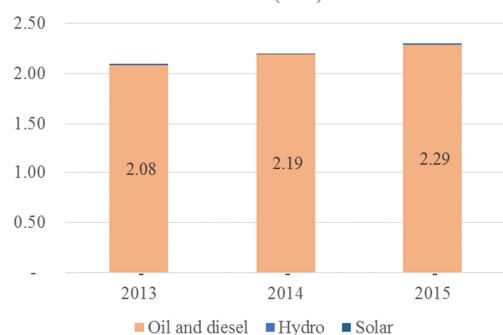
Electricity generation in Bangka, Belitung, S Nasik, and Seliu grids, by type of fuel used (TWh)



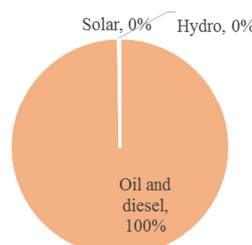
Share of electricity generation during 2013-2015 in Bangka, Belitung, S Nasik, and Seliu grids



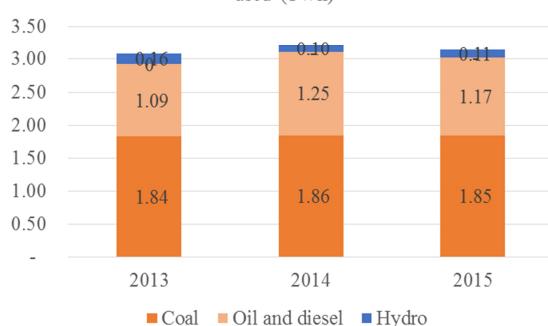
Electricity generation in Khatulistiwa grid, by type of fuel used (TWh)



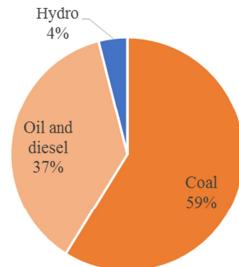
Share of electricity generation during 2013-2015 in Khatulistiwa grid



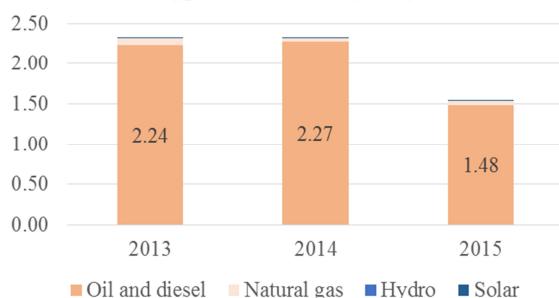
Electricity generation in Barito grid, by type of fuel used (TWh)



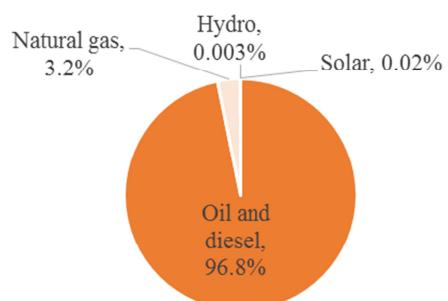
Share of electricity generation during 2013-2015 in Barito grid



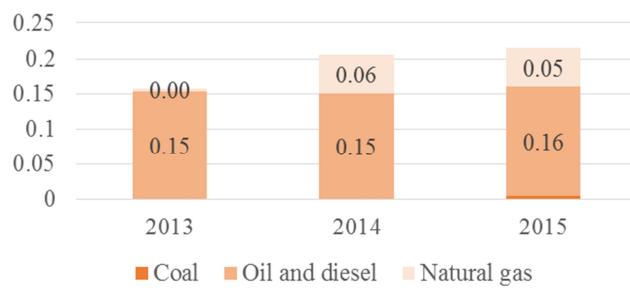
Electricity generation in Mahakam grid, by type of fuel used (TWh)



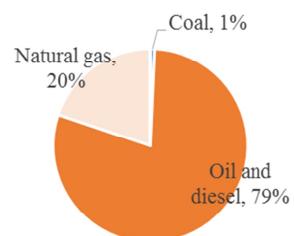
Share of electricity generation during 2013-2015 in Mahakam grid



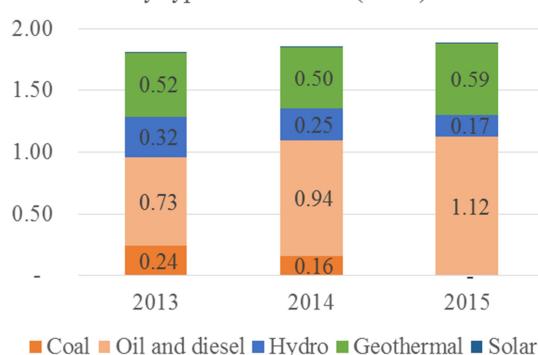
Electricity generation in Tarakan grid, by type of fuel used (TWh)



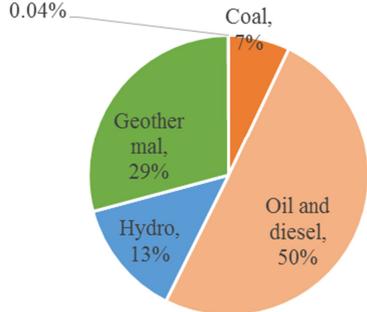
Share of electricity generation during 2013-2015 in Tarakan grid



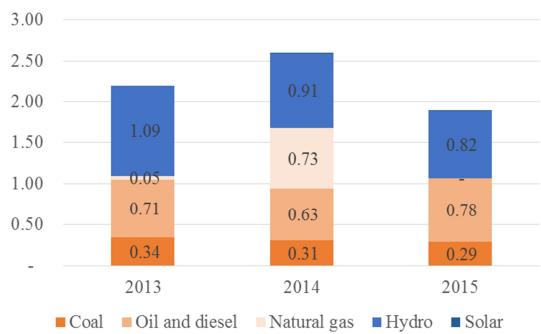
Electricity generation in Sulutgo grid, by type of fuel used (TWh)



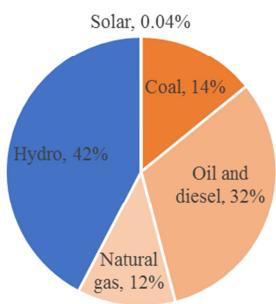
Share of electricity generation during 2013-2015 in Sulutgo grid



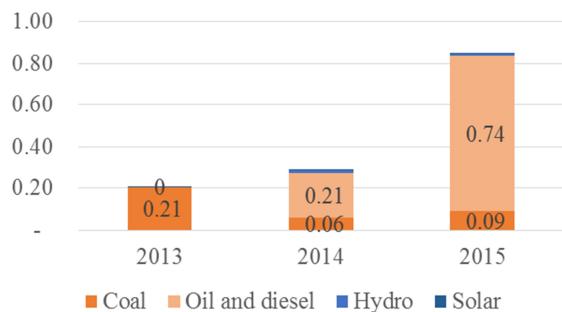
Electricity generation in Sulsebar grid, by type of fuel used (TWh)



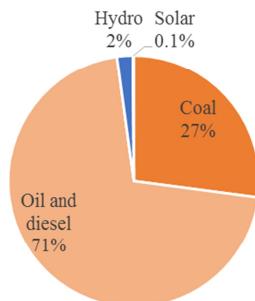
Share of electricity generation during 2013-2015 in Sulsebar grid



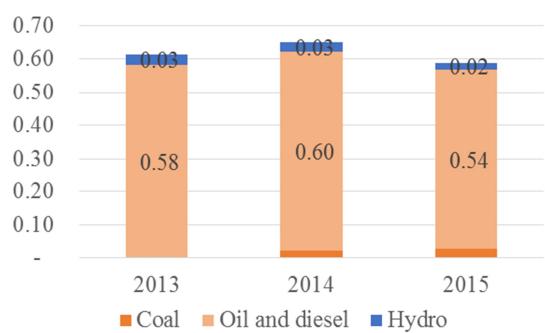
Electricity generation in Kendari, Bau Bau, Kolaka, Lambuya, Wangi Wangi, Raha grids, by type of fuel used (TWh)



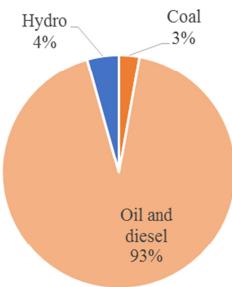
Share of electricity generation during 2013-2015 in Kendari, Bau Bau, Kolaka, Lambuya, Wangi Wangi, Raha grids



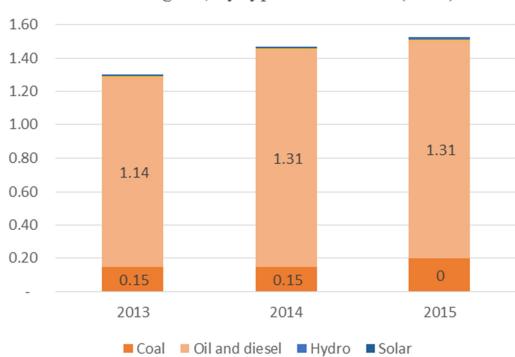
Electricity generation in Palu Parigi grid, by type of fuel used (TWh)



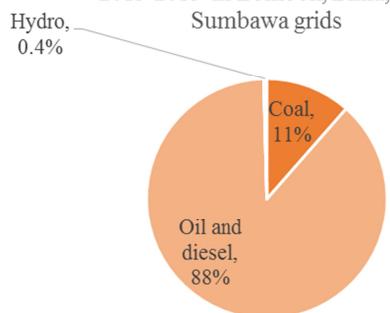
Share of electricity generation during 2013-2015 in Palu Parigi grid



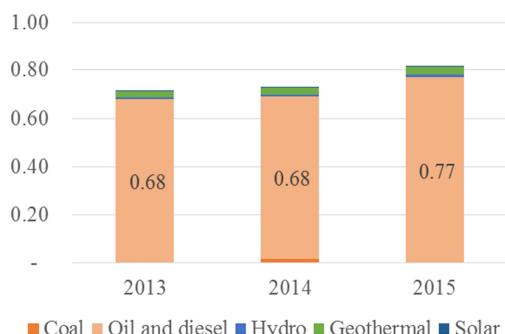
Electricity generation in Lombok, Bima, and Sumbawa grids, by type of fuel used (TWh)



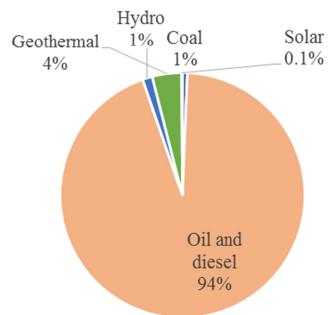
Share of electricity generation during 2013-2015 in Lombok, Bima, and Sumbawa grids



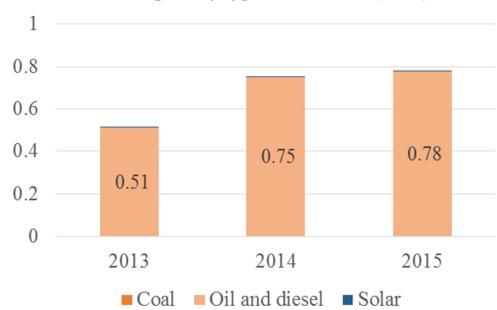
Electricity generation in Kupang, Ende, Maumere, and Waingapu grids, by type of fuel used (TWh)



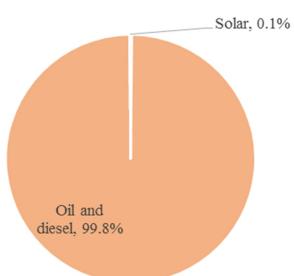
Share of electricity generation during 2013-2015 in Kupang, Ende, Maumere, and Waingapu grids



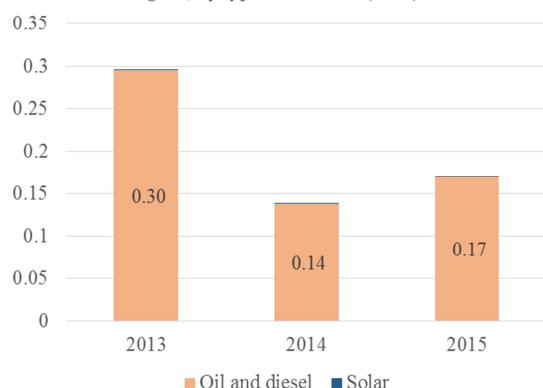
Electricity generation in Ambon, Tual, and Masohi grids by type of fuel used (TWh)



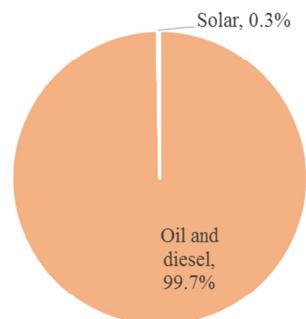
Share of electricity generation during 2013-2015 in Ambon, Tual, and Masohi grids



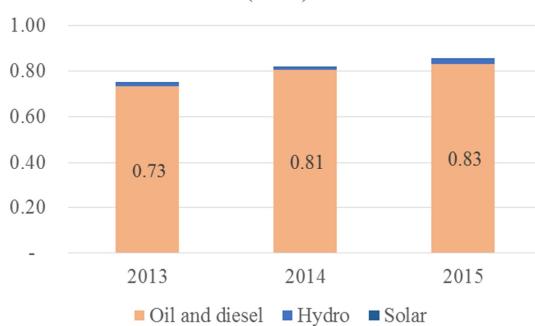
Electricity generation in Tobelo and Ternate Tidore grids, by type of fuel used (TWh)



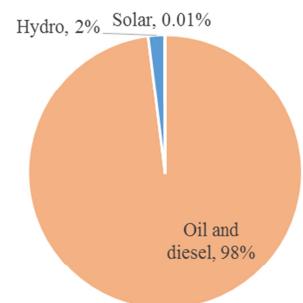
Share of electricity generation during 2013-2015 in Tobelo and Ternate Tidore grids



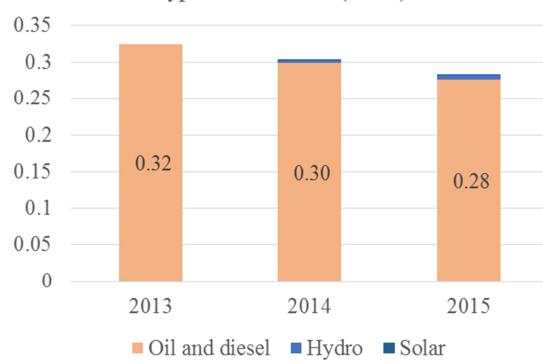
Electricity generation in Jayapura, Timika, and Genyem grids, by type of fuel used (TWh)



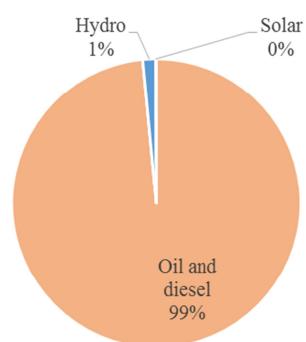
Share of electricity generation during 2013-2015 in Jayapura, Timika, and Genyem grids



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



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 (tCO2/MWh)	No.	Interconnection of Electric Power Systems	Emission Factor (tCO2/MWh)
1	Jamali	0.903	25	Sulselbar	0.714
2	Sumatera	0.855	26	Kendari	0.903
3	Batam	0.953	27	Bau Bau	0.841
4	Tanjung Pinang	0.805	28	Kolaka	0.743
5	Tanjung Balai Karimun	1.092	29	Lambuya	0.795
6	Tanjung Batu	0.734	30	Wangi Wangi	0.755
7	Kelong	0.946	31	Raha	0.733
8	Ladan	0.820	32	Palu Parigi	1.001
9	Letung	0.770	33	Lombok	0.793
10	Midai	0.771	34	Bima	0.718
11	P Buru	0.988	35	Sumbawa	0.634
12	Ranai	0.718	36	Kupang	0.722
13	Sedanau	0.811	37	Ende	0.710
14	Serasan	0.743	38	Maumere	0.741
15	Tarempa	0.735	39	Waingapu	0.760
16	Bangka	0.807	40	Ambon	0.769
17	Belitung	0.733	41	Tual	0.712
18	S Nasik	0.800	42	Namlea	0.724
19	Seliu	1.077	43	Tobelo	0.734
20	Khatulistiwa	0.721	44	Ternate Tidore	0.724
21	Barito	1.512	45	Jayapura	0.787
22	Mahakam	0.760	46	Timika	0.751
23	Tarakan	0.625	47	Genyem	0.006
24	Sulutgo	0.715	48	Sorong	0.779

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