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

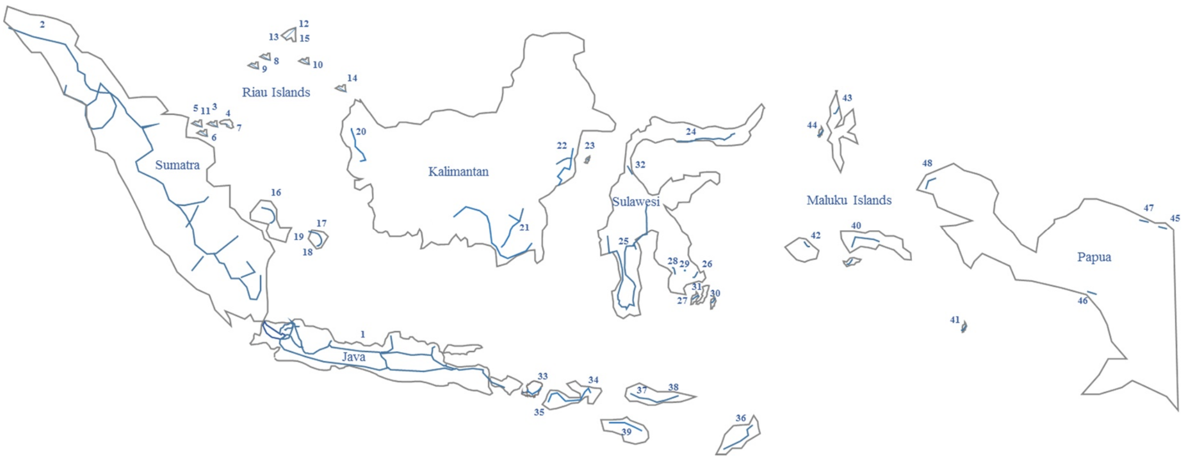
National/regional grid name	Emission factor for PV Case 1 (tCO_2/MWh)	Emission factor for PV Case 2 (tCO_2/MWh)
Jamali	0.616	0.533
Sumatra	0.477	0.477
Batam	0.664	0.533
Tanjung Pinang, Tanjung Balai Karimun, Tanjung Batu, Kelong, Ladan, Letung, Midai, P Buru, Ranai, Sedanau, Serasan, Tarempa	0.555	0.533
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 tCO_2/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.



1 Jamali	13 Sedanau	25 Sulselbar	37 Ende
2 Sumatera	14 Serasan	26 Kendari	38 Maumere
3 Batam	15 Tarempa	27 Bau Bau	39 Waingapu
4 Tanjung Pinang	16 Bangka	28 Kolaka	40 Ambon
5 Tanjung Balai Karimun	17 Belitung	29 Lambuya	41 Tual
6 Tanjung Batu	18 S Nasik	30 Wangi Wangi	42 Namlea
7 Kelong	19 Seliu	31 Raha	43 Tobelo
8 Ladan	20 Khatulistiwa	32 Palu Parigi	44 Ternate Tidore
9 Letung	21 Barito	33 Lombok	45 Jayapura
10 Midai	22 Mahakam	34 Bima	46 Timika
11 P Buru	23 Tarakan	35 Sumbawa	47 Genyem
12 Ranai	24 Sulutgo	36 Kupang	48 Sorong

Figure 1. Map of Indonesian grids[1]

[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	
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	Southeast Sulawesi
27. Bau Bau	
28. Kolaka	
29. Lambuya	
30. Wangi Wangi	
31. Raha	
32. Palu Parigi	Central Sulawesi
33. Lombok	West Nusa Tenggara
34. Bima	
35. Sumbawa	
36. Kupang	East Nusa Tenggara
37. Ende	
38. Maumere	
39. Waingapu	
40. Ambon	Maluku
41. Tual	
42. Namlea	
43. Tobelo	North Maluku
44. Ternate Tidore	
45. Jayapura	Papua
46. Timika	
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 power[2]. 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 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. 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%**[4], 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 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)[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 [tCO_2/MWh]

= (Emission factor of fuel source [$kgCO_2$/TJ]*10^{-3}*0.0036[TJ/MWh] / (Heat efficiency (LHV) [%]/100)

Applying the emission factors of 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 "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 tCO_2/MWh** for coal-fired power plants, **0.320 tCO_2/MWh** for gas-fired power plants and **0.533 tCO_2/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* [tCO_2/MWh]

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

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[4] JCM Proposed Methodology PW_AM001: Displacement of Grid and Captive Genset Electricity by a Small-scale Solar PV System, Additional Information (https://www.jcm.go.jp/pw-jp/methodologies/18/attached_document1)

[5] 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.

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

$EG_{i,j}$ = 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 factor for PV Case1 (tCO_2/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:

Emission factor of diesel power plant [tCO_2/MWh]
= (CO_2 emission factor of diesel oil [$kgCO_2$/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 "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 tCO_2/MWh**.

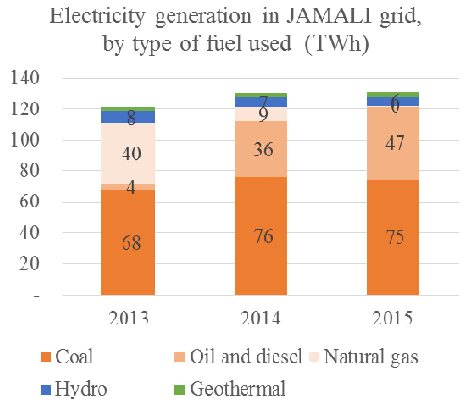
4. Selection of the calculated emission factors

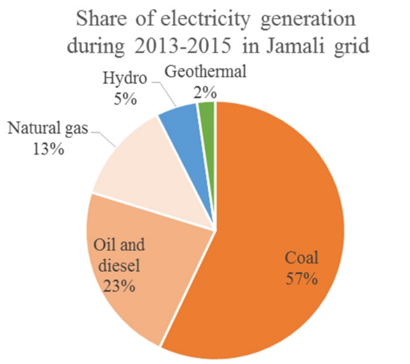
In case the PV system(s) in a proposed project activity is directly connected, or connected via an internal grid not connecting to either an isolated grid or a captive power generator, to a national/regional grid (PV Case 1), the value of operating margin including LCMR resources, using the best heat 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 (tCO_2/MWh)" of Table 1.

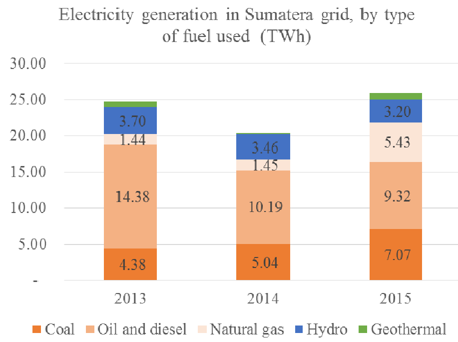
In case that the PV system(s) in a proposed project activity is connected to an internal grid connecting to both a national/regional grid and an isolated grid and/or a captive power generator (PV Case 2), the lower values between "Emission factor for PV Case 1 (tCO_2/MWh)" of Table 1 and the conservative emission factor of diesel-fired power plant of 0.533 tCO_2/MWh are applied. The emission factors to be applied are shown in column "Emission factor for PV Case 2 (tCO_2/MWh)" of Table 1.

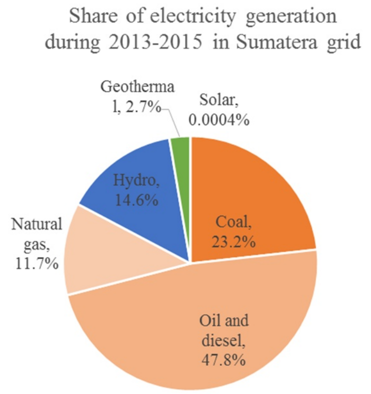
In case that the PV system(s) in a proposed project activity is only connected to an internal grid connecting to an isolated grid and/or a captive power generator (PV Case 3), the emission factor of 0.533 tCO_2/MWh is applied.

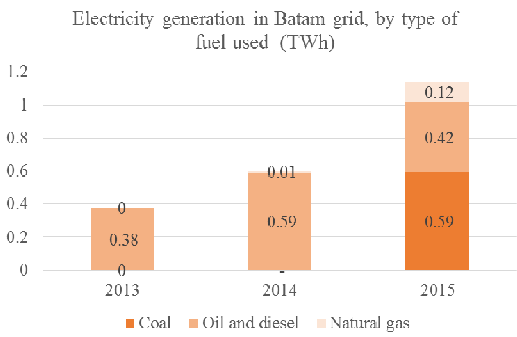
Appendix I Electric power source mix of each regional grid

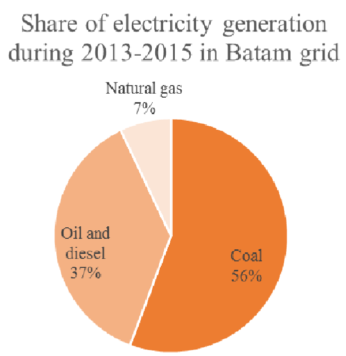


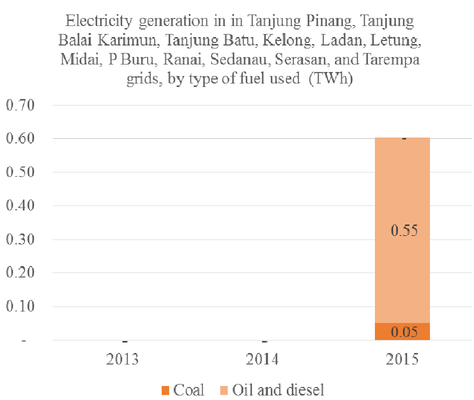


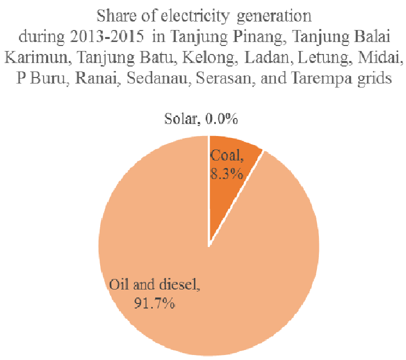


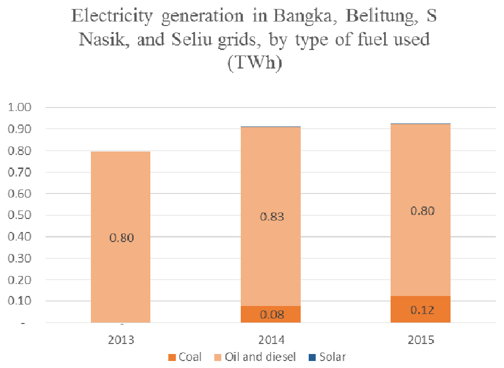


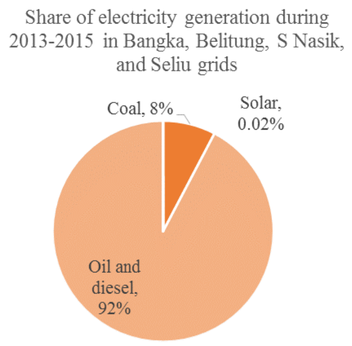


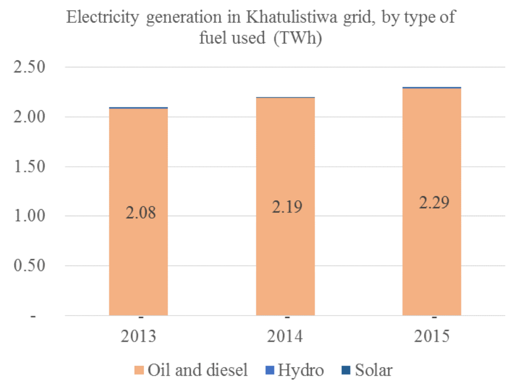


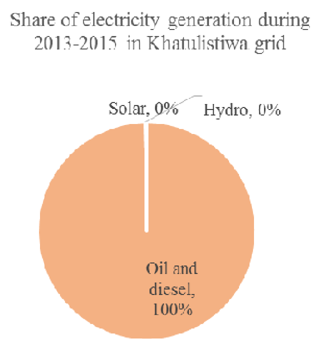


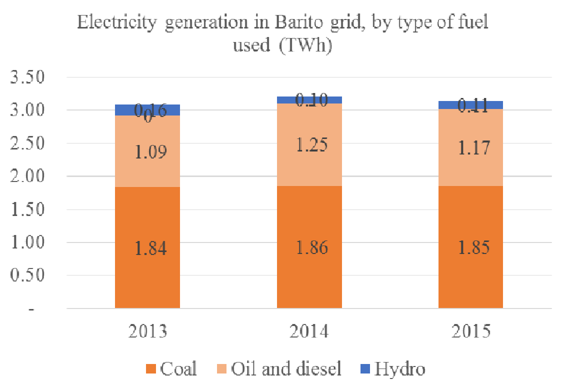


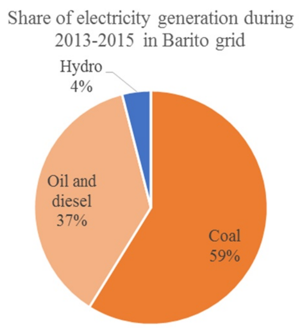

Electricity generation in Bangka, Belitung, S Nasik, and Seliu grids, by type of fuel used (TWh)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
-
0.80
0.83
0.08
0.80
0.12
2013
2014
2015
Coal
Oil and diesel
Solar

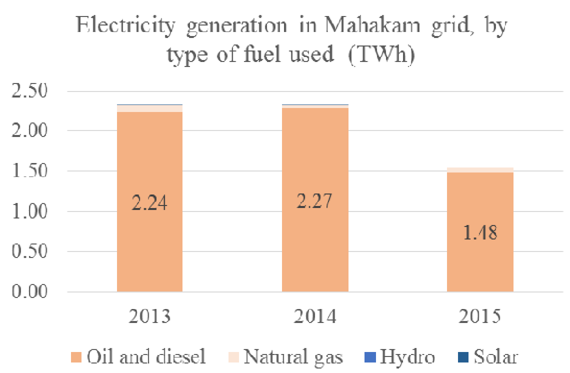

Share of electricity generation during 2013-2015 in Bangka, Belitung, S Nasik, and Seliu grids
Coal, 8%
Solar, 0.02%
Oil and diesel, 92%

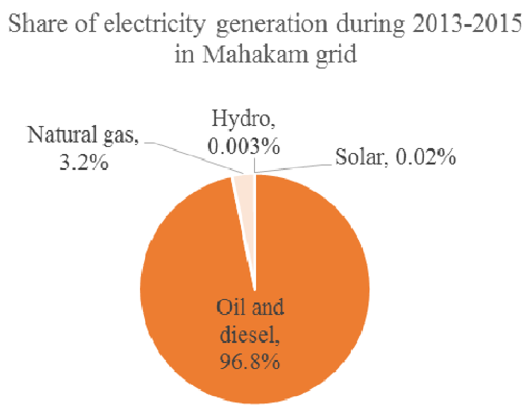

Electricity generation in Khatulistiwa grid, by type of fuel used (TWh)
2.50
2.00
1.50
1.00
0.50
-
2.08
2.19
2.29
2013
2014
2015
Oil and diesel
Hydro
Solar

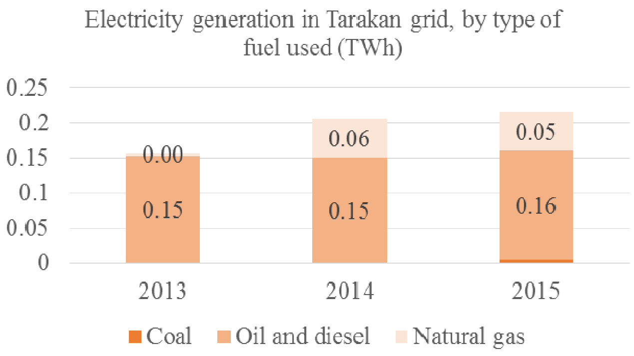

Share of electricity generation during 2013-2015 in Khatulistiwa grid
Solar, 0%
Hydro, 0%
Oil and diesel, 100%

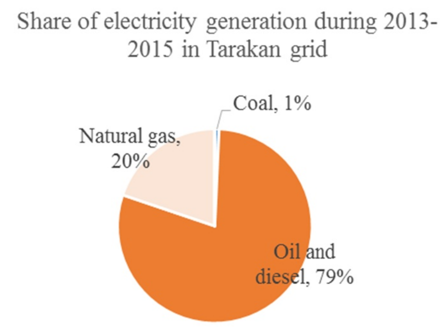

Electricity generation in Barito grid, by type of fuel used (TWh)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
-
0.16
1.09
1.84
0.10
1.25
1.86
0.11
1.17
1.85
2013
2014
2015
Coal
Oil and diesel
Hydro

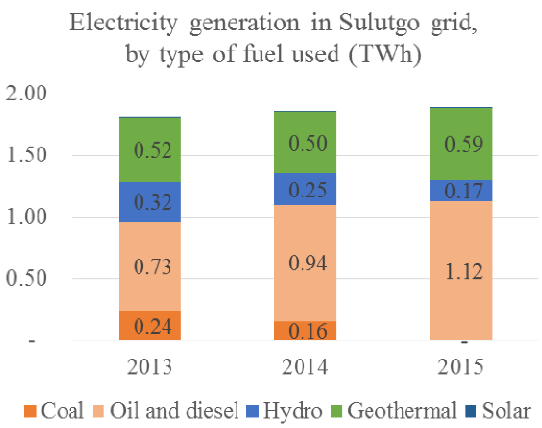

Share of electricity generation during 2013-2015 in Barito grid
Hydro 4%
Oil and diesel 37%
Coal 59%

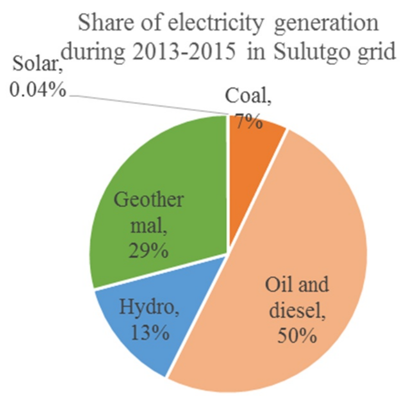

Electricity generation in Mahakam grid, by type of fuel used (TWh)
2.50
2.00
1.50
1.00
0.50
0.00
2.24
2.27
1.48
2013
2014
2015
Oil and diesel
Natural gas
Hydro
Solar

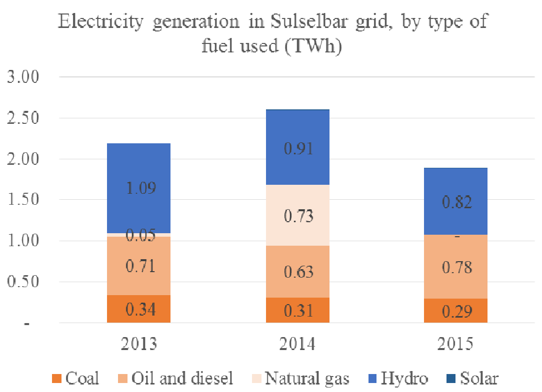

Share of electricity generation during 2013-2015 in Mahakam grid
Natural gas, 3.2%
Hydro, 0.003%
Solar, 0.02%
Oil and diesel, 96.8%

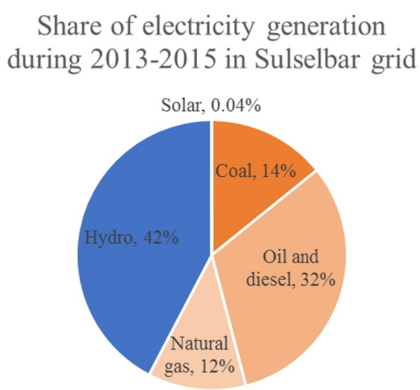

Electricity generation in Tarakan grid, by type of fuel used (TWh)
0.25
0.2
0.15
0.1
0.05
0
0.00
0.15
0.06
0.15
0.05
0.16
2013
2014
2015
Coal
Oil and diesel
Natural gas

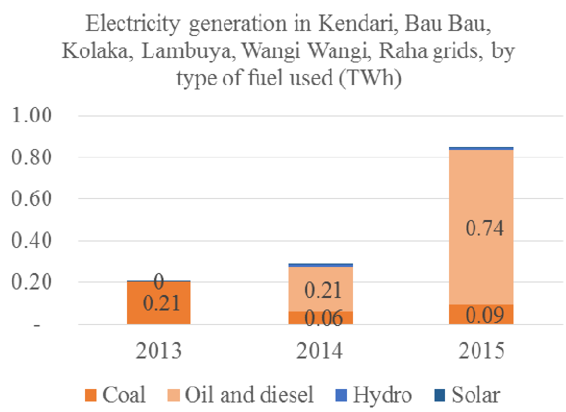

Share of electricity generation during 2013-2015 in Tarakan grid
Coal, 1%
Natural gas, 20%
Oil and diesel, 79%

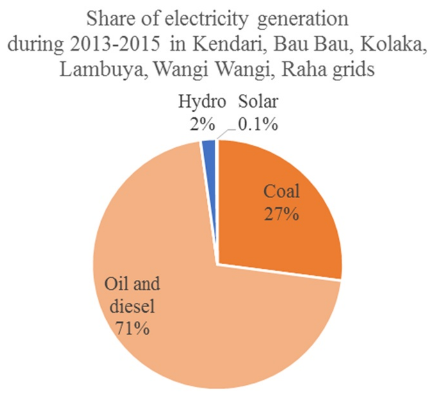

Electricity generation in Sulutgo grid, by type of fuel used (TWh)
2.00
1.50
1.00
0.50
-
0.52
0.32
0.73
0.24
0.50
0.25
0.94
0.16
0.59
0.17
1.12
-
2013
2014
2015
Coal
Oil and diesel
Hydro
Geothermal
Solar

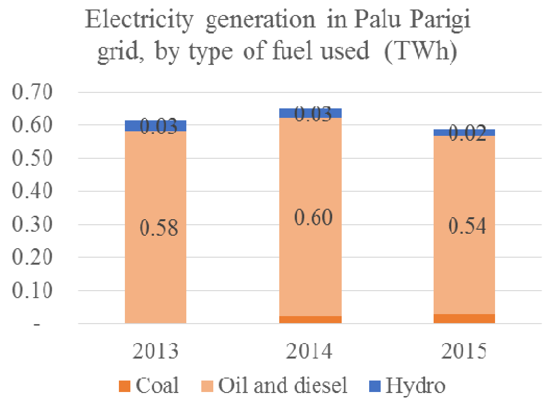

Share of electricity generation during 2013-2015 in Sulutgo grid
Solar, 0.04%
Coal, 7%
Geothermal, 29%
Hydro, 13%
Oil and diesel, 50%

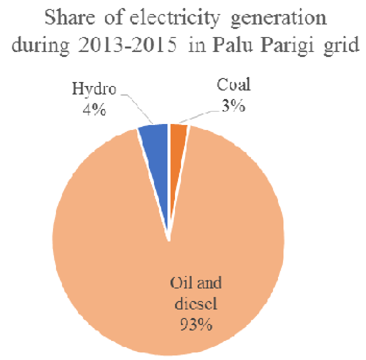

Electricity generation in Sulselbar grid, by type of fuel used (TWh)
3.00
2.50
2.00
1.50
1.00
0.50
-
1.09
0.05
0.71
0.34
0.91
0.73
0.63
0.31
0.82
-
0.78
0.29
2013
2014
2015
Coal
Oil and diesel
Natural gas
Hydro
Solar

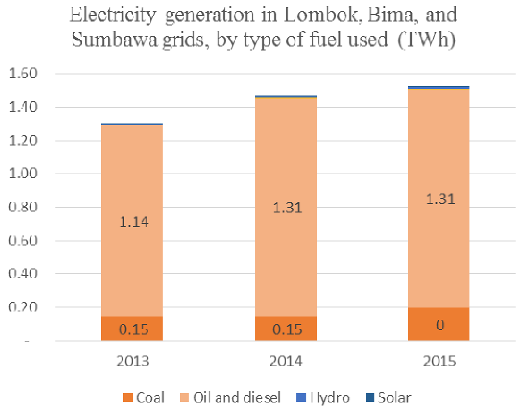

Share of electricity generation during 2013-2015 in Sulselbar grid
Solar, 0.04%
Coal, 14%
Hydro, 42%
Oil and diesel, 32%
Natural gas, 12%

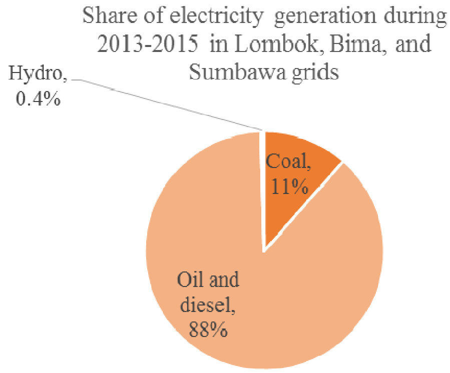

Electricity generation in Kendari, Bau Bau, Kolaka, Lambuya, Wangi Wangi, Raha grids, by type of fuel used (TWh)
1.00
0.80
0.60
0.40
0.20
-
0
0.21
0.21
0.06
0.74
0.09
2013
2014
2015
Coal
Oil and diesel
Hydro
Solar

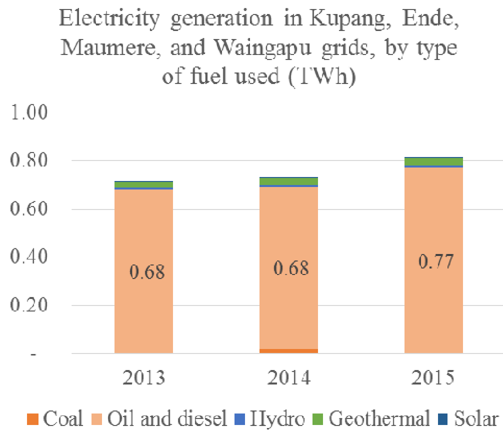

Share of electricity generation during 2013-2015 in Kendari, Bau Bau, Kolaka, Lambuya, Wangi Wangi, Raha grids
Hydro 2%
Solar 0.1%
Coal 27%
Oil and diesel 71%

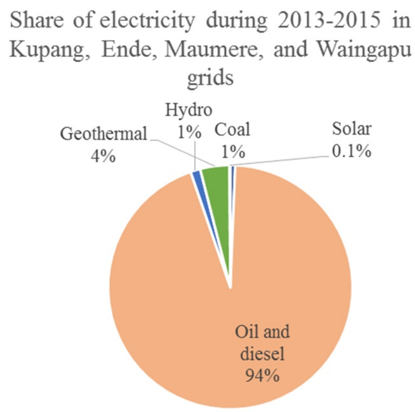

Electricity generation in Palu Parigi grid, by type of fuel used (TWh)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
-
0.03
0.03
0.02
0.58
0.60
0.54
2013
2014
2015
Coal
Oil and diesel
Hydro

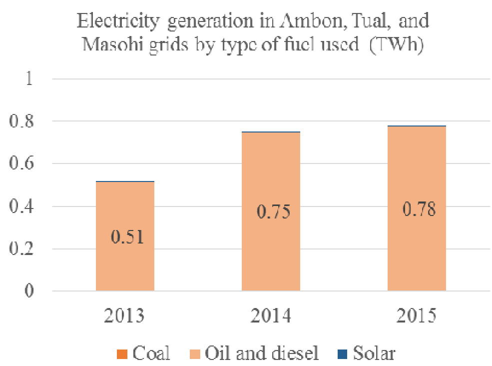

Share of electricity generation during 2013-2015 in Palu Parigi grid
Hydro 4%
Coal 3%
Oil and diesel 93%

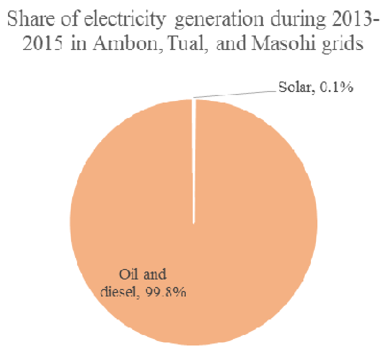

Electricity generation in Lombok, Bima, and Sumbawa grids, by type of fuel used (TWh)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
-
1.14
1.31
1.31
0.15
0.15
0
2013
2014
2015
Coal
Oil and diesel
Hydro
Solar

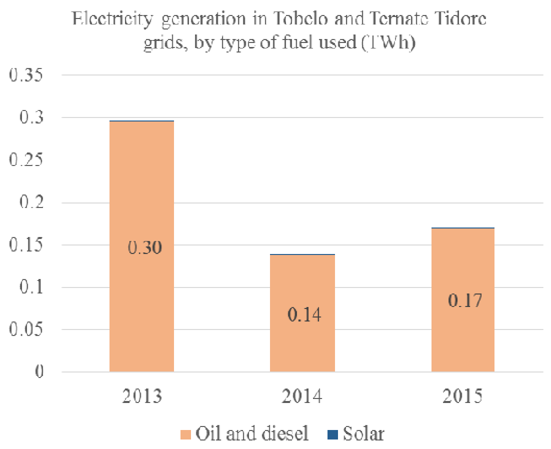

Share of electricity generation during 2013-2015 in Lombok, Bima, and Sumbawa grids
Hydro, 0.4%
Coal, 11%
Oil and diesel, 88%

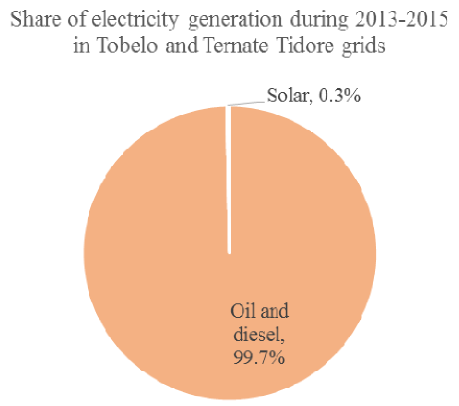

Electricity generation in Kupang, Ende, Maumere, and Waingapu grids, by type of fuel used (TWh)
1.00
0.80
0.60
0.40
0.20
-
0.68
0.68
0.77
2013
2014
2015
Coal
Oil and diesel
Hydro
Geothermal
Solar

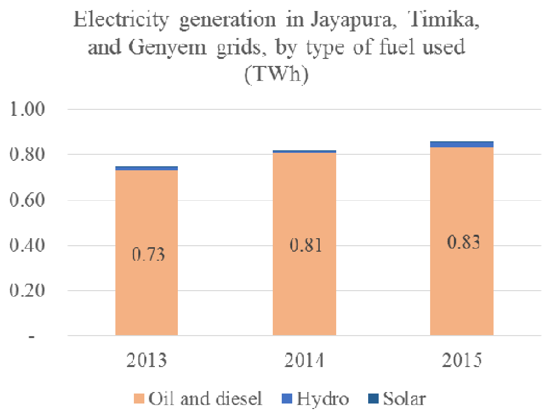

Share of electricity during 2013-2015 in Kupang, Ende, Maumere, and Waingapu grids
Geothermal 4%
Hydro 1%
Coal 1%
Solar 0.1%
Oil and diesel 94%

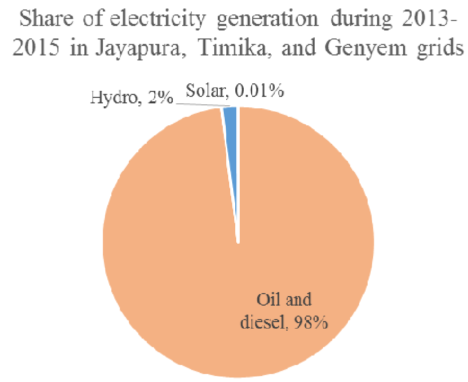

Electricity generation in Ambon, Tual, and Masohi grids by type of fuel used (TWh)
1
0.8
0.6
0.4
0.2
0
0.51
0.75
0.78
2013
2014
2015
Coal
Oil and diesel
Solar

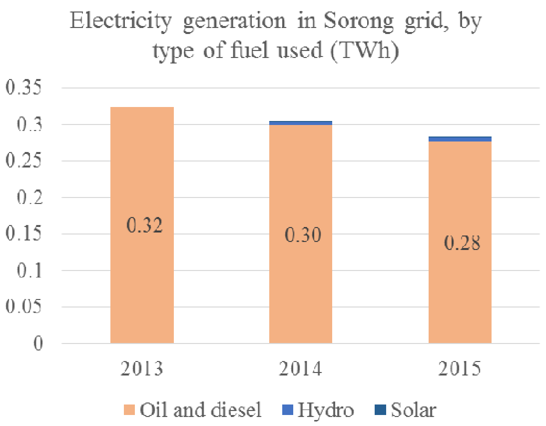

Share of electricity generation during 2013-2015 in Ambon, Tual, and Masohi grids
Solar, 0.1%
Oil and diesel, 99.8%

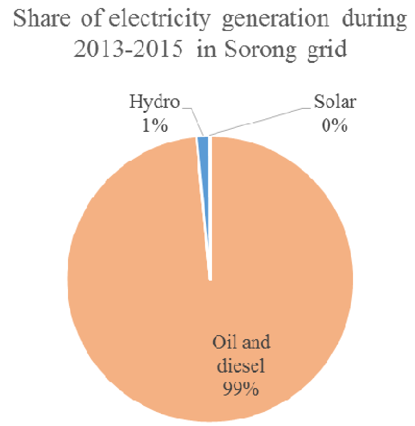












(Data source: Directorate General of Electricity, Ministry of Energy and Mineral Resources, 2016)

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

No.	Interconnection of Electric Power Systems	Emission Factor (tCO2/ MWh)
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 (tCO2/ 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)