Energy Supply Sector

Fossil Fuel Power Plant

Indonesia 2050 Pathway Calculator

Table of Contents

List of Tables

List of Figures

I. Overview of Fossil Fuel Power Plant

Fossil fuel power plant capacity in 2011 was dominated by steam power plant with the installed capacity of 16.32 GW (Figure 1). Of the total 34.51 GW installed capacity in 2011, most of the fossil-fueled plants are installed in Java. Only diesel power plant (*Pembangkit Listrik Tenaga Diesel, PLTD*) that has greater capacity outside Java.

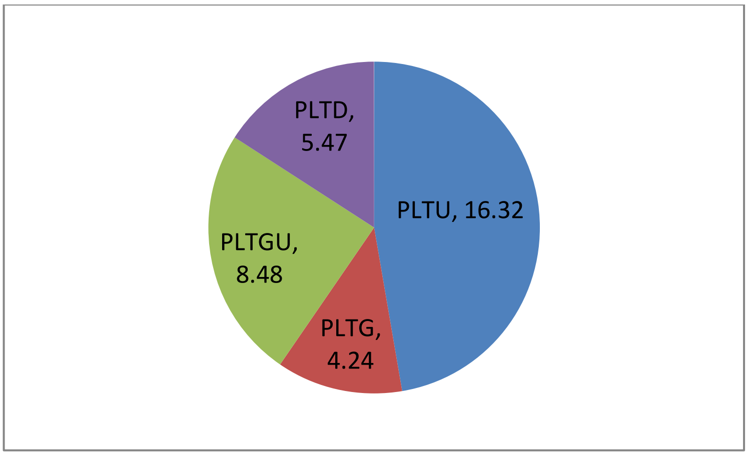
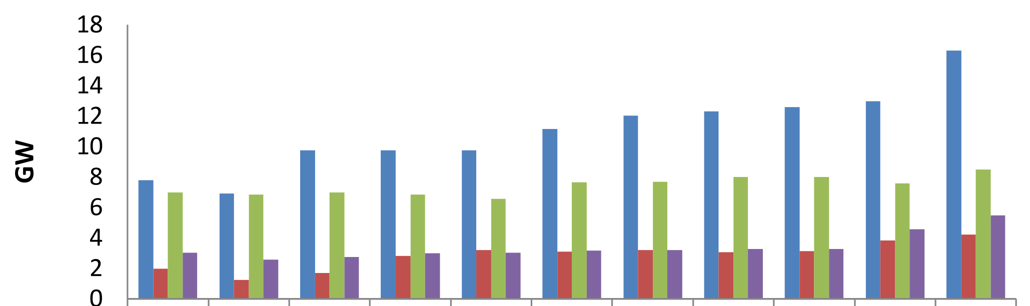


Figure 1. Installed Capacity of Fossil fuel Power Plant in 2011
(Source: Handbook of Energy & Economics, 2013)

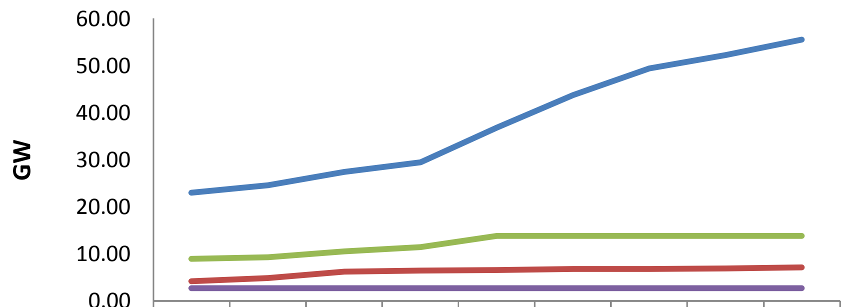
Historically, the total fossil-fuel power plant capacity increased from 19.78 GW in 2001 to 34.51 GW in 2011. In general, the increase was driven by a significant increase of steam power plant (*Pembangkit Listrik Tenaga Uap, PLTU*) capacity compared to the other plants (Figure 2).



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
PLTU	7.80	6.90	9.75	9.75	9.75	11.17	12.01	12.29	12.59	12.98	16.32
PLTG	1.97	1.22	1.69	2.80	3.19	3.10	3.22	3.07	3.14	3.82	4.24
PLTGU	7.00	6.86	7.00	6.85	6.57	7.66	7.70	8.01	8.01	7.59	8.48
PLTD	3.02	2.59	2.73	2.99	3.04	3.17	3.21	3.27	3.26	4.57	5.47

Figure 2. Installed Capacity of Fossil fuel Power Plant in 2001-2011
(Source: Handbook of Energy & Economics, 2013)

Based on the projected generation capacity listed in the Electricity Supply Business Plan (*Rencana Usaha Penyediaan Tenaga Listrik, RUPTL*) for the year 2013-2022, the capacity of steam and gas fired power plant *(Pembangkit Listrik Tenaga Gas, PLTG)* will continue to increase until 2022. The combined cycle power plant *(Pembangkit Listrik Tenaga Gas Uap, PLTGU)* will increase until 2018 and will remain steady until 2022. The document projects that there will not be any diesel power plant addition until 2022 (Figure 3).



	2014	2015	2016	2017	2018	2019	2020	2021	2022
PLTU	22.99	24.54	27.43	29.44	36.78	43.71	49.35	52.29	55.57
PLTG	4.18	4.82	6.20	6.47	6.60	6.76	6.82	6.95	7.07
PLTGU	8.96	9.29	10.49	11.44	13.79	13.79	13.79	13.79	13.79
PLTD	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67

Figure 3. Projected Fossil Fuel Power Plant Capacity 2014 - 2022
(Source: Adapted from RUPTL PLN, 2013-2022)

*) Capacity in 2014 was obtained by adding the data from 2013 (until September) with projected additional capacity in 2014

In the *Indonesia 2050 Pathway Calculator*, steam power plant capacity is not included in the leveling scenarios (level 1-4); there is only projected figures of the base year (2011) until 2050. In addition, the entire electricity needs will be met by domestic supply and the shortage will be supplied by steam power plant.

II. Fixed Assumption

2.1 Capacity Factor

In the Indonesia 2050 Pathway Calculator, capacity factor varies depending on the type of generator. It is determined based on the following equation sourced from the PLN (State Electricity Company) Statistics. The data assumptions used in the National Energy Policy (*Kebijakan Energi Nasional, KEN*) is also referred to. The PLN statistic equation is shown below:

$$\frac{\sum \text{kWh gross production per year}}{\sum \text{kW installed capacity x 8760}} \text{ x } 100\%$$

In determining the capacity factor of each plant, the data used is the data of energy production and installed capacity in 2011 from PLN Statistics 2011. The data is presented in Table 1 below.

Table 1. Energy Production and Installed Capacity of Power Plants

	PLTG	PLTGU	PLTD
Energy Production (GWh)	8246,22	40409,68	4010,94
Installed Capacity (GW)	2,84	7,83	2,57

Source: PLN Statistics, 2011

Based on the above equation, the capacity factor for each plant can be seen in Table 2.

Table 2. Capacity Factor of Power Plants

No	Power Plant Type	2011		2050	
		Liquid	Gaseous	Liquid	Gaseous
1	Coal power plant*	62 %		91 %	
1	Combined cycle power plant**	58,88 %	58,88 %	58,88 %	58,88 %
2	Gas fired power plant**	33,15 %	33,15 %	33,15 %	33,15 %
3	Diesel power plant*	30 %		50 %	

*) Based on KEN data assumption

**) Calculated using PLN Statistics equation

2.2 Own Use and Energy Losses

Own use parameter in Indonesia 2050 Pathway Calculator includes the own use for central system, substations and distribution systems as well as energy losses in transmission and distribution. The assumed percentage for own use is obtained from PLN Statistics 2011 as shown in Table 3.

Table 3. Assumed Own use and Losses

Year	Own use (%)	Energy Losses (%)		Total (%)
		Transmission	Distribution	
2011	4,32	2,25	7,34	9,54

Source: PLN Statistics, 2011

Percentage of own use at 9.54% is rounded up to 10%, and it is assumed to be valid for the entire conventional thermal plants (Table 4).

Table 4. Own use Percentage

No	Power Plant Type	Liquid	Gaseous
1	Coal power plant	10 %	
2	Combined cycle power plant	10 %	10 %
3	Gas fired power plant	10 %	10 %
4	Diesel power plant	10 %	

2.3 Thermal Efficiency

Thermal efficiency of fossil fuel power plant is based on journal by Cahyadi (2011) shown in Table 5.

Table 5. Comparison Power Plants Efficiency

Power Plant Type	Capacity (MW)	Thermal Efficiency (%)
Coal fired Steam Power Plant (Ultra/Supercritical)	400 – 600	40 – 45
Coal fired Steam Power Plant (Subcritical)	200 – 800	30 – 40
Gas fired power plant	50 – 100	22 – 28
Combined Cycle Power Plant	300 – 600	36 – 50
Diesel power plant	1 - 30	27 - 30

Source: Nag. PK, 2002 and Burr, 1999 *in* Cahyadi, 2011

Based on Table 5, the assumptions of thermal efficiency used in Indonesia 2050 Pathway Calculator are presented in Table 6.

Table 6. Fossil fuel Power Plants Thermal Efficiency

No	Power Plant Type	2011		2050	
		Liquid	Gaseous	Liquid	Gaseous
1	Coal fired Steam Power Plant (Ultra/Supercritical)	40 %		40 %	
2	Coal fired Steam Power Plant (Subcritical)	30 %		30 %	
3	Coal fired Steam Power Plant (Advance Ultra Super critical)	45 %		45 %	
4	Gas fired power plant	36 %	36 %	36 %	36 %
5	Combined Cycle Power Plant	28 %	28 %	28 %	28 %
6	Diesel power plant*	25 %		30 %	

*) Based on KEN assumption

2.4 Proportion of Plant Capacity by Fuel Type

The proportion of capacity by type of fuel goes for gas and combined cycle power plants. The fuels mix in the base year (2011) and 2050 refer to the assumptions of KEN. It shows that in 2050, both gas and combined cycle power plants use 100% gas as fuel. The data between 2011 and 2050 are obtained by extrapolation as shown in Table 7.

Table 7. Proportion of Plant Capacity by Fuel Type

Power plant type	Fuel	2011	2015	2020	2025	2030	2035	2040	2045	2050
PLTGU	Liquid	35.20%	31.56%	27.05%	22.54%	18.02%	13.51%	9.00%	4.48%	0.00%
	Gaseous	64.80%	68.44%	72.95%	77.46%	81.98%	86.49%	91.00%	95.52%	100%
PLTG	Liquid	42.85%	38.56%	33.05%	27.54%	22.02%	16.51%	11.00%	5.48%	0.00%
	Gaseous	57.15%	61.44%	66.95%	72.46%	77.98%	83.49%	89.00%	94.52%	100%

2.5 Retirement Schedule For Existing Power Plant

Asassumptions of retirement of each fossil fuel power plant are shown in Table 8. For combined cycle, gas and diesel power plants, the *retirement* occurs once every 5 years for 0.0001 GW capacity (combined cycle and gas fired power plant) and 0.00007 GW (diesel power plant).

Table 8. Asummed Retirement of Fossil Fuel Power Plant

No	Power Plant Type	Retirement (GW)
1	Steam power plant (Subcritical) in 2020 & 2035	0,25
2	Combined cycle power plant	0,0001
3	Gas fired power plant	0,0001
4	Diesel power plant	0,00007

2.6 Base Year Data

Base year data including plant capacity, electricity production and fuel consumption is presented in Table 9. Plant capacity in 2011 is taken from the Handbook of Energy & Economics 2013. While the electricity production and fuel consumption data are obtained from the Electricity Statistics 2011.

Table 9. Plant Capacity, Electricity Production and Fuel Consumption 2011

No	Power Plant Type	Capacity (GW)*	Electricity Production (GWh)**		Fuel Consumption **	
			Liquid	Gas	Liquid (kilo liter)	Gas (mmscf)
1	Combined cycle power plant	8,48	13159.71	26889.96	3296931.98	219227.65
2	Gas fired power plant	4,24	7658.38	2359.33	2139185.07	56057.13
3	Diesel power plant	5,47	16125.11		4243562.39	

*) Source: Handbook of Energy & Economics of Indonesia, 2013

**) Source: Electricity Statistics, 2011

III. Methodology

3.1 Installed Capacity

In the Indonesian 2050 Pathway Calculator modeling, the installed capacity of steam power plant is not included in the leveling scenario, steam power plant serves as a supplier of electricity needs in the event of electricity shortage. There is only one fixed scenario for projected installed capacity of steam power plant based on data from RUPTL PLN 2013-2022. Given the data on the installed capacity of RUPTL PLN only until 2022, the projected capacities from 2025 to 2050 are assumed to remain unchanged at 57.68 GW (Table 10).

Table 10. Installed Capacity of steam power plant (GW)

	2011	2015	2020	2025	2030	2035	2040	2045	2050
Installed Capacity of steam power plant	16.32	26.65	51.47	57.68	57.68	57.68	57.68	57.68	57.68

Projected installed capacity of combined cycle power plant and gas fired power plant until 2050 is built according to data of KEN, RUPTL PLN, and draft of National General Energy Plan *(Rencana Umum Energi , RUEN)*.

In general, the equation for calculation of power plant's installed capacity is described as follows:

$$\begin{aligned} Total\ installed\ capacity \\ &= installed\ capacity\ of\ previous\ year \\ &+ additional\ installed\ capacity\ in\ the\ current\ year - Retirement \end{aligned}$$

The following equation is used to find out the total installed capacity for each fuel type.

$$Installed\ capacity\ for\ each\ fuel\ type = Total\ installed\ capacity\ x\ Fuel\ mix\ for\ each\ fuel\ type$$

3.2 Available Supply

Available supply is defined as available capacity of power plants. The figure is obtained by multiplying the installed capacity with the capacity factor.

$$Available\ supply = installed\ capacity\ x\ capacityfactor$$

3.3 Available Generation

Available generation is defined as energy produced in certain duration of time. Available generation is obtained by multiplying the available supply with the operating hour per year.

$$Available\ generation = Available\ supply\ x\ operating\ time\ per\ year$$

3.4 Actual Generation

Actual generation is defined as total electricity generated. In the Indonesian 2050 Pathway Calculator, the actual generation is calculated using the following equation:

$$Actual\ Generation = Available\ Generation + Own\ Use$$

Meanwhile, own use and losses is formulated by the following equation:

$$Own\ use = Available\ Generation\ x\ own\ use\ percentage$$

3.5 Total Energy Need

Total energy need is defined as the amount of fuel needed to generate electricity. It is related to thermal efficiency of each power plant.

$$Total\ energi\ need = \frac{Actual\ generation}{Thermal\ Efficiency}$$

IV. Trajectory assumption

One pager for fossil fuel power plant include projected capacity for combined cycle power plant, gas fired power plant, diesel power plant and technology for coal combustion.

4.1 Combined Cycle Power Plant (PLTGU)

Combined cycle power plant is an installation of equipment to convert thermal energy (from combustion of fuel and air) into electricity. Basically, the combined cycle power plant is a combination of gas fired power plant and steam power plant. In Indonesia, there are currently more combined cycle power plants installed in Java (53 power plants). Total installed capacity of combined cycle power plant in 2011 was 8.48 GW.

Level 1

Level 1 assumes that the capacity of combined cycle power plant remains the same from base year (2011) until 2050 at 8.48 GW. This level assumes that the new combined cycle power plant experience a shortage in natural gas. Beside the gas reserves depletion issue, the other issue is the access to big gas reserves location, since the big gas reserves have been included in the long-term contracts with foreign buyers.

The existing capacity of combined cycle power plant can be maintained until 2050. This is caused by the gas supply that is assured for the main power plants in Java-Bali system, namely the combined cycle power plant of Muara Karang and Priok, and also Tambak Lorok. Most gas supply for the combined cycle power plant of Muara Karang and Priok is obtained from LNG FSRU West Java. Gas for Tambak Lorok combined cycle power plant is supplied from Gundih and Kepodong field.

As for the system outside Java-Bali, the combined cycle power plant is assumed to operate in East Kalimantan region, Northern Sumatera and Southern Sumatera. The combined cycle power plant in

East Kalimantan region is assumed to have gas supply from Salamander, Salamander Lapangan Tutung, and JOB Simenggaris. While the gas supply for the combined cycle power plant in Northern Sumatera and Southern Sumatera is assumed from FSRU LNG Tangguh.

Level 2

Level 2 assumes that the capacity of combined cycle power plant in 2050 will be 10.42 GW. Additional capacity of combined cycle is assumed from the conversion of power plant and the changes in the existing power plant's unit size, such as Muara Karang combined cycle power plant with additional capacity of 0.8 GW and Grati combined cycle power plant with additional capacity of 0.75 GW. Additional capacity of these power plants are possible since its is supported by the existing 97 km gas pipeline and the plan to add another 113 km of gas pipeline. Besides, the gas supply for additional capacity of combined cycle power plant for this level is assumed from several fields including Offshore North West Java (ONWJ), Cepu and Santos (Table 11).

Table 11. Projected Gas Supply and Natural Gas Pipeline for Muara Karang, Muara Tawar and Grati Combined Cycle Power Plant

No	Plant	Gas Supplier/ Operator	Route	Region	Diameter (inch)	Length (km)
1	Muara Karang	Offshore North West Java (ONWJ)/ PHE ONWJ *)	APN – MM Compressor Muara Karang Combined Cycle Power Plant	West Java	24	50
		Re-gasification LNG from Mahakam Block/ PT Nusantara Ragas **)	Offshore pipe from to ORF Muara Karang pipe		24	15
3	Grati	Santos – Oyong/ Santos (Sampang) *)	Oyong – PLN Grati	East Java	14	40
		Madura Strait (Husky Oil Ltd) & PT Inti Alasindo Energi **)	ORF Semare – Grati Combined Cycle Power Plant	Pasuruan – East Java	16	22
		Madura Strait (Husky Oil Ltd) / PT Parna Raya **)	ORF Husky Kraton – PLTGU Grati Pasuruan Combined Cycle Power Plant	Grati, Pasuruan – East Java	14	16,83
		Sampang (Santos	Distribution	Grati –	16	9

		Sampang)/ PT. PGN **)	Grati – Pasuruan – Probolinggo	Pasuruan – Probolinggo		

Source: Adapted from RUPTL PLN 2013-2022 and MEMR Ministerial Decree No 2700 K/11/MEM/2012

*) Exsisting Natural Gas Pipeline
**) Planned Natural Gas Pipeline

Level 3

Level 3 assumes the capacity of combined cycle power plant in 2050 will be 13.81 GW. Increase in combined cycle power plant capacity in this level is caused by the increase of electricity demand and higher peak load than Level 2. This level also assumes the infrastructure planned in MEMR Ministerial Decree No 2700 K/11/MEM/2012 has been fully built (25,754 km) and the gas supply is available from potential reserves that already under contract.

In order to fulfill electricity need especially during peak load, about 5 GW additional capacity of combined cycle power plant is needed in 2050. This additional capacity assumes to be fulfilled from Sumatera region with 1.19 GW, Eastern Indonesia region with 0.66 GW and Java-Bali grid system with 3.15 GW (RUPTL 2013-2022). Therefore, the total installed capacity including the existing capacity of 8.81 GW with additional capacity of 5 GW is 13.81 GW.

Additional capacity of combined cycle power plant mainly comes from Java-Bali grid system. This is caused by the electricity demand in 2022 is projected to come mostly from Java-Bali region (70%). To fulfill fuel need of combined cycle power plant that is projected to be able to use 100% gas in 2050, the gas distribution infrastructure in Java-Bali region is assumed to be sufficient for additional PLTGU operation. Currently, 6,678 km gas pipeline has been built and 25,745 km more is planned to be built in 2025 (MEMR Ministerial Decree No.2700 K/11/MEM/2012). For further detail, maps of existing and planned gas pipeline are shown in Appendix 2 to Appendix 6.

To support the development of combined cycle power plant additional capacity of 0.66 GW in the eastern part of Indonesia, it is assumed that the planned gas pipeline according to MEMR Ministerial Decree No. 2700 K/11/MEM/2012 has been built (Table 11).

Tabel 12. Plan of Gas Pipeline in east Indonesia

	Gas reserve location (Block)	Type of Pipe	Route	Region
KALIMANTAN				
1	Chevron, Total E & P Indonesia, Petronas Carigali Muriah Ltd	Transmission	East Kalimantan – Central Java	East Kalimantan, South Kalimantan, Central Java
2	Sanga-Sanga (VICO), Mahakam	Distribution	Network of	

	(Total), East Kalimantan (Chevron)		Samarinda Region Distribution	
3	Sanga-Sanga (VICO), Mahakam (Total), East Kalimantan (Chevron)	Transmission	Network of Balikpapan Region Distribution	
4	Chevron, Total E & P Indonesia, Petronas Carigali Muriah Ltd	Transmission	Banjarmasin – Palangkaraya – Pontianak	East Kalimantan, South Kalimantan, West Kalimantan,
5	Natuna Sea “A” (Premier Oil Natuna Sea BV)	Transmission	Natuna – Kalimantan West	West Kalimantan
SULAWESI				
1	Sengkang (Energy Equity Sengkang), Donggi Senoro	Transmission	Donggi – Pomala – Sengkang	North Sulawesi, Central Sulawesi
2	Sengkang (Energy Equity Sengkang)	Distribution	Region Jaringan Distribution Ujung Pandang	South Sulawesi
3	Sengkang (Energy Equity Sengkang)	Transmission	Sengkang – Pare-Pare – Makassar	South Sulawesi
MALUKU & PAPUA				
1	Salawati Kepala Burung (JOB Pertamina – Petrochina Salawati)	Distribution	Sorong Distribution	Sorong, Papua
2	SE Arar 1 (Petrocihina International (Bermuda) Ltd.)	Transmission	SE Arar – Ex P/L Arar	Papua
3	SE Arar 1 (Petrocihina International (Bermuda) Ltd.)	Transmission	NA 1 – PF Arar	Papua
4	Onshore Block Pulau Salawati Kepala Burung by JOB PT PHE and Petrochina International (Kepala Burung) Ltd.	Distribution	Flare JOB Pertamina – Petrochina to plant Intermega Sabaku PTE Ltd.	Sorong, West Papua

Level 4

Level 4 assumes that the capacity of combined cycle power plant in 2050 will be 25 GW. Significant increase of the capacity in this level is caused by the significant increase in electricity demand and higher peak load than Level 3. This level also assumes the infrastructure planned in MEMR Ministerial Decree No 2700 K/11/MEM/2012 has been built 100% (25,754 km) and also other infrastructure such as FSRU and new LNG plant, for example Arun Regasification unit, FSRU Labuhan

Maringgai (Lampung), FSRU Cilegon (Banten), FSRU Central Java, LNG Plant Donggi Senoro, LNG Plant South Sulawesi and LNG Plant Masela. Gas supply for this level is assumed from the potential reserves that has been under contract and also from the imported gas supply.

In Level 4, it is assumed that 45% of total combined cycle power plant capacity is installed in Java. While Sumatera and other islands share 35% and 20% of total combined cycle power plant capacity, respectively.

Significant increase in installed capacity of combined cycle power plant in Sumatera is triggered by the increase in electricity demand and the higher peak load in the area. The development of combined cycle power plant in Sumatera is supported by sufficient infrastructures comprising the existing gas pipeline (2012) of 4,567.92 km and readily available pipeline according to National General Plan Natural Gas Transmission and Distribution Line of 15,803.3 km. Gas pipeline from Natuna archipelago to Sumatera become the important infrastructure considering the gas reserves in Natuna (51,46 TSCF). Gas supply for combined cycle power plant in Sumatera will be fulfilled by the optimal exploration of gas reserves in Sumatera that reaches 31.65 TSCF (Statistik Gas Bumi, 2012).

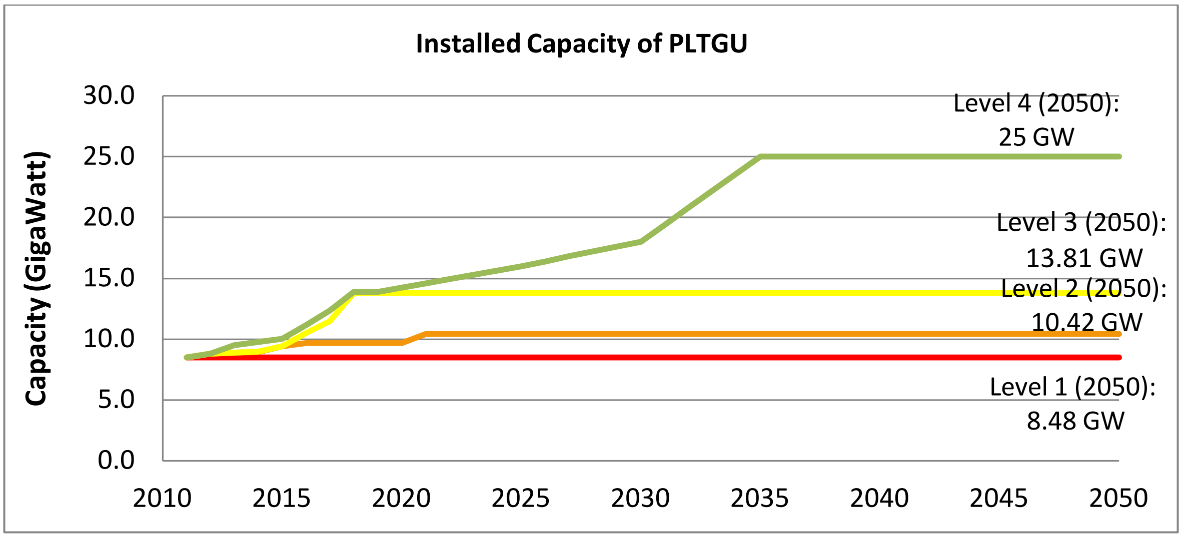


Figure 4. Levels of Installed Capacity of PLTGU 2011 to 2050

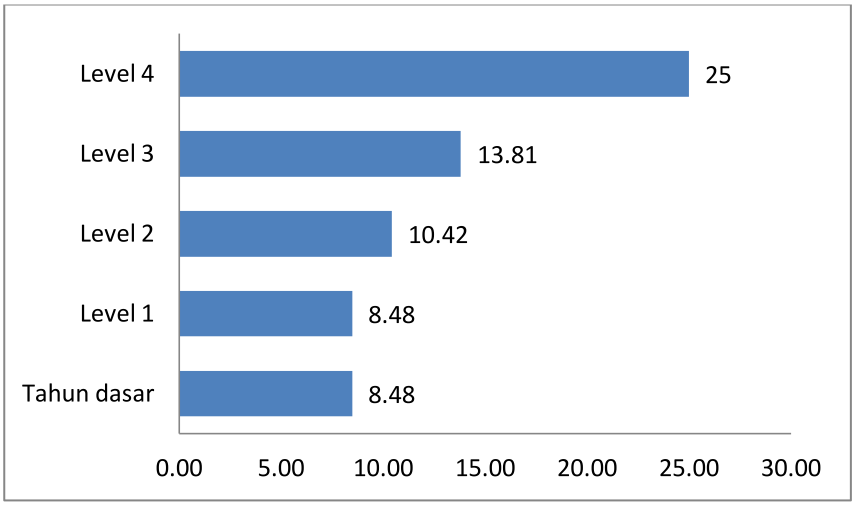


Figure 5. Installed Capacity of Combined Cycle Power Plant in 2050 (GW)

4.2 Gas fired Power Plant (PLTG)

Gas fired power plant is a power plant that utilizes the power resulted from fuel combustion and high pressure gas. The result of combustion that is high-pressure gas will move the turbine and generator, thus electricity is generated.

One of drawbacks of gas-fired power plant is its low efficiency. Therefore, gas fired power plant can be combined with steam power plant to get higher efficiency, such combination is called combined cycle power plant.

According to PLN Statistics 2011, the number of gas fired power plant and combined cycle power plant are 71 units and 61 units respectively with installed capacity of 2839.44 MW and 7833.97 MW. Therefore, the average capacities of gas fired power plant and combined cycle power plant are 39.99 MW and 128.42 MW. Based on this data, gas fired power plant is still needed to fulfill moderate electricity demand (like combined cycle power plant) especially to supply the electricity outside Java. The number of gas fired power plant outside Java in 2011 was 40 unit, higher than the number of gas fired power plant in Java (Statistik PLN, 2011).

Level 1

Level 1 assumes that the capacity of gas fired power plant remain the same from base year (2011) until 2050 at 4.23 GW. Level 1 assumes that there will not be any new gas fired power plant installed and the existing gas fired power plant will be maximized. This level assumes that the new gas-fired power plant faces the natural gas shortage issue due to the low exploration activities in exploration and slow exploitation of new gas field. Besides, the development of new gas fired power plant outside Java is hindered by insufficient gas pipeline and infrastructure.

The existing gas fired power plants in Java in 2011 were operated by PT.Indonesia Power, PT PJB and Pembangkitan Muara Tawar. Muara Tawar gas fired power plant is assumed to be operating until 2050 due to continuous gas supply from Pertamina Hulu Energi (PHE), Program SWAP FSRU Jawa West and SWAP Premier. Meanwhile, Cilegon gas fired power plant is assumed to obtain gas supply from CNOOC and PGN. Sunyaragi gas fired power plant is assumed to be operating with gas supply from Pertamina EP Reg Jawa. In addition, additional capacity of Pesanggaran gas fired power plant is supplied by LNG Sengkang.

The existing gas fired power plants outside Java are assumed to still operate until 2050, among others: the gas fired power plants in West Kalimantan, South Kalimantan, East Kalimantan, South Sulawesi, KIT Northern Sumatera and KIT Southern Sumatera.

Level 2

Level 2 assumes that the capacity of gas-fired power plant in 2050 will be 6.65 GW. Level 2 assumes that there is a 2.4 GW additional capacity compared to the base year (2011). Such additional capacity is assumed from the gas-fired power plants in Sumatera region with 0.88 GW, eastern part of Indonesia with 1.34 GW and Java-Bali system with 0.21 GW.

Additional capacity in Sumatera Region is assumed from Sungai gelam gas fired power plant (0.092 GW), Duri gas fired power plant (0.112 GW), Lampung Sribawuno gas fired power plant , Sutami gas fired power plant (0.2 GW), Payo selincah gas fired power plant (0.05 GW), Arun gas fired power plant (0.2 GW), East Tanjung Jabung gas fired power plant (0.1 GW), Aceh (0.025 GW) and Jambi Peaker gas fired power plant (0.1 GW).

For east Indonesia region, additional capacity of gas fired power plant is assumed from East Kalimantan peaking (0.1 GW), Senipah (0.082 GW), South Kalimantan Peaker-1 (0.2 GW), South Kalimantan peaker-2 (0.05 GW), East Kalimantan peaker-2 (0.1 GW), East Kalimantan peaker-3 (0.05 GW), Minahasa peaker (0.15 GW), Sengkang (0.06 GW), Makassar peaker (0.45 GW), and Gorontalo peaker (0.1 GW). For Java-Bali grid system, additional capacity of gas-fired power plant is assumed from Pesanggaran peaker (0.21 GW).

For this level, it is assumed that storage and regasification facilities are available in LNG Arun to be used for supplying the gas fired power plant in Arun and northern Sumatera. For the gas fired power plants in Sungai Gelam, Duri, Lampung and Jambi, the gas is supplied in the form of Compressed Natural Gas (CNG) from PEP-TAC, Energasindo, Jambi Merang, FSRU Lampung and Petro china.

The gas-fired power plants in eastern part of Indonesia, especially East Kalimantan peaker, uses LNG from Simenggaris field as fuel. For peaker in Makassar, Minahasa and Sengkang, gas supply is assumed from Sengkang (Wasambo field) using mini LNG technology. And for Pesanggaran gas fired power plant, the gas is supplied from Sengkang (Wasambo field) using mini LNG technology.

Level 3

Level 3 assumes that the capacity of as fuel in 2050 will be 8.12 GW. Increase in gas fired power plant capacity in this level is caused by the increase of electricity demand and higher peak load than Level 2. This level also assumes the infrastructure planned in MEMR Ministerial Decree No 2700 K/11/MEM/2012 has been built 100% (25,754 km) and the gas supply is available from potential reserves that have been under contract. In order to fulfill the electricity need especially during peak load, about 3.89 GW additional capacity of gas-fired power plant is needed in 2050. This additional capacity assumes to be fulfilled in Sumatera region with 1.5 GW, Eastern Indonesia region with 2.18 GW and Java-Bali grid system with 0.22 GW.

Most of additional capacity of gas-fired power plant comes from the eastern part of Indonesia with low capacity per plant yet spread out in the region. To fulfill the fuel need of gas fired power plant, the new gas pipeline of 3,960 km long has been built in 2050 therefore the total length of pipeline reach 7,080 km (MEMR Ministerial Decree No.2700 K/11/MEM/2012). Gas supply for gas fired power plant in east Indonesia region comes from several gas field including Salamander, Donggi, Total Senipah and LNG Sengkang (Table 13).

Gas fired power plant development in Sumatera region and Java-Bali grid system are supported by sufficient gas pipeline infrastructure. It is assumed that the available gas pipeline in 2050 for Sumatera region reach 20,371 km and 32,423 km pipeline for Java-Bali. Gas supply for gas fired power plant in Java-Bali comes from block gas Corridor (ConocoPhilipsIndonesia) and Cepu (Exxon Mobil Oil Indonesia). Meanwhile for Sumatera region, gas supply comes from potential block such as Seng, Segat in Pelalawan regency, Bento and Baru in Pekanbaru that is currently operated by PT Kalla, Jambi Merang, and FSRU LNG Tangguh.

Tabel 13, Projected Gas Supply for PLTG in East Indonesia Region

No	Power Plant	Province	Gas Supplier
1	Pontianak Peaker	West Kalimantan	LNG PLN Bantam (planned)
2	Bangkanai	Central Kalimantan	Salamander
3	South Kalimantan Peaker	South Kalimantan	Salamander (potential)
4	Bontang	East Kalimantan	Salamander Lapangan Tutung (potential), Total Bontang
5	Sambera	East Kalimantan	VICO (potential)
6	East Kalimantan	East Kalimantan	JOB Simenggaris (potential)

	peaker		
7	Senipah	East Kalimantan	Total Senipah
8	Tarakan	North Kalimantan	GSA Pertamina EP, Manhattan KI
9	Minahasa Peaker	North Sulawesi	LNG Sengkang
10	Gorontalo Peaker	Gorontalo	Donggi (potential)
11	Morowali	Central Sulawesi	Tiaka (potential)
12	Sengkang	South Sulawesi	Energy Equity Epic (sengkang)
13	Makassar Peaker	South Sulawesi	LNG Sengkang
14	Lombok Peaker	West Nusa Tenggara	Marine CNG from Gresik
15	*Kawasan Indonesia Timur* (KTI) Tersebar		LNG Sengkang (potential), Perusda Salawati (potential), Sorong Petrochina (planned), BP Berau (potential)

Source: Adapted from RUPTL PLN 2013-2022

Level 4

Level 4 assumes that the capacity of gas-fired power plant in 2050 will be 21 GW. Significant increase of gas fired power plant capacity in this level is caused by the significant increase of electricity demand that is higher than Level 3. This level also assumes that the infrastructure planned in MEMR Ministerial Decree No 2700 K/11/MEM/2012 has been built 100% (25,754 km) and also other infrastructure such as FSRU and new LNG plant, for example Arun Regasification unit, FSRU Labuhan Maringgai (Lampung), FSRU Cilegon (Banten), FSRU Central Java, LNG Plant Donggi Senoro, LNG Plant South Sulawesi and LNG Plant Masela. The gas fired power plant in eastern part of Indonesia will be supplied by mini LNG, for example the gas fired power plants of peaker Makassar, Minahasa, Kupang, Pesanggrahan, Ambon and Jayapura. Gas supply for this level is assumed from the potential reserves that have been under contract and also from the imported gas supply.

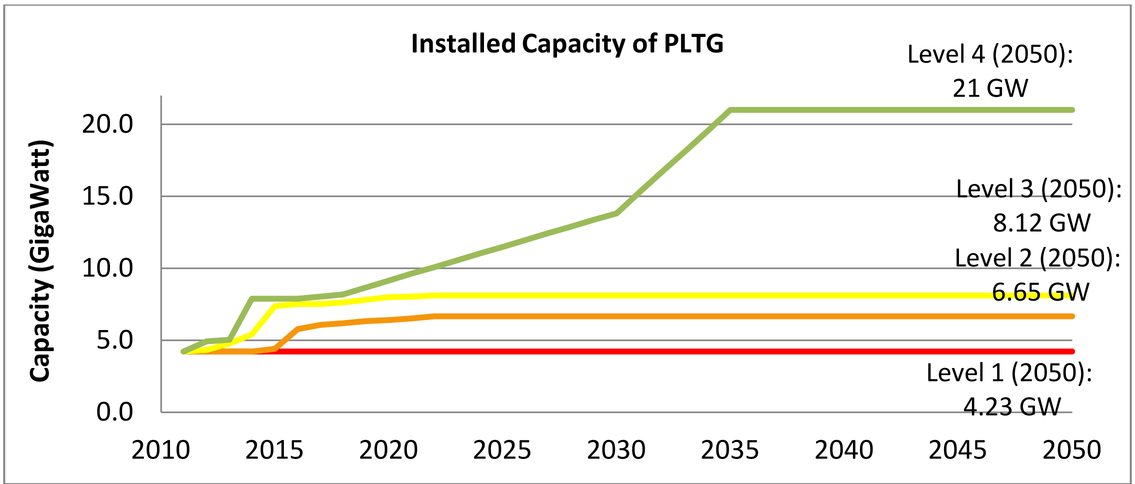


Figure 6. The leves of Installed Capacity of gas fired power plant 2011 - 2050

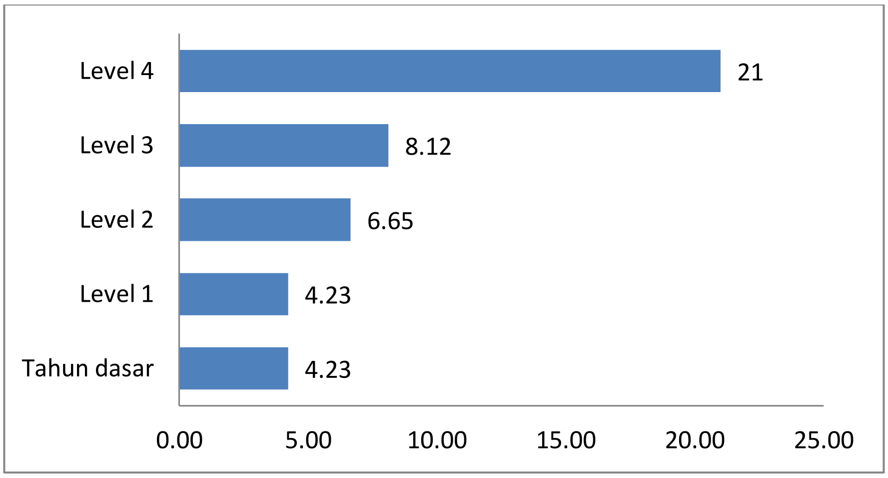


Figure 7. Installed Capacity of gas fired power plant in 2050 (GW)

4.3 Diesel Power Plant (PLTD)

In 2011, installed capacity of diesel power plant in Indonesia was 5,47 GW. It belongs to PLN owned power plant (5.02 GW) and private owned (0.45 GW). Most diesel power plants are installed outside Java-Bali grid system (5.24 GW), and the rest (0.23 GW) is installed in Java-Bali grid system (*Statistik Ketenagalistrikan*, 2011). Outside Java-Bali system, diesel power plant is used for base load, peak load and also captive power. Diesel power plant condition is usually old, not feasible economically and technically for operation due to high operational cost or needs to be replaced or reconditioning. Due to high operational cost, especially for diesel fuel, replacement technology is needed to reduce fossil fuel use. The appropriate replacement technology includes small-scale coal fired steam power plant, thermal modular power plants (*pembangkit thermal modular pengganti diesel, PTMPD*) and hybrid renewable energy power plant with diesel or biofuel power plant.

Level 1

Level 1 assumes that the capacity of diesel power plant remains the same from base year (2011) until 2050 at 5.47 GW. This level assumes that the diesel power plant is used to fulfill electrification ratio target of 100%. Therefore, the diesel power plant is still used in remote islands in eastern part of Indonesia, particularly in the area that is difficult to be covered by PLN grid. The technology to replace diesel power plant, through the use of renewable energy source, is assumed not fully developed so that the diesel power plant is still being used. If in 2011, most diesel power plants are installed in Sumatera and Kalimantan; in 2050, the diesel power plant is assumed to be installed mostly in Maluku, Papua dan Nusa Tenggara. It happens because the diesel power plants in Sumatera dan Kalimantan have been replaced by small-scale coal fired, while the diesel power plant is needed to meet the electrification ratio target in Maluku, Papua and Nusa Tenggara region.

Level 2

Level 2 assumes that the capacity of diesel power plant in 2050 decrease to 2 GW. This level assumes that the fossil fuel is expensive and its supply is fluctuated that causes the diesel power plant to be uneconomical to develop. On the other hand, the technology replacement using renewable energy resources is assumed to be ready that the diesel power plants in Maluku, Nusa Tenggara and Papua region have been replaced. Besides, the number of small-scale coal fired power plant installed in Sumatera dan Kalimantan regions is higher compared to Level 1.

Level 3

Level 3 assumes that the capacity of diesel power plant in 2050 decreases to 1.5 GW. This level assumes that the fossil fuel is expensive and its supply is fluctuated that causes the diesel power plant to be uneconomical to develop. The use of green diesel is assumed to be uneconomical for small-scale diesel power plants . On the other hand, the technology replacement using renewable energy resources is assumed to be ready that diesel power plants in Nusa Tenggara are totally replaced. Only some areas in Maluku and Papua that still use diesel power plants in 2050. Besides, the number of small-scale coal fired power plant in Sumatera dan Kalimantan regions is similar to Level 2.

Level 4

Level 4 assumes that capacity of diesel power plants in 2050 decreases to 1 GW. This level assumes that the fossil fuel is expensive and its supply is fluctuated that causes the diesel power plant to be uneconomical to develop. Similar to Level 3, the use of green diesel is considered uneconomical for small-scale diesel power plants. On the other hand, technology replacement of small-scale steam power plant has been proven to be reliable. Therefore the use of diesel power plants has been replaced. The installed capacity of diesel power plants that reach 1 GW is assumed from the diesel power plant that is combined with renewable energy resources in some areas like Nusa Tenggara and Papua.

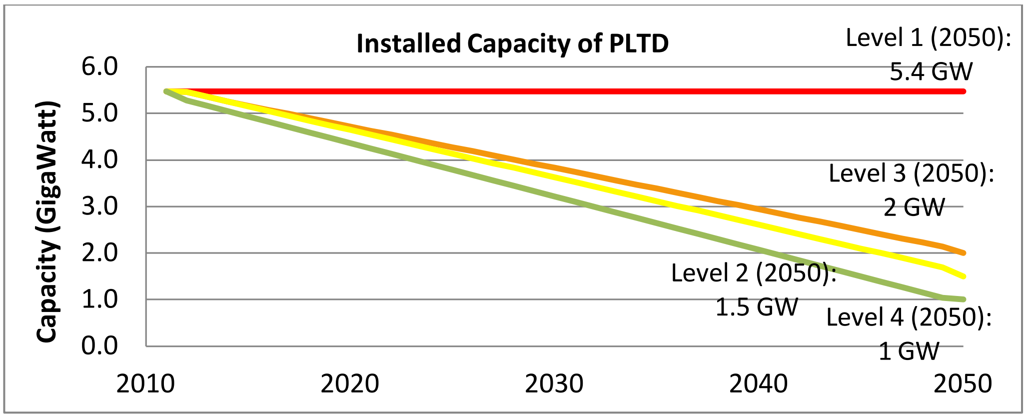


Figure 8. Leveling of Installed Capacity of PLTD 2011 to 2050

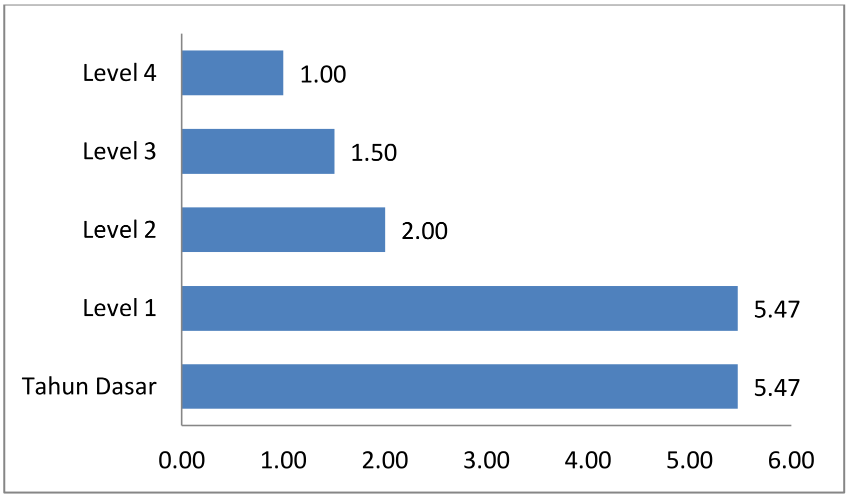


Figure 9. Installed Capacity of PLTD in 2050

4.4 Coal Combustion Technology

Based on the coal combustion technology that is efficient and environmentally friendly, the combustion technology is later divided into:

a. Subcritical pulverizer, operates under high temperature and pressure (221 bar) compared to conventional pulverizer. The efficiency can reach up to 38%.
b. Supercritical pulverizer, developed from subcritical type and it is operated under pressure of 230-265 bar, therefore increase the efficiency up to 42%.
c. Ultra supercritical, this technology uses steel material that enable very high operating condition (300bar) therefore efficiency reach 44%.
d. Advance Ultra Supercritical, the operating condition for this technology is at 700-760^{o}C.

The more efficient the technology, the less coal required. Therefore the less emission will be resulted. In Indonesia, the steam power plants with super critical technology are Paiton steam power plant Unit III and Cirebon I steam power plant. According to RUPTL PLN 2013-2022, PLN has planned to develop 1,000 MW of coal-fired power plant with ultra super critical and supercritical technologies for 600 MW capacity in Java-Bali grid system.

Option A

Option A assumes 80% of steam power plant use Sub Critical boiler and 20% use Super Critical boiler.

Option B

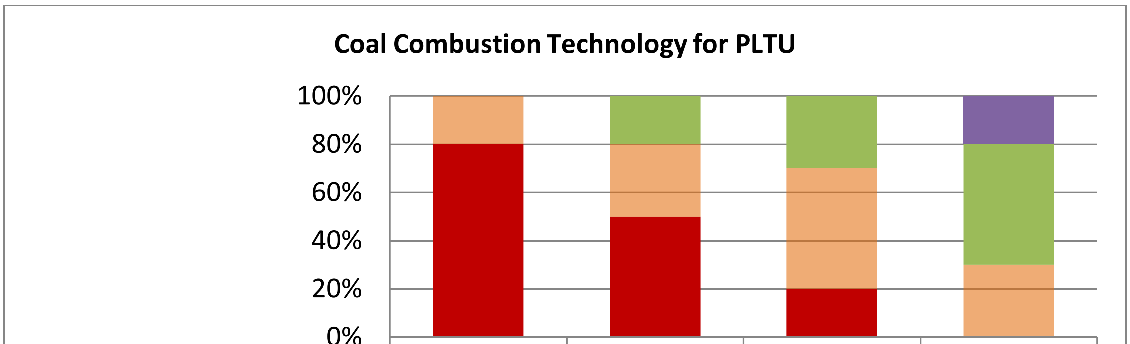
Option B assumes 50% of steam power plant use Sub Critical boiler, followed by 30% of *Super Critical* boiler and 20% of *Ultra Supercritical* boiler.

Option C

Option C assumes the use of Sub Critical boiler for steam power plant decrease to 20% the use of Super Critical and Ultra Supercritical boiler for PLTU increase to 50% and 30% respectively.

Option D

Option D assumes *Sub Critical* boiler is not being used anymore. *Advance Ultra Supercritical* boiler technology has been used for 20% PLTU. While Super Critical and Ultra Supercritical boiler are used with percentage of 30% and 50%.



	Opsi A	Opsi B	Opsi C	Opsi D
Advance Ultra Super Critical	0%	0%	0%	20%
Ultra Super Critical	0%	20%	30%	50%
Super Critical	20%	30%	50%	30%
Sub Critical	80%	50%	20%	0%

Figure 10. The Levels of Coal Combustion Technology

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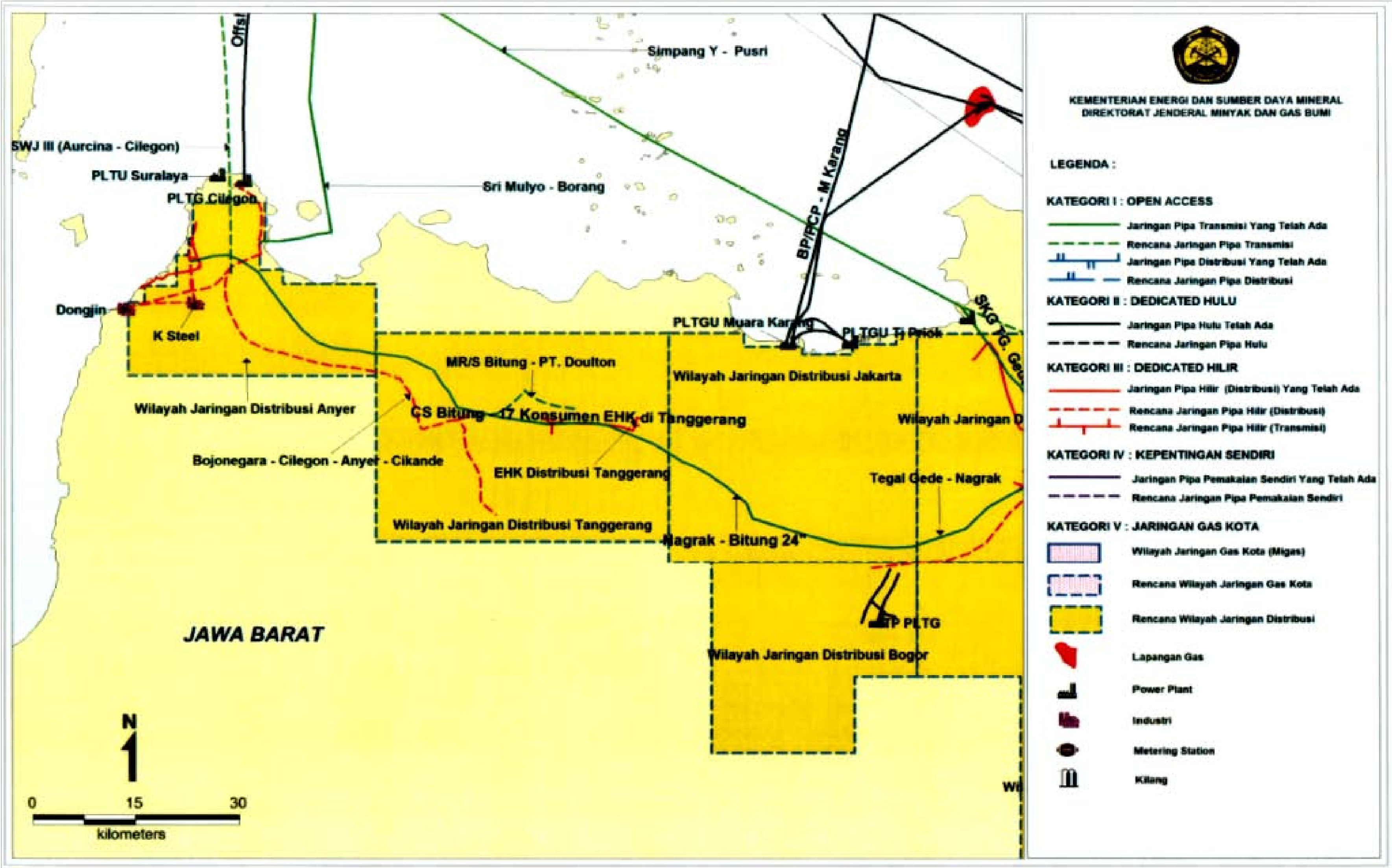
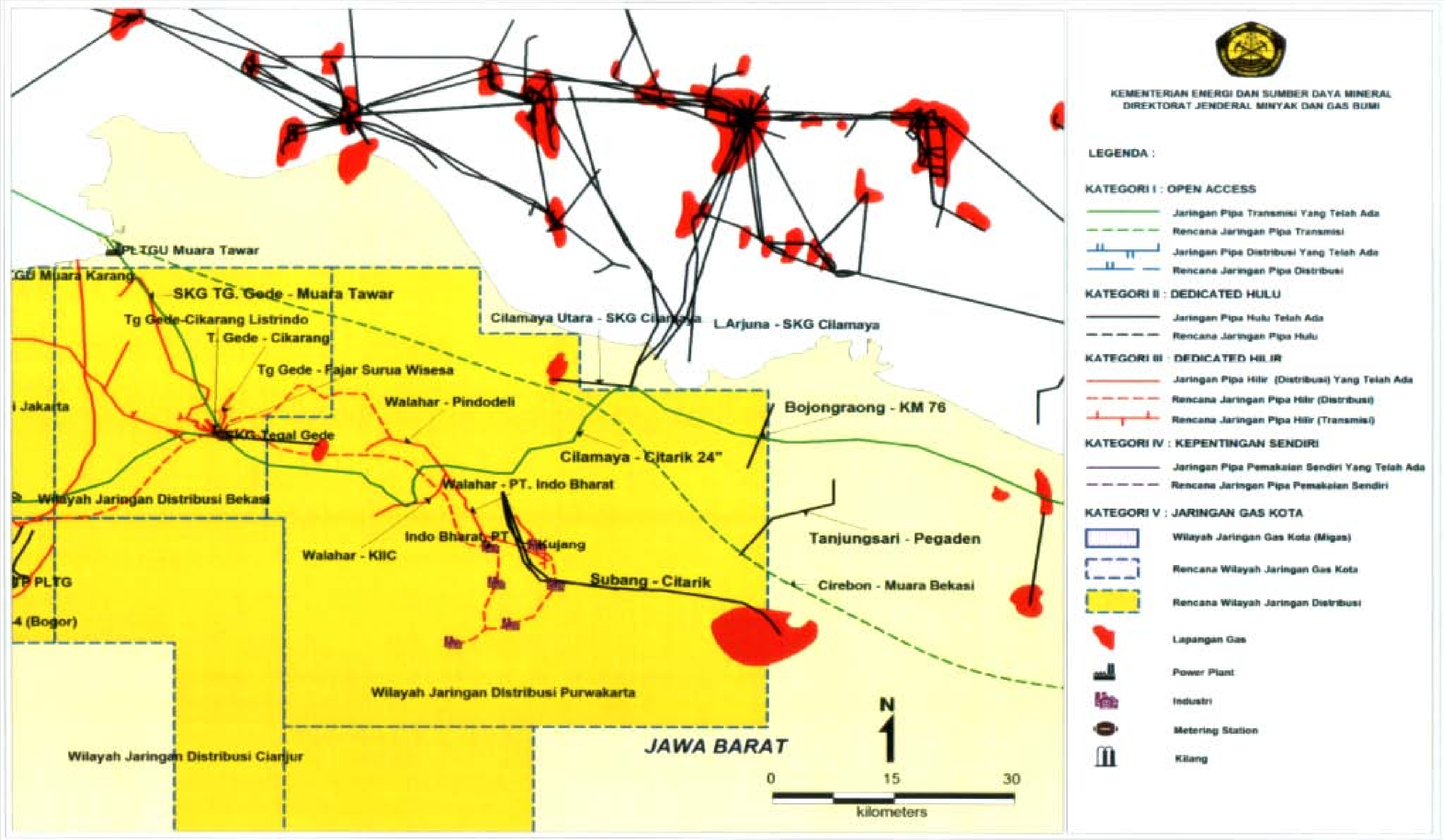
Appendix 1. Map of National General Plan for Gas Transmission and Distribution Pipeline Year 2012 - 2025

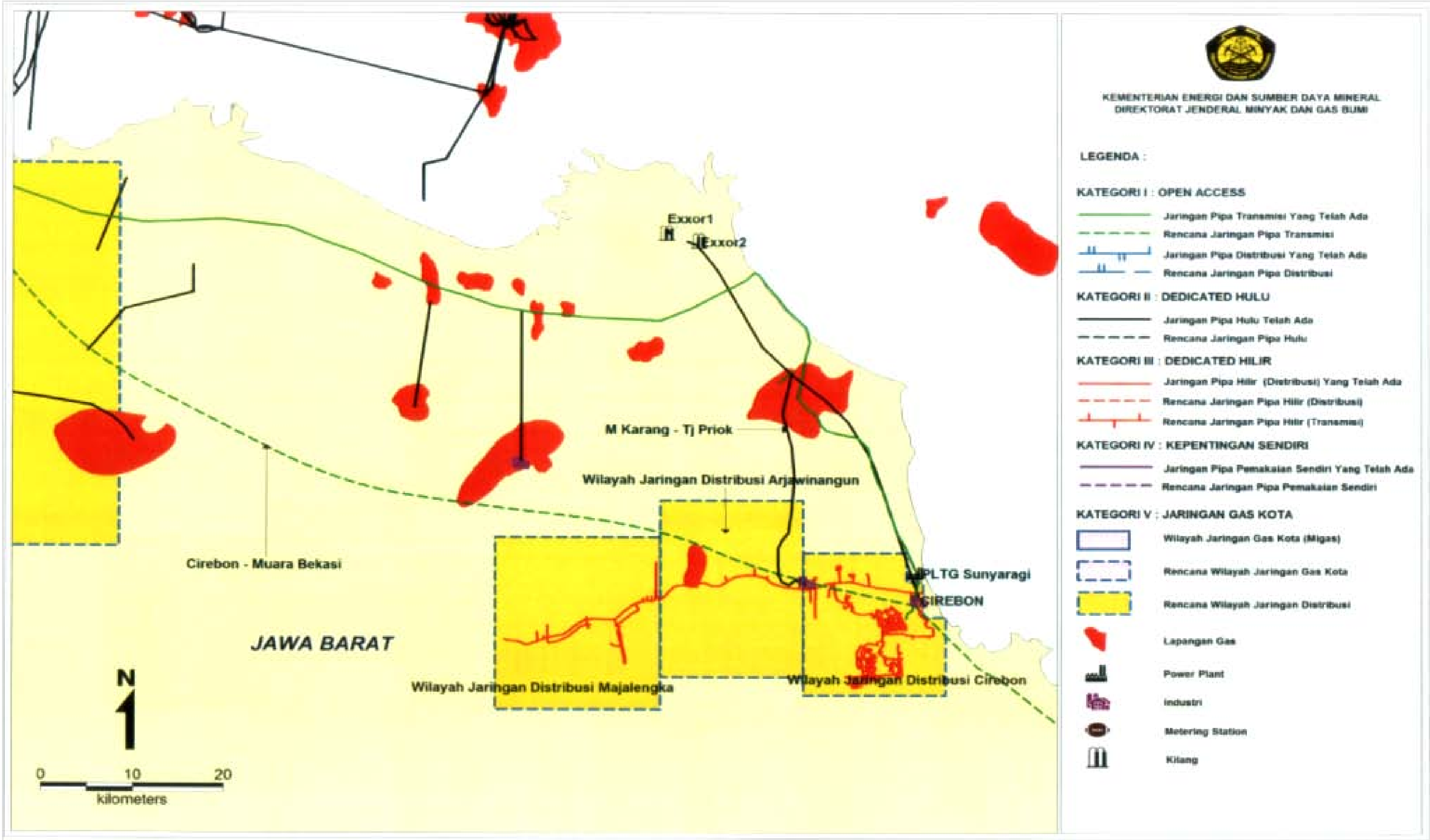
Appendix 2. Map of Existing and Planned Gas Pipeline in Java (1)



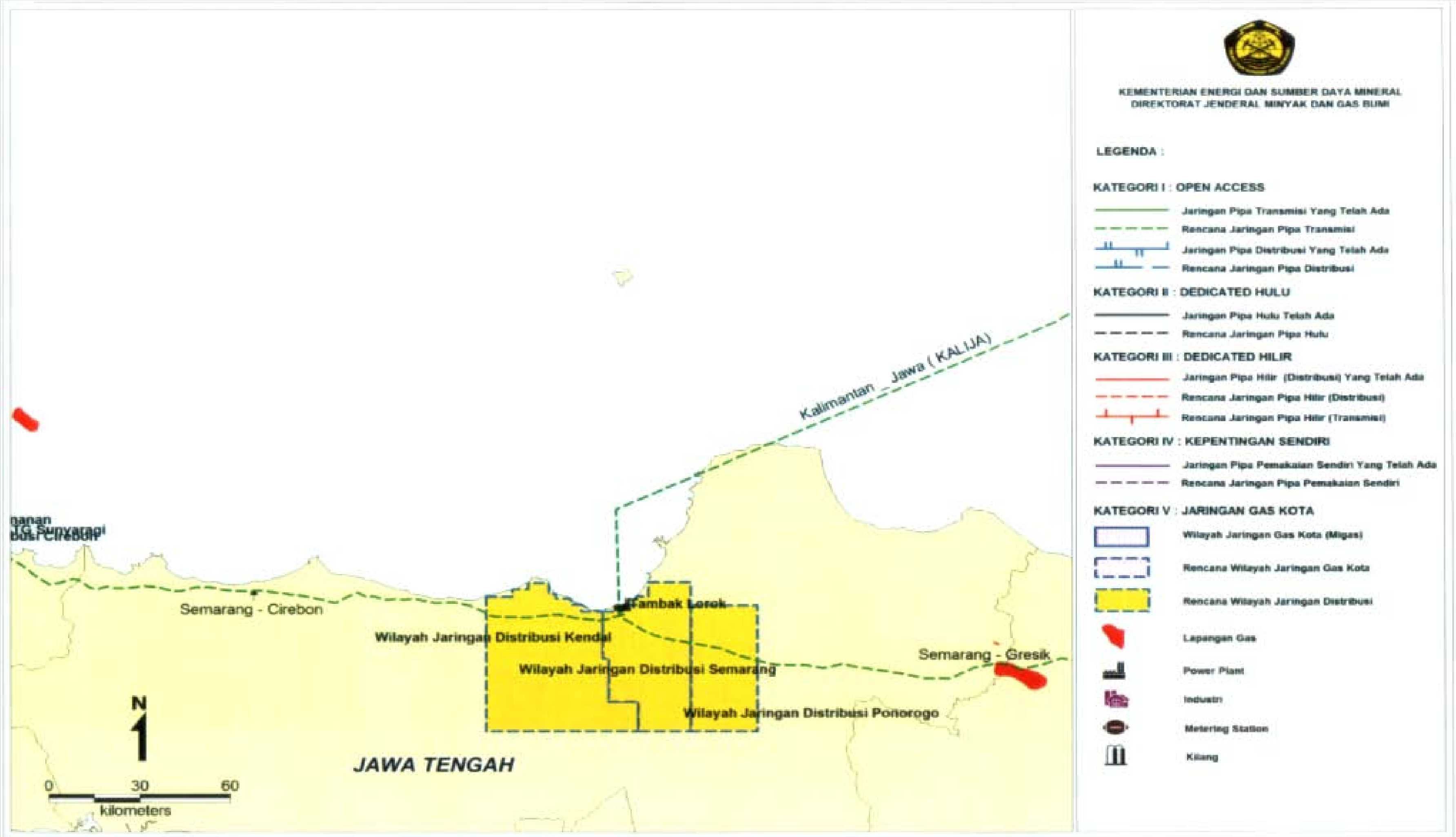
Appendix 3. Map of Existing and Planned Gas Pipeline in Java (2)



Appendix 4. Map of Existing and Planned Gas Pipeline in Java (3)



Appendix 5. Map of Existing and Planned Gas Pipeline in Java (4)



Appendix 6. Map of Existing and Planned Gas Pipeline in Java (5)