FINAL REPORT
MERCURY EMISSIONS FROM COAL-FIRED POWER PLANTS IN INDONESIA

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ABBREVIATIONS AND ACRONYMS

ASTM	American Standard Testing and Material
APBI	Indonesian Coal Mining Association
APC	air pollution control
APP	Amamapare Power Plant
BaU	business as usual
BAT/BEP	best available techniques and best environmental practices
BCRC-SEA	Basel Convention Regional Centre for South-East Asia
cal	calorie
CCT	clean coal technologies
CEMS	continuous emission monitoring system
CFPP	coal-fired power plant
CO_2	carbon dioxide
CSE	Centre of Science and Environment
CV	calorific value
DEN	Dewan Energi Nasional (Energy National Committee)
DGE	Directorate General of Electricity
DMO	domestic market obligation
EIA	Environmental Impact Assessment
EP	environmental permit
EPMA	Environmental Protection and Management
ESP	electrostatic precipitator
ER	electrification ratio
FC	fixed carbon
FGD	flue-gas desulfurization
FTP	fast track program
GDP	gross domestic product
GHG	green house gas
gr	gram
GW	gigawatt
IGCC	integrated gasification combined cycle
IPP	independent power producer
ISO	International Organization for Standardization

kcal	kilocalorie
KEN	Kebijakan Energi Nasional (National Energy Policy)
KPC	Kaltim Prima Coal
kWh	kilowatt hour
LEB	local environmental board
LNG	liguid natural gas
MOEF	The Ministry of Environment and Forestry
MOEMR	The Ministry of Energy and Mineral Resources
mg	milligram
Mt	metric tones
MTOE	million tones of oil equivalent
Mw	megawatt
NAAQS	National Ambient Air Quality Standards
NEA	Niksa Energy Associates
NGO	non-governmental organization
NO_x	nitrogen dioxides
Nm^3	normal cubic meter
NRE	new and renewable energy
PC	Pulverize coal
PLN	State Electricity Company
PLTU	steamed powered electric generator
POG	process optimization guidance
ppb	parts per billion
ppm	parts per million
PPU	private power utility
RE	renewable energy
RUEN	Rencana Umum Energi Nasional (Nation's General Energy Plan)
RUKN	Rencana Umum Ketenagalistrikan Nasional (Nation's General Electricity Plan)
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik (Electricity Supply Service Plan)
SC	supercritical
SNI	Standar Nasional Indonesia (Indonesian Standard Test Method)
SO_x	sulfur dioxide

SSFA	small scale funding agreement
Twh	terawatt hour
UKL	Upaya Pengelolaan Lingkungan (Environmental Management Effort)
UPL	Upaya Pemantauan Lingkungan (Environmental Monitoring Effort
USC	ultra supercritical
US EPA	United States Environmental Protection Agency
UNEP	United Nations Environment Programme / UN Environment
VM	volatile matter

1. INTRODUCTION

1.1. BACKGROUND

Emissions of mercury from thermal power stations are a subject of increasing concern because of its toxicity, volatility, persistence, long range transport in the atmosphere. Mercury has the tendency for bioaccumulation as methyl mercury and thus enters into the food chain. Once released into the environment, mercury contaminates soil, air, surface and ground water. Mercury is a neurotoxin and exhibits adverse health effects. Mercury is a global pollutant that is emitted, deposited, and reemitted on both a local and global scale in both terrestrial and marine environments.

The mercury emitted from coal-fired power plants (CFPP) originates from the mercury present in the coal. Typically, mercury is present in the coal in the tens of parts-per-billion (ppb) range. Burning of enormous quantity of coal for power generation makes it the largest anthropogenic source of mercury emissions at global level.

In Indonesia based on Balifokus inventory of mercury release in Indonesia in 2012, coal combustion and other coal use contribute as the third largest mercury emitter. Indonesia is one of the biggest reserves of coal globally, beside USA, Russia, China, India and Australia. The Government launched a 35,000 MW electricity project in which 78% will use non-renewable energy (oil, gas, coal) with a coal percentage of 55%. This will increase the mercury emission.

The Ministry of Environment and Forestry of Republic of Indonesia (MOEF), United Nations Environment Programme (UNEP) and Basel Convention Regional Centre for South-East Asia (BCRC-SEA) have entered into a Small Scale Funding Agreement (SSFA) to undertake a project titled “Mercury emissions from the coal-fired power sector in Indonesia”. In accordance with UNEP Governing Council priorities identified in Decisions 24/3 and 25/5 and with the goal of the reduction of mercury emissions from coal partnership area under the UNEP Global Mercury Partnership, the project aims to present national information on coal types and coal usage, characterize coal-fired power sector in Indonesia and develop an emission inventory for the coal fired energy sector as well as present other relevant information to improve accuracy of future emission inventories for the sector.

The responsible ministries and related agencies will extend their support in collection of samples from power stations along with infrastructural and logistic support at the sites. A technical team was established for the Hg measurement in CFPP which consist of MOEF, Ministry of Energy and Mineral Resources (MOEMR), Centre for Technology, Mineral and Coal Resources, BCRC-SEA and local experts.

1.2. PROJECT OBJECTIVES

The project has the following objectives:

1. Assessment of mercury content of coals fed to CFPP; this includes in-country coals as well as imported coals;
2. Development of projections of coal consumption (2025);

3. Characterization of existing power plants with regard to air pollution control technologies installed;
4. Direct measurements of the emissions of mercury from the flue gas of selected power plants based on the capacity, vintage, fuel types, emission control systems, including speciation of mercury in flue gas and partitioning of mercury in the combustion products;
5. Estimation of the mercury emission factors based on the information gained during this project and comparison with relevant published emission factors;
6. Calculation of 2016 mercury emissions from the coal-fired power sector in Indonesia based on developed emissions factors and projection of mercury emissions in 2025;
7. Capacity building and information seminar;
8. Propose activities on how to reduce emissions and releases from the coal-fired power sector.

1.3. MAJOR TASKS OF THE STUDY

Task 1. Coal information:

1. Information will be collected on the amount of coal consumed (for electricity production) by coal source; available information on coal analysis on dry basis (including Hg, As, Se, Cl, Br, Ca, Na content).
2. Information will be collected or estimated on coal consumption (projected coal use) for electricity generation for the target year 2025.
3. Analyses of untreated coal samples from Indonesia will follow relevant international accepted standards. Coal sample analysis will include proximate and ultimate analysis and will include determination of Hg, As, Se, Cl, Br, Ca, Na content of coal.
    a. Collection of coal samples from power plants – 60 samples.
    Samples will be obtained to broadly cover coals from the major coal fields of Indonesia, from major import sources, and from major power plants. The distribution of samples will reflect distribution of sources of coal used in Indonesian power plants.
    b. Coal washery samples[1] (feed and products) - 10 samples
4. Inter-calibration of analysis will be carried out on 10 selected number of coal samples as a quality control of analysis results.

Task 2. Power plant information:

1. Available national and provincial information will be collected on installed power plant capacity and electricity generation by coal combustion as of 2016, including the approximate locations of power plants.

[1] If coal washing is not practiced in Indonesia, then 10 additional coal samples should be taken for analysis, in total 70 coal samples.

2. Available national and provincial information will be collected on the installed configuration of any air pollution control equipment and its typical operational efficiency.
3. Available national and provincial information will be collected on any available results of measurements of Hg emissions from CFPPs.
4. Hg emission measurements at selected power plants.
   Direct measurements at minimum three CFPPs adopting standard procedures for solid and gaseous sampling according to internationally accredited methods (recommended flue gas measurement method: US EPA Method 30B utilizing US EPA Mercury Measurement Toolkit). The selection of three power plants for measurements will reflect the distribution of power plants by their size and age. Measurements will be carried out on one boiler unit (representative unit size for Indonesia) at each of the selected plants:

   In addition to Hg measurement as summarized below, at each power plant the samples to be collected are:
   - Crushed coal (-20 mm) from mill feeder
   - Fly ash
   - Bottom ash

   At each of the power plants, 20 samples of crushed coal from mill feeder, fly ash, and bottom ash shall be taken.

   Total number of samples for analysis:

Coal samples as mined and delivered to the power plants	: 60
Coal samples from washeries[2]	: 10
Power plant samples (coal, fly ash, bottom ash) from the plants where Hg measurements are done	: 60
Total number of samples	:130

Task 3. Mercury emission inventories and future estimates

1. Mercury emission factors will be developed based on data sets from selected power plants.
2. The emission inventories will be shared by a network of experts and stakeholders for comments.
3. Future mercury emission estimates will be developed (scenario for 2025).

Task 4. Report preparation

Four quarterly reports will be made periodically during the annual year 2017 and a final report submitted by the end of 2017, prior to the end of the project.

Task 5. Capacity building and proposals for measures to reduce emissions

Capacity building activities will be carried out to inform stakeholders about the goals, progress and intended outcome of the project in the context of developing a preliminary national action plan/strategy. Capacity building activities may include, for example, visits to institutions participating in the program, production of informational

[2] If coal washing is not practiced in Indonesia, then 10 additional coal samples should be taken for analysis, in total 70 coal samples

materials, etc. An information seminar, including a workshop on the "Process Optimization Guidance for Reducing Mercury Emissions from Coal Combustion in Power Plants (POG)" and the INC guidance on Best Available Techniques and Best Environmental Practices (BAT/BEP) will be organized to disseminate information to relevant stakeholders (policymakers, administrative staff in the power plant sector.

Preliminary proposal for a plan on how to reduce mercury emissions and releases from the sector will be developed. The preliminary plan will include target mercury emission reduction from the sector and the timeline for achieving the reductions. The plan will account for growth projections for coal consumption, installed capacity, and electricity generation. The plan will discuss approaches that may be utilized to reduce future Hg emissions from the sector. These approaches may include coal switching, coal preparation, installation of air pollution control technology for the reduction of emissions of particulate matter and acid gases and utilizing the co-benefit Hg removal by optimizing existing control technologies, or utilization of dedicated Hg removal technologies. Improvement of energy efficiency of electricity generation should also be considered. This could be accomplished by installation of modern boilers and/or by improvement of operational practices at existing power plants.

1.4. WORK PROGRESS

The work progress are as follows:

1. Desk study on coal-fired power plant in Indonesia and the coal information (coal characteristic, reserves, pattern of coal consumption, energy overview and energy development of coal-fired power plant, capacity and electricity generation by coal combustion, including the location of power plant;
2. Developed criteria for selection of coal fired power plant for Hg measurement. The selection criteria are as follows:

   a. capacity of the power plant and supercritical technology;

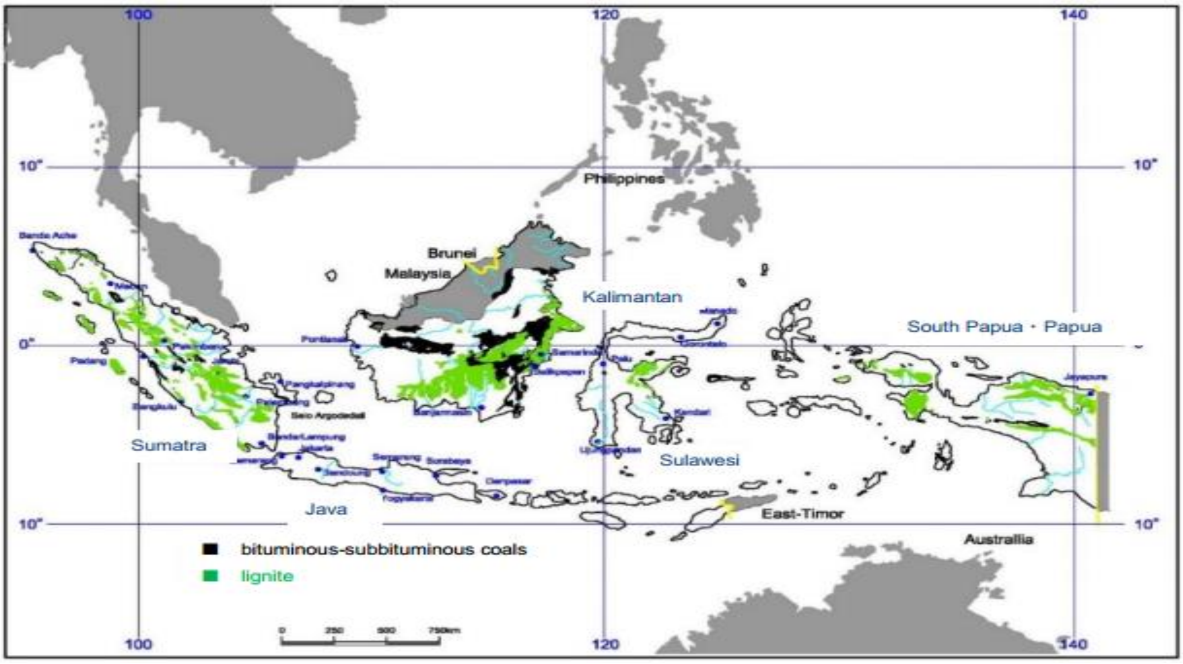
   b. scoring performance of the power plant;

   PLTU Suralaya Unit 2, PLTU Cirebon and PLTU Indramayu were selected as pilot CFPPs facility for Hg measurement;
3. Developed coordination among sectors related in Hg sampling measurement;
4. Select accredited laboratory and independent laboratory for coal and Hg emission sampling and analysis and for inter-calibration. Laboratory for coal analysis, Hg emission and inter-calibration will be carried out by TEKMIRA, SYSLAB and GEO SERVICE respectively;
5. Participated in the workshop energy efficiency and expert meeting on mercury emissions from coal combustion in South Africa on 28 February - 3 March 2017;
6. Workshop on Hg emissions from coal fired power plants in Indonesia on 20 March 2017;
7. Conducted sampling in the coal-fired power plant (PLTU) Suralaya Unit 2 in Banten Province;
8. Conducted sampling in the PLTU Cirebon in West Java Province;

9. Conducted sampling in the PLTU Indramayu in West Java Province;
10. Analysis of the coal, fly ash and bottom ash from the measured power plant is still on-going.
11. Intercalibration by Geoservices laboratory and Carsurin laboratory has been completed.
12. Mercury emission measurement from 3 selected CFPPs were carried out successfully.
13. A pre-final workshop with major power plant managers was held hosted within the vicinity of the Ministry of Energy and Mineral Resources. The workshop was conducted to verify secondary data that have been provided by the power plants and on information on obtaining coal samples from their individual plants. Around 40 representatives from power plant companies attended the meeting. Power plant representatives were also interested in the final outcome of the study and on future steps the government will embark in addressing the pollution from mercury and also other pollution with regard to government policy.
14. A final workshop was held within the vicinity of the Ministry of Environment and Forestry to disseminate the preliminary finding s of the study. A wide range of audience participated in the workshop mainly from representatives from the Ministryof Environment and Forestry, ministry of Energy and Mining, power plant representatives, university and NGOs. The workshop was also attended by representatives from the UN Environment represented by the members of the UN Environment Coal Partnership, Dr. Lesley Sloss and Dr. Wojciech Jozewicz. Around 100 participants attended the worshop with the agenda as attached.
15. A meeting was also held the next day within the compounds of the Ministry of Environment and Forestry between the UN Environment representatives and the Minamata team assigned to the project to discuss on the technical findings of the study. Corrections and adjustments were made toward the study based on the findings available until that moment. The study is expected to be finalized on schedule by end of the year 2017.

2. OVERVIEW OF INDONESIAN COAL SECTOR

2.1. CHARACTERISTICS OF INDONESIAN COALS



Source : Ministry of Energy and Mineral Resource 2015

Figure 2.1. Distribution of Indonesia coal based on the characteristic

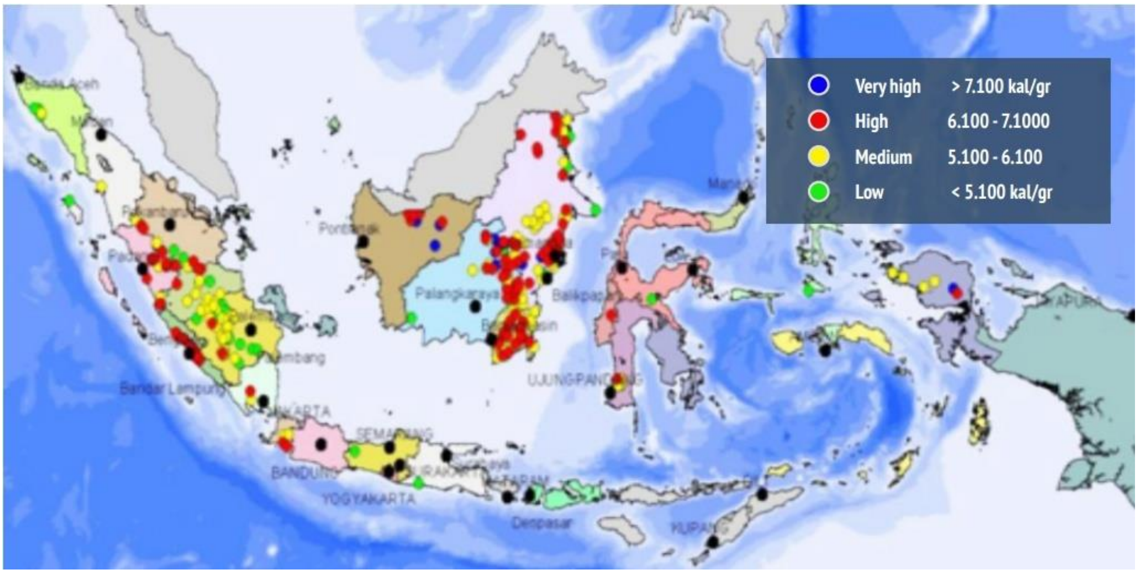
Indonesian coals are characterized by the high shares held by bituminous-subbituminous coals and lignite. Yet, though in very limited quantities, anthracite is also proven. Distribution of Indonesia coal based on its characteristic is shown in Figure 2.1. With regards to proven reserves over 80% proves to be coals having a calorific value of under 6,100 kcal/kg. Particularly more than 41% of reserves is found to be coals under 5,100 kcal/kg in calorific value. It is noted that high-rank coals (high: 6,100-7,100) and ultra-high-rank coals (very high: >7,100) are limited, but coal resources with a calorific value of over 7,100 kcal/kg are put at around two hundred million tons.

A large part of Indonesian coal reserves are of coals of low calorific values. As previously mentioned, coal under 5,100 kcal/kg accounts for 41% of coal reserves. No formal standards are available for defining low-rank coals. Accordingly, low-rank coals tentatively are defined here as those having calorific value of around 5,100 kcal/kg or less. These coals can be counted as categorized into subbituminous coals and/or lignite. Low-rank coals are found abundant in Kalimantan, South Sumatra, Jambi and Riau. In recent years, the Indonesian government has been promoting the use of low-rank coals. Coal potency based on its calorific value in Indonesia can be seen Table 2.1 and Figure 2.2.

Table 2.1. Indonesia coal potency based on its calorific value

Calorific value (CV)	Reserve (million ton)		
	Probable	**Proven**	**Total**
Low (<5100 kal/gr)	7,108.27	7,121.47	14,229.74
Medium (5100-6100 kal/gr)	3,570.70	6,841.66	10,412.36
High (6100-7100 kal/gr)	541.60	2,769.20	3,310.80
Very high (>7100 kal/gr)	264.19	240.21	504.39
Total	**11,484.76**	**16,972.53**	**28,457.29**

Source: Geological Agency, Status 2016



Source : Ministry of Energy and Mineral Resource 2015

Figure 2.2. Distribution of Indonesia coal based on the calorific value

Indonesian coal potency in percentage based on its calorific value is described in Figure 2.3.

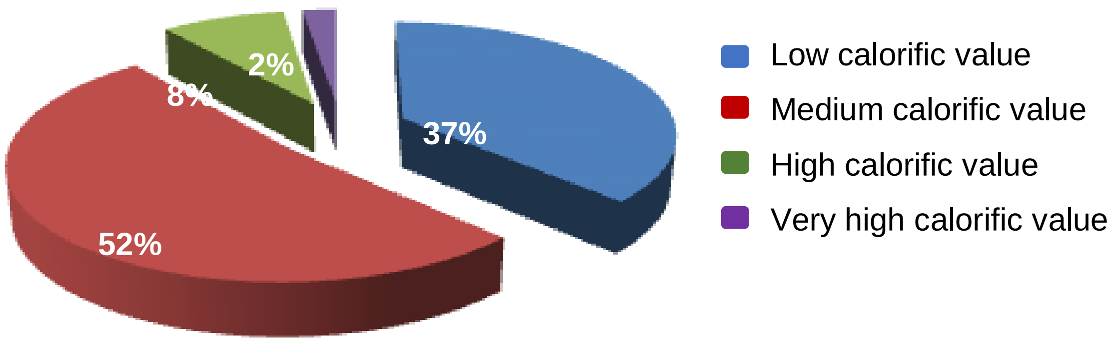


Figure 2.3. Indonesian coal potency in percentage based on its calorific value

One type of Indonesian coal from Kaltim Prima Coal (KPC), a mining company in Kalimantan, are Prima (CV>6900), Pinang (CV 5800-6900) and Melawan (CV 5500). Pinang type of coal is used by the Amamapare Power Plant (APP) and its characteristic is shown in Table 2.2 and Table 2.3.

Table 2.2. Ultimate and proximate analysis of coal sample from KPC

No	Parameter	Unit	Result (±)
1	Calorific	Kcal/kg	6,057
2	Carbon	%	77.6
3	Oxygen	%	14.18
4	Hydrogen	%	5.55
5	Calorfic Net Value	Kcal/kg	5,678
6	Moisture content	%	16.2
7	Total Sulfur	%	0.84
8	Ash	%	4.7

Table 2.3. Metal analysis of coal sample from KPC

No	Parameter	Unit	Result
1	Arsenic	Ppm	1.68
2	Cadmium	Ppm	<0.16
3	Chromium	Ppm	5.77
4	Pb	Ppm	2.11
5	Mercury	Ppm	<0.012
6	Thalium	Ppm	<0.8
7	Antimony	Ppm	<0.8
8	Cobalt	Ppm	1.5
9	Nickel	Ppm	3.69
10	Cuprum	Ppm	14.5
11	Vanadium	Ppm	11.3
12	Zinc	Ppm	6.53
13	Selenium	Ppm	0.8

Source: MOEF, 2016

2.2. COAL RESERVES OF INDONESIA

At current rates of production (and if new reserves are not found), global coal reserves are estimated to last around 112 years. The biggest reserves are found in the USA, Russia, China, India, Australia and Indonesia. The top 10 coal producer in 2015 can be seen in Table 2.4.

Indonesia is among one of the world's largest producers and exporters of coal. Although ranked 5th among the coal producers, Indonesia became the world's largest exporter of steam coal in 2013 and remains the top exporter through 2040[3]. A significant portion of this exported thermal coal consists of a medium-quality type (between 5100 and 6100 cal/gram) and a low-quality type (below 5100 cal/gram) for which large demands originates from China and India. According to information presented by the Indonesian Ministry of Energy, Indonesian coal reserves are estimated to last around 83 years if the current rate of production is to be continued. Regarding global coal reserves, Indonesia currently ranks 10th, containing roughly 3.1 percent of total proven global coal reserves according to the most recent BP Statistical Review of World Energy.

[3] https://www.eia.gov/outlooks/ieo/coal.cfm

Table 2.4 Top 10 coal producers in 2015[1,2]

No	Country	Production (Mt)
1	China	1827.0
2	USA	455.2
3	India	283.9
4	Australia	275.0
5	Indonesia	241.1
6	Russia	184.5
7	South Africa	142.9
8	Colombia	55.6
9	Poland	53.7
10	Kazakhstan	45.8

[1] commercial solid fuels only, i.e. bituminous coal, anthracite (hard coal), lignite and brown (sub-bituminous) coal
[2] million tons oil equivalent
Source: BP Statistical Review of World Energy 2016

There are numerous smaller pockets of coal reserves in the islands of Sumatra, Java, Kalimantan, Sulawesi and Papua but the three largest regions of Indonesian coal resources are found in:

1. South Sumatra
2. South Kalimantan
3. East Kalimantan

Distribution of coal reserve in percentage in Indonesia is shown in Figure 2.4.

Source: Geological Agency, 2016

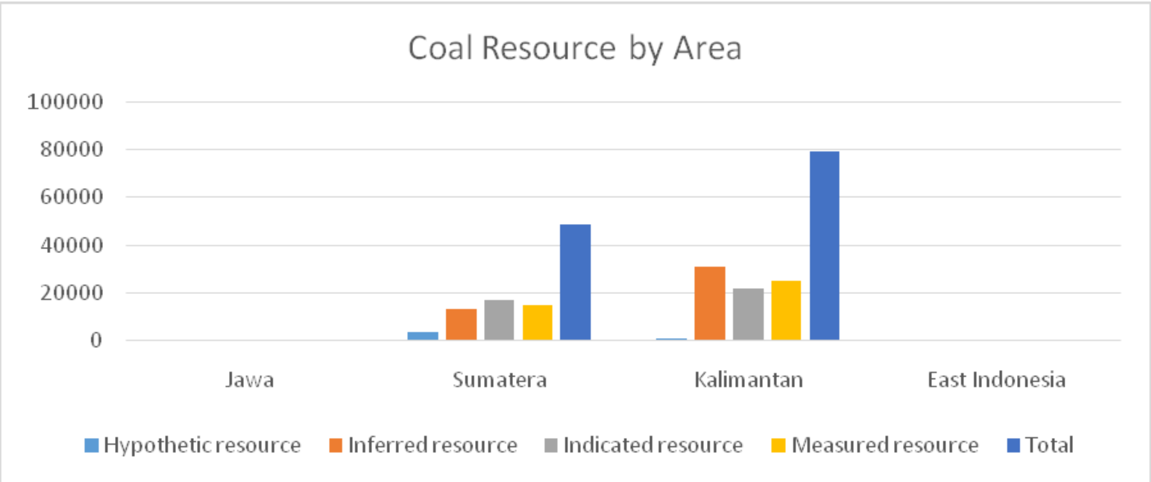
Figure 2.4 Distribution of coal reserve in percentage in Indonesia

Indonesia’s coal resource and reserves amount to some 128.06 and 28.45 billion tons respectively. By area, the larger portion is found in Sumatra and Kalimantan.

Table 2.5. Coal resource and reserves in Indonesia (million ton)

Location		Resource (million ton)					Reserve (million ton)		
		Hypothetic	Inferred	Indicated	Measures	Total	Probable	Proved	Total
JAWA	Banten	5.47	38.98	28.45	25.10	98.00	0.00	0.00	0.00
	C. Jawa	0.00	0.82	0.00	0.00	0.82	0.00	0.00	0.00
	E. Jawa	0.00	0.08	0.00	0.00	0.08	0.00	0.00	0.00
SUMATERA	Aceh	0.00	423.65	163.69	662.93	1250.27	95.30	321.38	416.68
	N. Sumatera	0.00	7.00	1.84	25.75	34.59	0.00	0.00	0.00
	Riau	3.86	209.85	587.82	689.28	1490.81	85.57	523.32	608.88
	W. Sumatera	19.90	304.25	278.78	347.38	950.30	1.67	196.17	197.84
	Jambi	129.16	1216.54	896.04	1038.02	3279.77	314.09	351.62	665.71
	Bengkulu	0.00	117.33	171.74	126.48	415.54	16.20	62.92	79.12
	S. Sumatera	3290.98	10859.38	14826.24	12020.27	40996.88	5557.53	5509.45	11066.98
	Lampung	0.00	122.96	8.21	4.47	135.63	11.74	0.00	11.74
KALIMANTAN	W. Kalimantan	2.26	477.69	6.85	4.70	491.50	0.00	0.00	0.00
	C. Kalimantan	22.54	11299.92	3806.64	2849.22	17977.32	910.76	1090.57	2001.33
	S. Kalimantan	0.00	4739.10	4402.79	5893.65	15035.53	1308.49	3961.76	5270.25
	E. Kalimantan	909.95	13680.45	13049.18	15401.10	43040.68	2760.01	4434.93	7194.94
	N. Kalimantan	25.79	795.83	595.37	1041.20	2458.19	423.34	520.36	943.70
SULAWESI	W. Sulawesi	8.13	15.13	0.78	0.16	24.20	0.00	0.00	0.00
	S. Sulawesi	5.16	48.81	128.90	53.09	235.96	0.06	0.06	0.12
	C. Sulawesi	0.52	1.98	0.00	0.00	2.50	0.00	0.00	0.00
MALUKU	N. Maluku	8.22	0.00	0.00	0.00	8.22	0.00	0.00	0.00
PAPUA	W. Papua	93.66	32.82	0.00	0.00	126.48	0.00	0.00	0.00
	Papua	7.20	2.16	0.00	0.00	9.36	0.00	0.00	0.00
		4532.79	**44394.72**	**38952.31**	**40182.81**	**128062.64**	**11484.76**	**16972.53**	**28.457.29**

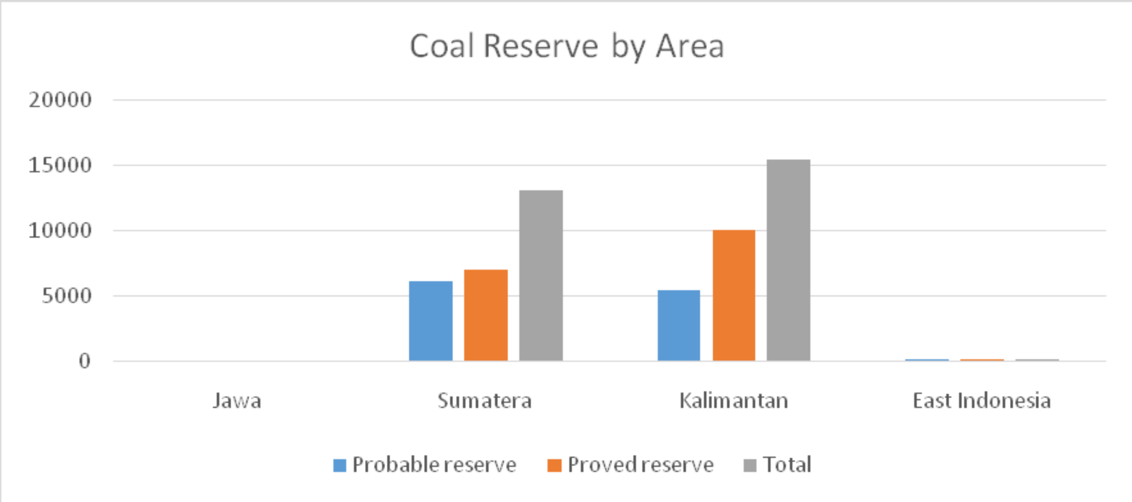
Source: Geological Agency, 2016



Source: Geological Agency, 2016

Figure 2.5 Coal resource by area

Coal resource and reserve by area in Indonesia can be seen in Table 2.5, Figure 2.5 and Figure 2.6. Coal resources are defined as total quantities of coal available in a given area, while coal reserves mean the quantities of coal recoverable feasibly in economic terms.



Source: Geological Agency, 2016

Figure 2.6 Coal reserves by area

2.3. PATTERN OF COAL CONSUMPTION

More than 80% of coal produced in Indonesia is exported and the rest is consumed domestically. The amount of coal production, export and domestic consumption is shown in Table 2.6.

Table 2.6. Indonesian coal production, export and consumption

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Production (in million tons)	240	254	275	353	412	474	458	461	419[1]
Export (in million tons)	191	198	210	287	345	402	382	366	333[1]
Domestic (in million tons)	49	56	65	66	67	72	76	87	86[1]

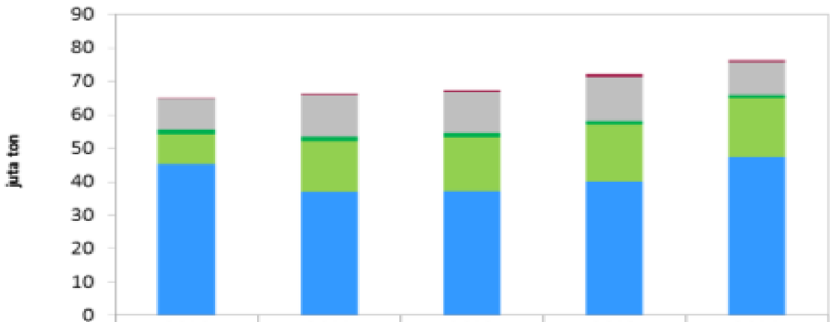
[1] Government target
Sources: Indonesian Coal Mining Association (APBI) & MOEMR 2016

Under Presidential Regulation No. 2 Year 2015 concerning the National Medium Term Development Plan 2015 – 2019 enforcing the security of domestic coal demand, mines are allowed to export coal only when domestic demands are met. The Indonesian government determines the quantity of domestic coal demand and also sets the minimum ratio percentage of domestic coal marketing (supply) to coal output from the mines. Some of the mines are producing coals having qualities suitable for the domestic market while other mining productions are more fitting for exports. For this reason, in order to fulfill the domestic market obligation (DMO), mines are allowed quarterly transfers among them.

As shown in Table 2.6, domestic consumption amounted to 67.25 million tons in 2012 and increased to 74.32 million tons in 2013. Of the supply in 2012, coal-fired power plants received 54.69 million tons, accounting for the largest portion of 81%, followed by cement, textile and fertilizer which, when combined, received 12.23 million tons or 18.1%, and foundry/metallurgy around 330,000 tons or 0.49%. Among the coal-fired power plants, the largest is PLN (55.29%). IPP also claims a slice as big as 23.72%. Among others, cement accounts for 12.49%, followed by textile/textile manufacturing at 2.87%.

The compositions changed slightly in 2013, topped by coal-fired power plants with 60.49 million tons or 81%, followed by cement and textile/fertilizer with 13.09 million tons or 17.61%, and foundry/metallurgy 740,000 tons or 1%. Among the coal-fired power plants, PLN remains the largest consumer at 49.29 million tons or 66.32% of the coal consumed.

In 2013 coal output was projected at 366.04 million tons and the minimum domestic coal marketing ratio is set at 20.30%. The minimum domestic coal marketing ratio has been set at 25% so far. But since output grew more than planned and since domestic consumption did not increase so much as projected, the ratio of domestic supplies to total coal output has been on the decline. The pattern of coal consumption for 2010-2014 in Indonesia can be seen in Figure 2.7.

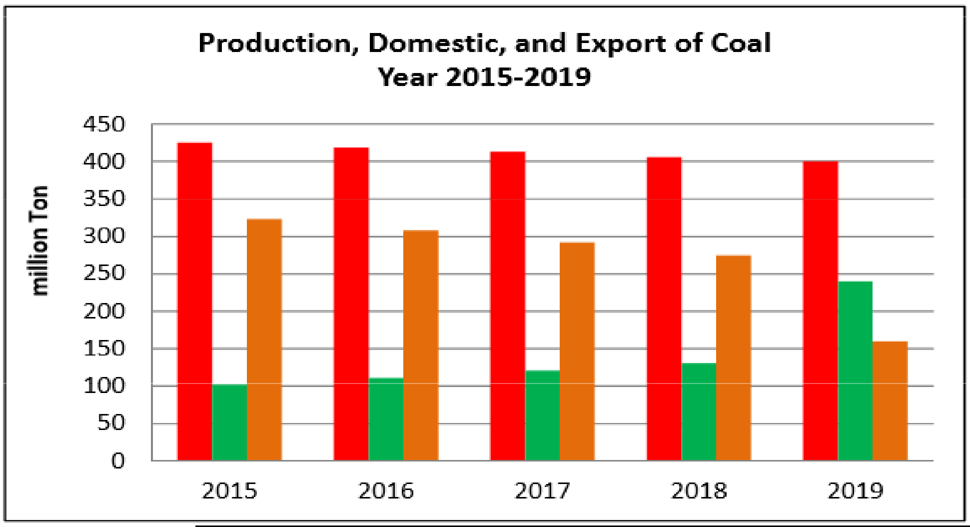


	2010	2011	2012	2013	2014
Total	65,0	66,2	67,3	72,1	76,2
Metalurgi	0,3	0,3	0,3	0,7	0,3
Semen, Pupuk, Pulp & Tekstil	9,2	12,4	12,2	13,1	9,9
Non PLN & IPP	1,3	1,5	1,6	1,4	1,0
IPP	9,1	15,0	16,0	16,9	17,6
PLN	45,1	37,0	37,2	40,0	47,4

Source: MOEMR Strategic Plan 2015

Figure 2.7. Pattern of coal consumption in Indonesia

Under the era of the new government headed by President Jokowi from 2015 onward the policy to increase DMO was introduced by targeting the 35,000 MW target policy for electricity to be achieved by 2025 through the issue of Presidential Regulation No. 4 Year 2016 on DMO. Subsequently it would be expected that the rise in increase in air pollution would be expected to increase including the rise in mercury emissions in the upcoming years unless certain measures are made to curb the rate of increase in air pollutant emissions.



	2015	2016	2017	2018	2019
Production (mton)	425	419	413	406	400
Domestic (mton)	102	111	121	131	240
Export (mton)	323	308	292	275	160

Figure 2.8 National Medium Term Development Plan 2015 – 2019 for Domestic Market Obligation (DMO)

Figure 2.8 shows that the percentage of domestic market obligation increase by year 2015 is 24% and will reach as high as 60% by 2019.

3. POWER GENERATION SECTOR IN INDONESIA

3.1. ELECTRICITY OVERVIEW

Indonesia has two specific plans related to power development, the nation's General Electricity Plan (RUKN) and the Electricity Utility Supply Service Plan (RUPTL). RUKN represents the nation's overall electricity development plan while RUPTL represents PLN's annual electricity supply plan. At present the revised 2008 RUKN is pending approval by parliament based on directives of the amended 2009 Electricity Act. Currently under preparation is the newly revised RUKN of 2015-2040 containing provisions on electricity tariff increase. The latest version of RUPTL (2017~2026) published in February 2017 will reflect the revised 2015 RUKN. Figure 3.1 below illustrates the stages of implementation as related to the policy on energy in Indonesia

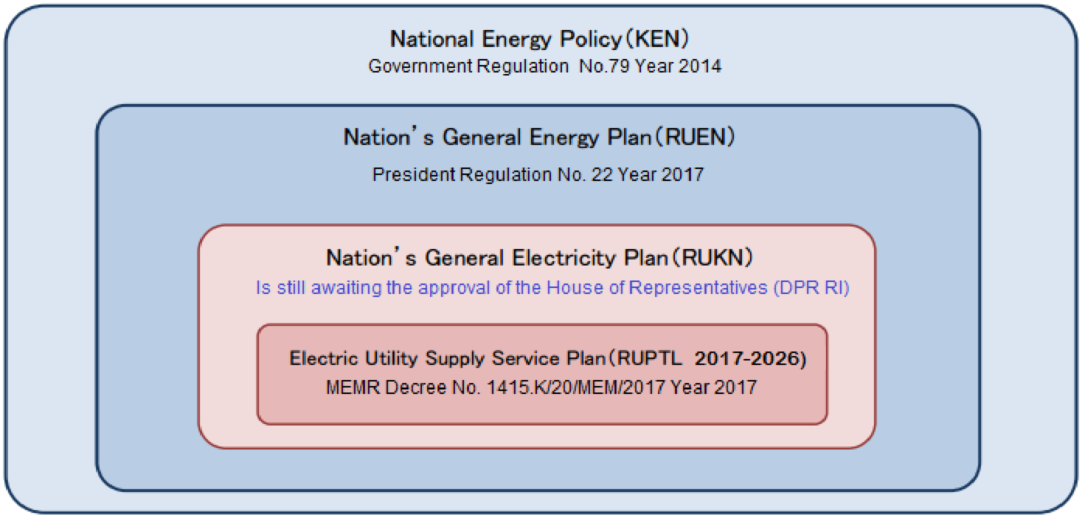


Figure 3.1 Energy policy scheme in Indonesia

As projected under the 2016-2025 Electricity Supply Business Plan, the annual electricity demand in Indonesia is forecasted to grow 8.6% between 2016–2025. The current capacity of the electrical infrastructure will have to be expanded to achieve economic growth above 6% annually. Equally important, the expansion of the electrical network will be necessary to achieve the electrification ratio currently at 91.16 % to 97.35% in 2019 providing electricity access to all Indonesian households.

The Government of Indonesia launched several power development programs, mainly the Fast Track Program Stage I, Fast Track Program Stage II under the previous Yudhoyono government and the 35,000 megawatt power development program which in the end will be dominated by coal fired power plant (CFPP) by more than 50%. Increasing newly installed CFPP will expectedly increase the existing coal consumption of 77 million tons under current conditions to around 111 million tons by 2019. Energy mix on electricity based on draft RUKN 2015-2034 is shown in Figure 3.2.

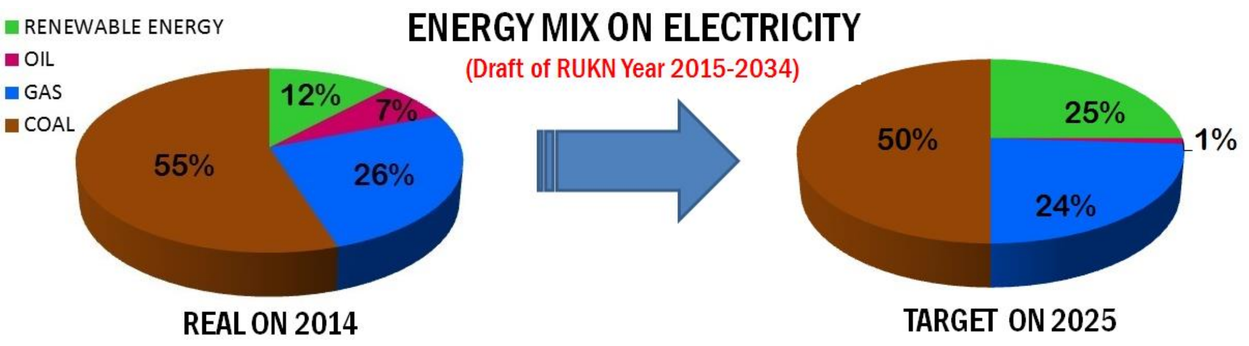


Figure 3.2 Energy mix on electricity based on draft RUKN 2015-2034

Based on the 2017 RUPTL (2017-2026), power demand in Indonesia will increase from 200 TWh to 528 TWh by 2026 increasing the rate of power demand by 8.7% annually, see Figure 3.3

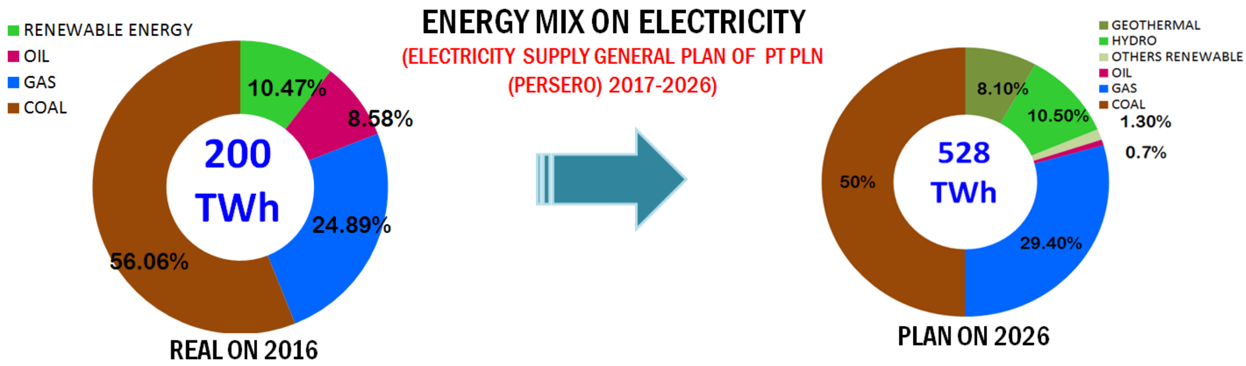


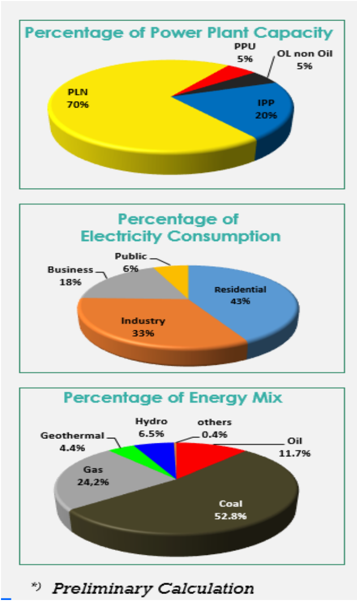
Figure 3.3 Energy mix on electricity based on Electricity Supply General Plan (RUPTL) 2017-2026

In meeting this demand, the nation will requires an additional power generation of 528 TWh by 2026. Hence, the government has embarked on a policy in accelerating the development of power supply, power transmission and distribution network including for coal-fired power plant. Hence the government encourages foreign capital investment and invites the involvement of the private sector.

In addition, since Indonesia's energy consumption per GDP unit is five times more than Japan and Korea promoting efficient energy use (energy conservation) will be a matter of vital importance. The challenges are in applying energy pricing policy mainly as related to electricity tariff increase. In promoting energy conservation, it is essential that the future youth generation be involved through educational and public relation means.

Currently the installed capacity just covers about 91.16**%** household, lower than Singapore (100,0%), Brunei (99,7%), Thailand (99,3%), Malaysia (99,0%), and Vietnam (98,0%). Within the next 5 years, demand for electricity will rise up to around 8,7% per year in average, with a target electrification ratio of 97,35% by end of 2019. Hence the reason for President Jokowi's ambitious program to fulfill the electricity demand growth and to achieve the electrification ratio target through adding new additional capacity to 35,000 MW (excluding the 7.4 GW on-going project) for the period 2015-2019.

The overview of Indonesia's electricity condition can be seen in Figure 3.4.



Installed Capacity (2016)
59,656 MW
(PLN: 41,049 mw, IPP: 13,781 MW, PPU: 2,434 MW, IO Non Oil: 2,392 MW)

Electricity Consumption (2016)*	Electricity Production (2016)*
247 TWh	290 TWh

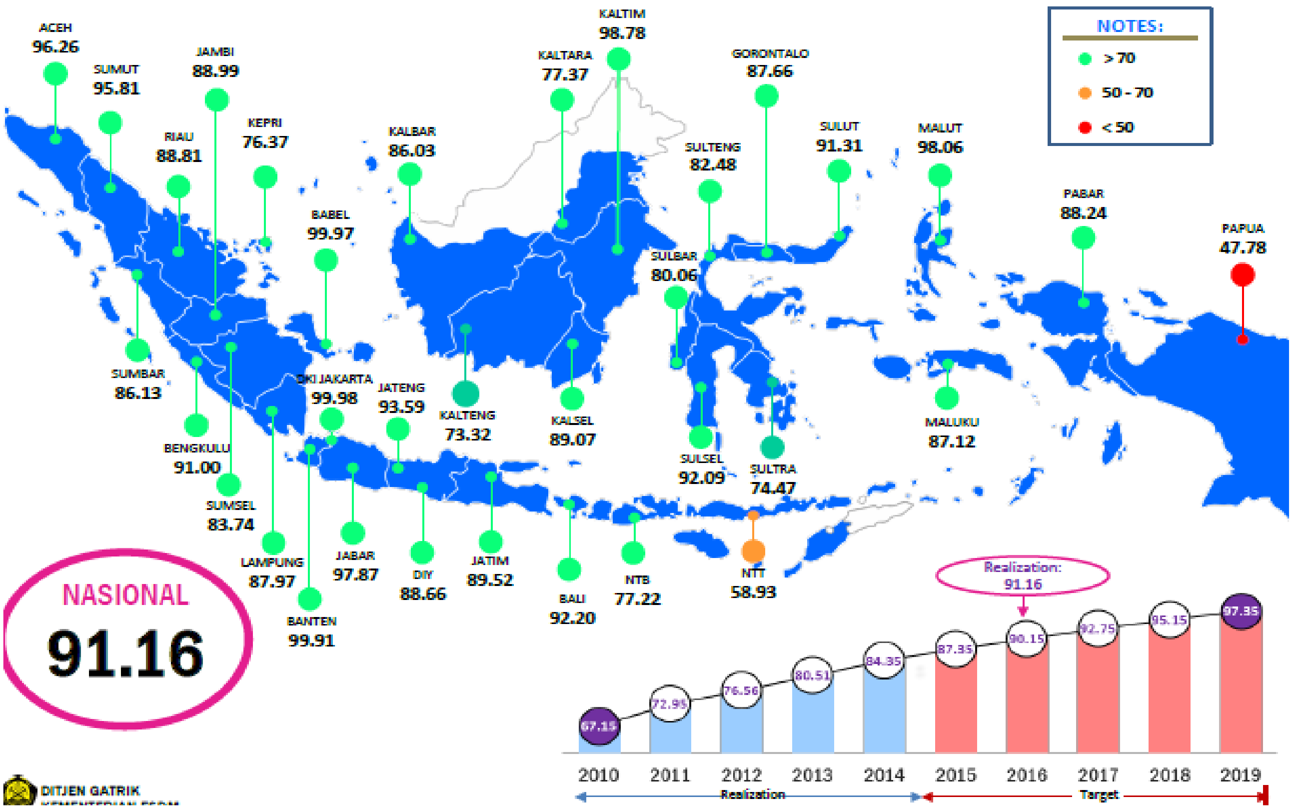
Electricity Ratio (2016)
91.16%

Kwh Per Capita (2016)
910.2 kWh/capita

Source: DGE, MOEMR 2017

Figure 3.4 Overview of Indonesia's electricity condition

From Figure 3.4, the installed generation capacity of electricity in Indonesia as of 2016 is 59,656 MW. This installed capacity is not sufficient enough to supply electricity to the community. The electricity ratio of Indonesia is 91.16% as shown in Figure 3.5.



Source: DGE, MOEMR 2017

Figure 3.5 Electricity ratio in Indonesia

State-run Electric Utility (PLN)

In Indonesia electricity production is undertaken by PLN, a listed company of which shares are possessed 100% by the national government, its subsidiaries and IPPs (independent power producers) while the transmission/distribution sector is monopolized by PLN. Table 3.1 depicts PLN's business operation system for the nation.

Table 3.1 PLN's business operation system

	Java Bali	Sumatra	Others
Power production	PLN's power plants Indonesia Power Java Bali Power Generation IPPs	North Sumatra Power Generation BU South Sumatra Power Generation BU IPPs	9 local branch offices, and PLN Batam PLN Tarakan
Transmission/substations	Java Bali Transmission/Load Dispatching Center (P3B Java Bali)	Sumatra Transmission/Load Dispatching Center (P3B Sumatra)	
Load dispatching			
Distribution/marketing	5 distribution offices	7 local branch offices	

IPPs (Independent Power Producers)

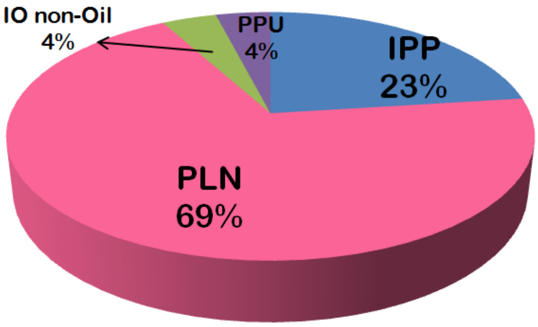
During the second half of the 1980s it became difficult for PLN to cope with the sharply growing electricity demand single-handedly andintroduced private capital into electric utility business (IPP participation) through 1992 onward. At present, IPPs account for 22% of Indonesia's installed capacity

By regulation, generated electricity output by IPPs should be totally purchased by PLN and private operators engaged in IPP operations when selling their generated output to PLN are required in principle to do so through competitive biddings. However, in certain cases such as renewables-based power production (micro-hydro, geothermal, biomass, wind, photovoltaic), surplus power and supplies to electricity-stricken areas, IPPs can directly be nominated without bidding.

In February 2014, it is expected that 50% of the power construction budget would be funded by private capital. On certain special cases, rich-experienced IPPs, when installing additional capacity within the same site (being more efficient and less environmental-laden capacity if the new plant is identical to conventional unit in size), are allowed negotiated contracts without bidding.

Currently PLN's contribution towards total electricity produced is 69% as compared to IPP 23% and PPU 4% and non oil 4%.

Shares in installed capacity by producer types can be seen in Figure 3.6.



Source : DGE, MOEMR 2017

Figure 3.6 Shares in installed capacities by producer types

In achieving sustainable growth in Indonesia, dealing with energy and power development is as important as dealing with other infrastructure projects, such as roads, seaports and airports. Today, in Indonesia, where energy shifts are already under way from reserve-depleting oil to coal and gas, it is predicted that, by 2020, the country should have no choice but to depend on coal in covering most of its energy needs. At the same time, environmental pollution should remain unchanged as a major problem confronting the country.

For the government, maintaining a stable electricity supply for sustaining its economic growth will a challenge of critical significance, therefore its energy policy will consist of a stepped-up energy diversification, more efficient energy use, energy pricing policy while meeting environmental sound practices in its energy use. In meeting its energy supply-demand issue and environmental considerations, Indonesia, given its vast territories, will need to embark on a numerous number of approach. Among its main consideration is the area coverage issue between the Java and non-Java islands in which the former is responsible for 70% of the country's total energy consumption covering less than one tenth of the entire land coverage of the nation. For instance, within the non-Java islands where electricity demand remains low, rural electrification is counted as the top priority. Also, measures are required to help increase the use of renewable energy sources specifically fitting to certain given areas.

In addition, since Indonesia's energy consumption per GDP unit is five times more than Japan and Korea, promoting efficient energy use (energy conservation) becomes a matter of vital importance. In particular, the most difficult issue confronted is on energy pricing policy which involves electricity tariff increases. As for energy conservation, it is essential to endeavor for enlightening the next-generation young through educational/ public relations efforts.

3.2. COAL FIRED POWER PLANT IN INDONESIA

As mentioned above the Indonesian electrification ratio (ER) is 91,16%. Electricity generation is mainly dominated by coal-fired power plant (CFPP) at around 55%. In that percentage of electricity generation, Indonesia has 41 CFPP which are interconnected with a 21,903 MW total installed capacity, 19 CFPP using others schemes, i.e. *private power utility* (PPU) which has a 1,750 MW total installed capacity as shown in Figure 3.4.

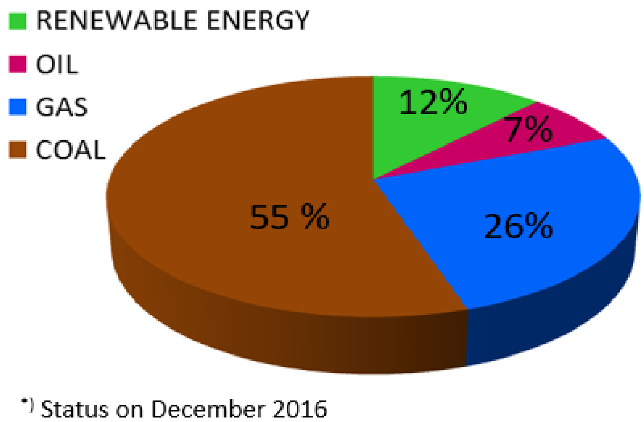


Figure 3.7 Energy mix on electricity production in 2017

The location of CFPP in Indonesia can be seen in Figure 3.8.

Source: DGE, MOEMR 2017

Figure 3.8 Installed capacity existing CFPP in Indonesia

3.3. ELECTRICITY SUPPLY DEVELOPMENT

Indonesian energy demand is expected to increase strongly driven by rising economic and social development and a growing population. Despite the focus on energy efficiency measures, KEN's initial projections for total energy demand by 2025 were revised in December 2015 from 380 MTOE to 400 MTOE (excluding traditional biomass). Proposed targets on how Indonesia can meet the rising energy demand while sustaining the country's environmental outlook are notable. Dewan Energi Nasional or National Energy Committee (DEN) plans to transform the energy mix by raising the share of new and renewable energy (NRE) sources to 23 per cent by 2025 (Figure 3.9.). In order to meet the country's targeted energy mix for 2025, natural gas and coal use must increase two-fold and renewable energy by nine-fold. The new policy aims to complete the electrification of the country by 2019 as a challenge considering Indonesia's diverse geography. The target is to raise power capacity to 137 Giga Watts (GW) by 2025 and 430 GW by 2050, compared with 55.5 GW by the end of 2015. These targets are the point of reference for setting the electricity sector policy and both Ministry of Energy and Mineral Resources (MOEMR) and Perusahaan Listrik Negara (PLN), have adopted compatible targets in their respective power development plans.

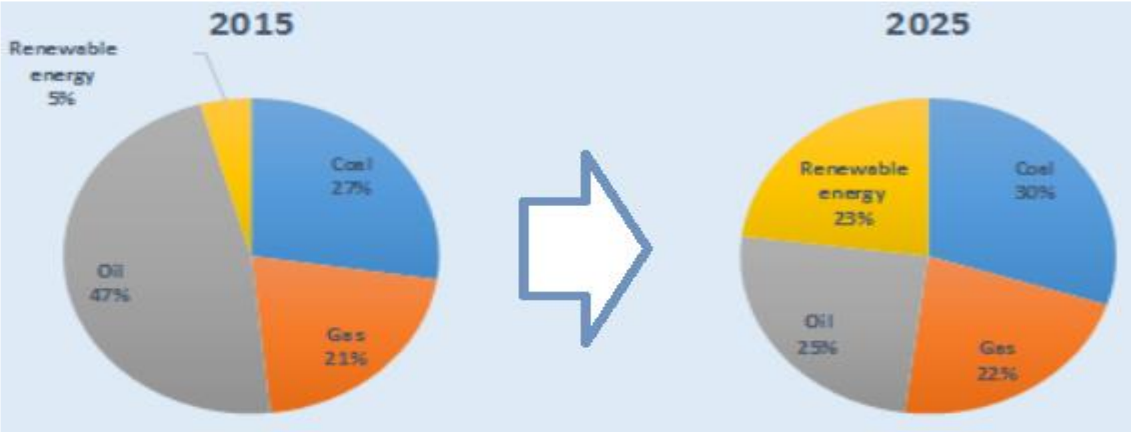


Figure 3.9 Energy mix in 2015 (actual) and 2025 (KEN)

At present 88 per cent of Indonesia's population has access to electricity compared to less than 68 per cent in 2010. Despite this substantive progress, Indonesia still has a low electrification rate compared to countries with similar income levels. Eastern Indonesia lags behind the western area of the country with provinces such as Papua only providing electricity to 43% of its population. Even in grid-connected areas, electricity capacity additions have not kept pace with electricity demand growth, leading to power shortages. Power consumption per capita is also one of the lowest in the region with only a 910 kWh/capita in 2015.[4] Despite the huge call for infrastructure development across the value chain, development has been hindered by PLN's limited capacity and poor financial health, caused by rising subsidies stemming from controls over retail prices for electricity.

A key priority for Indonesia is to increase the country's power generation capacity to complete the electrification of the country and meet increasing electricity consumption. The National Medium-Term Development Plan for the period 2015-2019 (RPJMN 2015-19) projects reaching nearly full electrification by 2019.[5] Furthermore, for the government to maintain its annual economic growth target of up to 6-7%, which it achieved over the past decade, an estimated 35,000 MW will need to be added over the period 2015-2019. To achieve these goals, a fast track programme (FTP) was launched by the government in 2015.

The 35,000 MW program aims to add 35 GW of power capacity from 2015 to 2019, mainly from coal-fired by 56% (20 GW) and natural gas 36%. From the government's perspective, coal is considered the quickest, easiest and cheapest way to provide millions of people with electricity. The abundance of coal resources in the country is the basis for the planning of coal-fired power plants. In addition, generating electricity from coal is considerably cheaper than generating it from either natural gas or oil products.

[4] MOEMR 2016
[5] BPKP 2015

Gas-based electricity is twice as costly as coal-based electricity, while electricity from diesel or fuel oil is four times as expensive.[6]

The 35,000 MW program will require $73 billion of investment in generation, transmission and distribution. Most of the projects are to be developed by IPPs, while PLN will be responsible for the construction of transmission and distribution lines.

The 35,000 MW program does not incorporate projects committed under FTP1 and FTP2 launched during the previous government (2004 – 20014) of which 7,400 MW, mainly coal-fired capacity, were under construction during early 2015 and planned to be online by 2019. In combination, the total program will bring 42,900 MW of generated electricity online from 2015 to 2019 (Figure 3.9). Coal projects dominate the electricity development program with 25,800 MW of capacity to be added over the period.

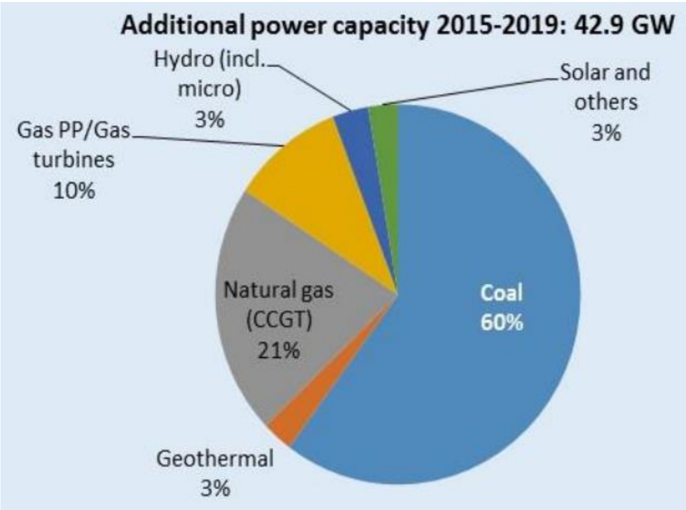


Figure 3.10 Fast track programs: Additional capacity by plant type (2015-2019)

The 35,000 MW program is an ambitious program considering that the total capacity of 42,900 MW taking into account ongoing projects represent 81 percent of Indonesia's installed power capacity by end of 2014. Many of the projects involved are still in their procurement or planning stage[7] although the government has taken steps to shorten approval processes in order to accelerate the realization of the program and facilitate private investment. Supporting regulations include MOEMR Regulation No. 3/2015 on pricing benchmark for the IPP and excess power, Presidential Regulation No. 30/2015 on the implementation of land acquisition for public purposes, as well as Presidential Regulation No. 4/2016 on the acceleration of electrical power infrastructure construction.[8] The government has also set up a "one stop shop" for infrastructure projects in 2015, which will cut the process for obtaining necessary project licenses. In addition, power price reform continues, with PLN implementing monthly power tariffs adjustment for its customers since early 2015. Numerous challenges remain which may

[6] National Bureau of Asian Research (2015). This does not include externalities coming from the burning of coal

[7] As of June 2016, 8.2 GW (22 per cent of the planned 35 GW) were under construction, 9.8 GW (27 per cent) were approaching financial closure, 10.4 GW (28 per cent) were in the procurement stage and 8.1 GW (22 per cent) in the planning phase. PLN (2016)

[8] Indonesian regulation requires that a power plant project be listed on the RUPTL in order to qualify for various incentives, including, in the case of Presidential Regulation No.4/2016, the provision of government guarantees.

hamper the development of the program, in particular land acquisition and growing opposition to coal projects and financial issues.[9]

RUPTL 2017- 2026

The Directorate General of Electricity (DG Electricity) under MOEMR is responsible for developing the General Plan for National Electricity Development (Rencana Umum Ketenagalistrikan Nasional, or RUKN) which is the main policy document guiding electricity sector development in Indonesia which PLN uses as the framework for developing its ten-year electricity supply business plan (RUPTL).

The draft RUKN 2015-2034, published in July 2015, is built on three key policy pillars:

1) it maximizes the use of RE to 25% of the electricity generation mix by 2025;
2) it limits the share of coal to 50% by 2025, while that of natural gas (including LNG) is raised to 30% and oil is almost completely phased out; and
3) it encourages energy conservation.[10]

RUPTL 2016-2025 significantly differs from the plan adopted in 2015. Electricity demand growth has been revised slightly downwards thanks to energy conservation measures. It is nevertheless projected to expand at 8.6% per year from 224 TWh in 2016 to 457 TWh in 2025 (PLN's system only: does not include captive power). Additional generation capacity totals 80.5 GW over the period 2016-2025 or an average increase of 8.1 GW per year, compared with 7 GW per year in the previous plan. More capacity will be required to meet the 25% target from renewable energy (RE) sources in the electricity mix by 2025, as stated in the draft RUKN, and almost full electrification of the country. Despite the growing capacity additions, the projected additional coal capacity has been revised downwards (7.3 GW). Several coal projects have been postponed[11], and replaced by gas-fired power plants to meet the 50% limit of coal in the electricity mix in 2025. Nevertheless, coal still dominates additional capacity with 34.8 GW added over the period 2016-2025 (43% of total additional capacity), followed by natural gas (23 GW), hydro (14.5 GW) and geothermal (6 GW).

[9] See for instance Concord Review, 9 August 2016.

[10] PLN's business plan, adopted in June 2016 (RUPTL 2016-2025), incorporates the new policy targets set in RUKN and the 35,000 MW program. The RUPTL is a key document for all investors in the Indonesian power sector as it indicates the projects PLN plans to develop, and those that are available for IPP investors. Direct selection or direct appointments for IPPs to build power plants are based on the RUPTL

[11] Namely, Java Power Plant-11 (1X600 MW), Java Power Plant-12 (2X1,000 MW) and Java Power Plant-13 (2X1,000 MW)

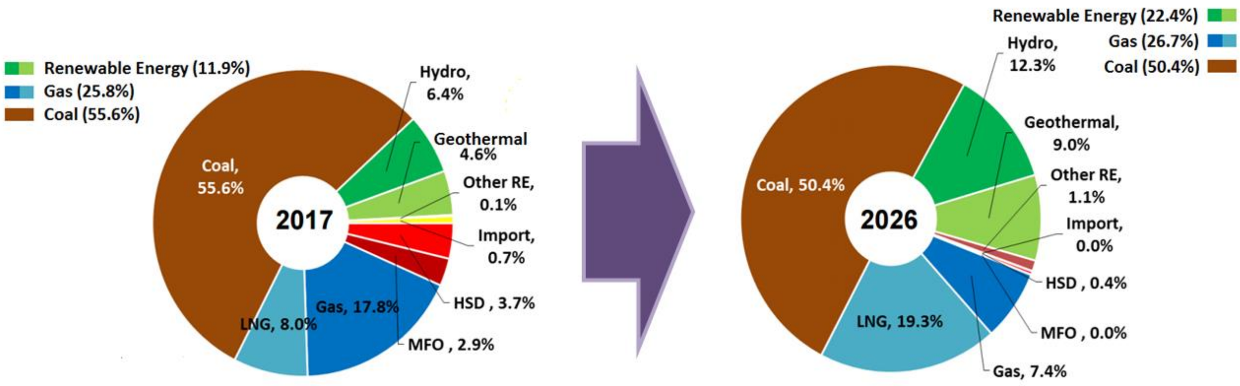


Figure 3.11 Energy mix of power generation development (RUPTL 2017- 2026)

Despite the ambitious target for additional renewable energy (RE) capacity, RUPTL 2017-2027 fails to meet the 25 per cent share of RE in power generation set in the draft RUKN, as the share is raised to just 19 per cent by 2025 (The share of coal in electricity generation rises to 60 per cent by 2019 and will reaches 64% in 2023 before falling to 50% in 2025. It should be mentioned that this decline – based on the fulfillment of the 50% limit set in the draft RUKN - is not consistent with additions to coal capacity after 2020 (6 GW between 2021 and 2025). Alternatively, it would require that many old inefficient coal plants be retired by 2025.

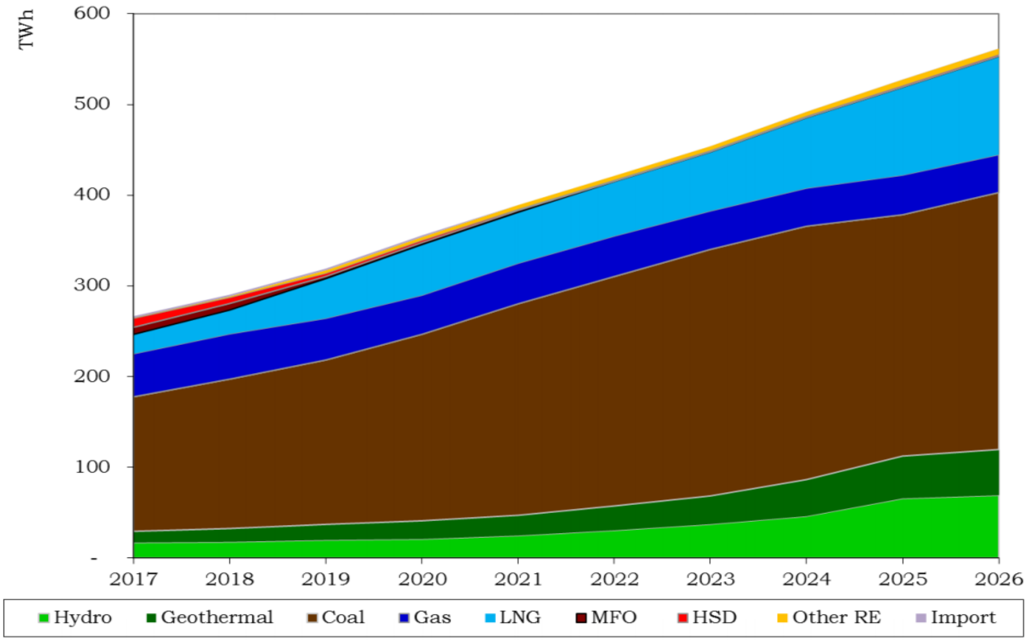


Figure 3.12 Electricity production (TWh) of energy mix

Massive capital investment will be required to develop the electricity system. Total investment needed is estimated at $153.7 billion during the period 2017-2026, of which $120.1 billion is in generation ($78.2 billion expected to come from IPPs and $31.9 billion from PLN), $29.1 billion in transmission and $14.6 billion in distribution. Most large coal-fired power plants are expected to be developed and financed by IPPs.

There are many challenges associated with the implementation of RUPTL 2017-2026. In the past, IPPs were constrained by uncertainties over fuel supply, particularly gas, and sometimes by poor access to the grid. Land acquisition and permission to use were also major issues, as well as lengthy investment permit processes and uncertain regulations. There are also concern raised over the availability of coal for the full lifetime of power plants. Moreover, environmental risks, community demands for environmental issues such as health, waste, and pollution, as well as social issues, may challenge the building of several coal-fired power plants. Growing social and environmental opposition from the Indonesian population has delayed some coal projects. For instance, the development of the 2,000 MW Batang plant in Central Java was delayed by four years, having initially been scheduled to start construction in 2012. It finally reached financial closure in June 2016 and is expected to be commissioned in 2019.

3.4. MERCURY EMISSION REDUCTION BASE ON COAL CONSUMPTION PLAN

The growing reliance on coal will have serious implications for Indonesia's ability to meet its greenhouse gas (GHG) emissions reduction targets and address climate change. Under the Paris Climate Agreement, Indonesia has committed unconditionally to reducing GHG emissions by 29% in 2030 compared to business as usual. The Indonesia government expects coal consumption by the power sector to increase from 85 Mt in 2017 to 99 Mt in 2019 before peaking at 151 Mt in 2024. After 2024, coal consumption by the power sector is expected to decline by 146 Mt in 2025 and increase again to 155 Mt in 2026. This coal consumption plan will be expected to support Indonesia's unconditional commitment of GHG emissions reduction of 29% by 2030 (Figure 3.13).

To reconcile growing coal consumption and its commitment to reduce GHG emissions, Indonesia is increasing the share of RE sources to a minimum of 23% of the energy mix by 2025 and is implementing clean coal technologies (CCT). While the existing coal power fleet uses subcritical technology, most of the planned coal-fired power plants are ultra-supercritical (USC) plants with a unit size of 1,000 MW. Indonesia commissioned its first supercritical (SC) power plants in 2011/2012 (the 660-MW Cirebon and 815-MW Paiton 3 power plants) and intends to commission its first USC power plant in 2019 (Central Java IPP). Altogether, there are 16.5 GW of USC plants at different stages of development in Java, of which 9 GW are expected to come online by 2019. In addition, there are 4 GW of USC plants (with unit size of 600 MW) to be built in Sumatra. Integrated gasification combined cycle (IGCC).

As the Indonesian coal fleet operates at an efficiency well below its design value, improving existing capacity would require a programme of upgrading and retrofitting while, at the same time, closing the smallest, least efficient units. By reducing specific fuel consumption, it would place less pressure on fuel resources and lessen the impacts of the coal supply chain on the environment including the mercury emission

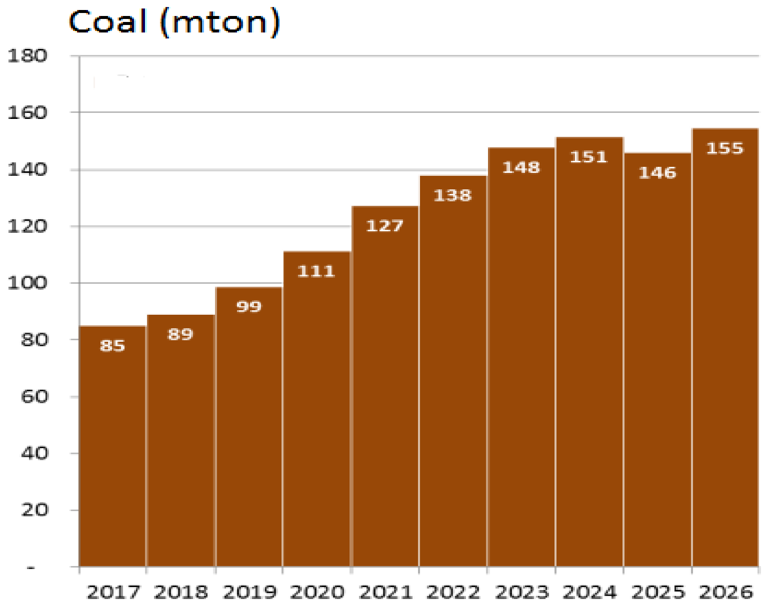


Figure 3.13 Coal consumption plan in consideration of Paris Agreement commitments (energy mix)

In addition, within the energy sector, Indonesia has embarked on a mixed energy use policy. Indonesia has also established the development of clean energy sources as a national policy directive. Collectively, these policies will eventually put Indonesia on the path to de-carbonization. Government Regulation No. 79/2014 on National Energy Policy, set out the ambition to transform, by 2025 and 2050, the primary energy supply mix with shares as follows:

a) new and renewable energy at least 23% in 2025 and at least 31% in 2050;
b) oil should be less than 25% in 2025 and less than 20% in 2050;
c) coal should be minimum 30% in 2025 and minimum 25% in 2050; and
d) gas should be minimum 22% in 2025 and minimum 24% in 2050.

According to RUPTL 2017-2026, Indonesian power sector CO2 emissions are projected to increase from 211 Mt in 2016 to 373 Mt in 2026, primarily due to the growth in coal-fired generation. The growth is however far less than in the BAU scenario which includes less RE and natural gas and brings CO2 emissions to 543 Mt in 2026. The GHGs emission from energy mix of electricity development as GHGs emission reduction (2017-2026) is as shown in Figure 3.14.

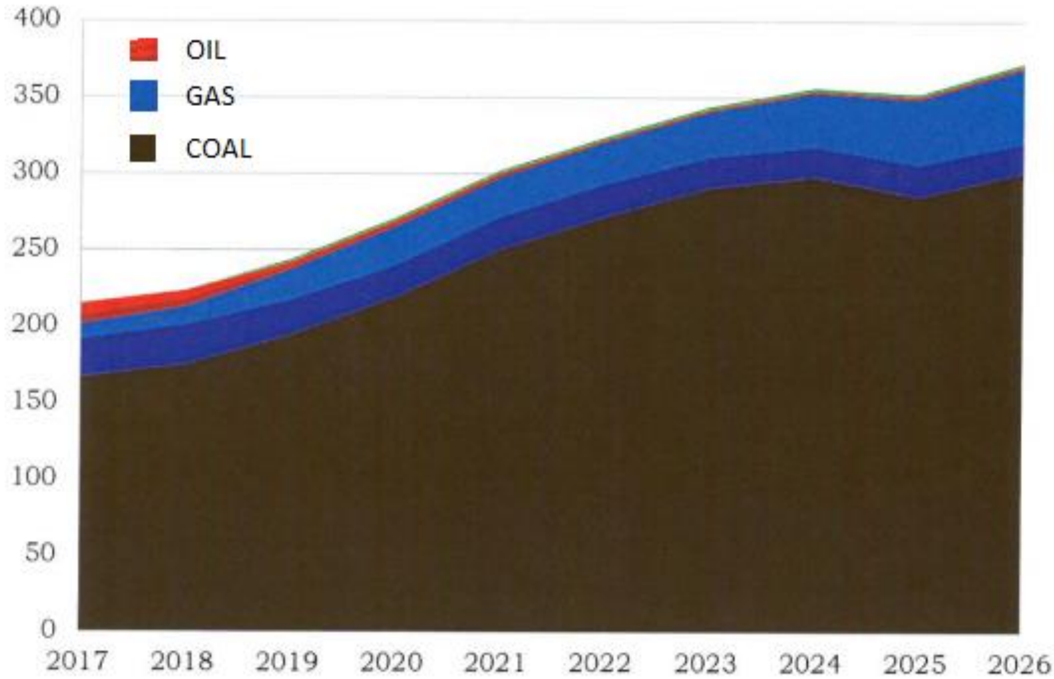


Figure 3.14 GHGs emission from energy mix of electricity development as GHGs emission reduction (2017-2026)

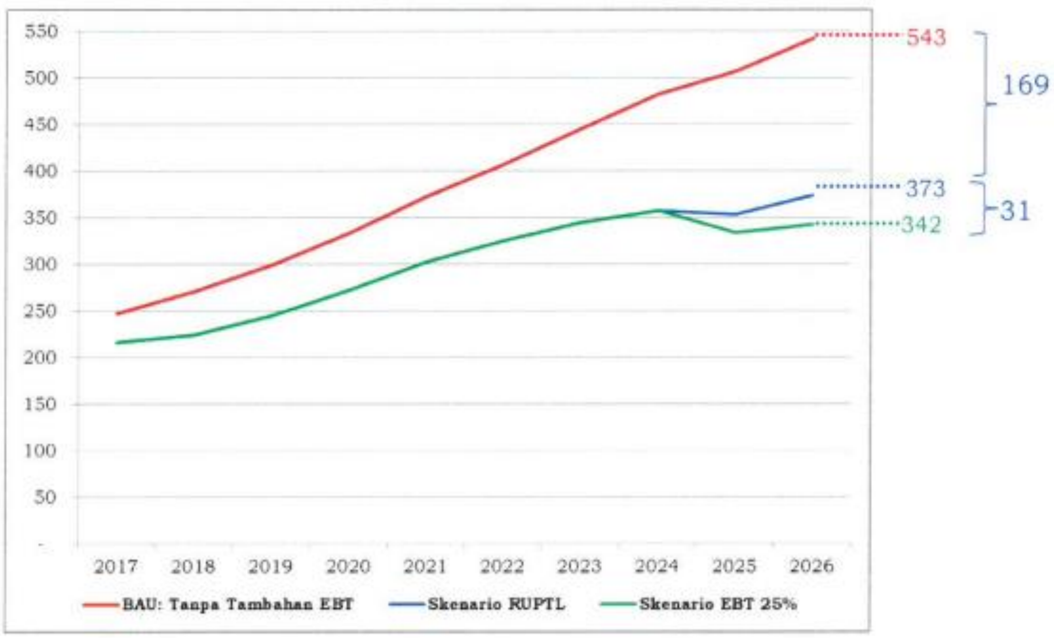


Figure 3.15 GHGs emission reduction (2017-2026) from Business as Usual (BaU)

Figure 3.15 illustrates GHGs emission reduction from the energy mix plan configuration of electricity development as compared to the business as usual (BaU) scheme in electricity development with no additional renewable energy for its power generation (2017-2026) except fossil fuel. Therefore, it is expected the mercury emission will also decrease subsequently according to RUPTL 2017-2026 compared to BaU.

4. PRESENT STUDY

4.1. METHODOLOGY

The methodology adopted for the collection of coal samples, solid residues, flue gases and suspended particulate matter; sample preparation/dissolution; testing and analytical techniques are set by the relevant national and international standards, the details of which are given in Table 4.1.

Table 4.1 The methods adopted for collecting, preparing and analyzing samples

No.	Analysis	Sample	Method Description	PIC
1	Sample preparation	Coal and coal ash	ASTM D.2013 – Standard Practice for Preparing Coal Samples for Analysis	TEKMIRA
2	Chemical analysis	Coal	ASTM D.3172 – Practice for Proximate Analysis of Coal and Coke	TEKMIRA
			ASTM D.3173 – Test Method for Moisture in the Analysis Sample of Coal and Coke	TEKMIRA
			ASTM D.3174 - Test Method for Ash in the Analysis Sample of Coal and Coke	TEKMIRA
			ASTM D.3175 - Test Method for Volatile Moisture in the Analysis Sample of Coal and Coke	TEKMIRA
			ASTM D.3176 - Test Method for Ultimate Analysis Sample of Coal and Coke	TEKMIRA
			ASTM D.5865 – Standard Test Method for Gross Calorific Value of Coal and Coke	TEKMIRA
			ASTM D.4239 - Standard Test Method for Sulfur in Sample of Coal and Coke Using High Temperature Tube Furnace Combustion	TEKMIRA
			ASTM D.5373 - Standard Test Method for Determination of Carbon, Hydrogen and Nitrogen in Analysis Sample of Coal and Coke	TEKMIRA
3	Trace elements analysis (Hg, As and Se)	Coal and coal ash	ASTM D.4208 – 13 Standard Test Method for Total Chlorine in Coal by the Oxygen Bomb Combustion/Ion Selective Electrode Method	TEKMIRA

			ASTM D.4606 – 15 Standard Test Method for Determination of Arsenic (As) and Selenium (Se) in Coal by the Hydride Generation/Atomic Absorption Method	Geoservices
			ASTM D. 6414 – 14 Standard Test Methods for Total Mercury (Hg) in Coal and Coal Combustion Residues by Acid Extraction or Wet Oxidation/ Cold Vapor Atomic Absorption	For FABA analysis: TEKMIRA Limit of detection (LoD) for *TEK*MIRA 0.070 mg/kg Geoservices Limit of detection (LoD) for Geoservices 0.5 mg/kg
4	Inter-laboratory	Coal and coal ash	ISO 13528 - Statistical methods for use in proficiency testing by interlaboratory comparisons	Carsurin Geoservices
5	Flue gas sampling (gaseous and particulate) and analysis	Flue gas & suspended particulate matter	SNI 7117.20:2009 Indonesian Standard Test Method refer to US EPA Method 29-2000	Syslab
			ASTM D6784-2002 Standard test method for elemental, oxidized, particle bound and total mercury in flue gas generated from coal fired stationary sources (Ontario Hydro Method)	Syslab

There are 33 local coal companies available which supplies to all CFPPs in Indonesia. The sample of coals were collected from 47 CFPPs. All samples were analyzed at TEKMIRA. The coal, fly ash and bottom ash were collected from 3 (three) CFPPs where the mercury emission measurement were carried out. The intercalibration was conducted at Carsurin laboratory and Geoservices laboratory where the coal, fly ash and bottom ash from Suralaya CFPPs were used as the samples.

Three CFPPs were selected for the mercury emission measurement based on the several criteria such as the capacity, age of CFPPs, boiler technology and the carbon dioxide emission per MWh electricity produced by CFPP. The selection of the 3 (three) CFPPs evolved through meeting discussion and agreement between MOEMR, MOEF and representatives from all CFPPs in Indonesia. The selected CFPPs are shown in Table 4.2.

Table 4.2 Selected CFPPs for mercury measurement in the emission, fly ash and bottom ash

No	CFPPs	Capacity (MW)	Established	Boiler Technology	APC	Emission factor ton CO_2/ MWh
1	Suralaya Unit#2	400	1986	Subcritical, Pulverized Coal	ESP	1.24
2	Cirebon	695	2012	Supercritical, Pulverize Coal, Tangential	ESP	0.91
3	Indramayu	330	2011	Subcritical, Pulverized Coal	ESP	1.01

All data are supplied by MOEMR

Suralaya CFPP has 7 (seven) boiler units. However, in this study only emissions from unit #2 was measured. Cirebon CFPP has only 1 (one) unit which is equipped with the latest technology (supercritrical). The Cirebon CFPP management plans to build a new unit utilizing ultra supercritical technology. Previously Lontar CFPP was also considered to be selected for mercury emission measurement. Nevertheless, for safety reason due to the unavailability of the lift facility to carry equipments to the sampling hole, the selection for mercury emission measurement was shifted to the Indramayu CFPP. Indramayu CFPP has 3 (three) boiler units with only one stack. Therefore, the mercury emission measurement could reflect to all 3 (three) boiler units. Coal samples were collected from all 3 (three) boilers where each boiler use 5 (five) coal feeders. The coal samples were then mixed with the same ratio before subjected to be analyzed.

The emission measurement for each selected CFPP using 2 (two) methodologies (SNI 7117.20:2009/US EPA Method 29-2000 and ASTM D6784-2002) were carried out in the study. The SNI 7117.20:2009 was used to follow the Indonesian regulation on the emission form stationery source while the ASTM D6784-2002 (Ontario Hydro Method) was also implemented to determine the mercury speciation released.

4.2. COAL ANALYSIS

Indonesian coal deposits are generally in the age of Paleogene to Neogene and are distributed along the islands of Sumatra, Kalimantan, Java, Sulawesi and Irian Jaya. The coal rank varies from lignite to low volatile bituminous. The higher rank coals are affected by local igneous intrusions or more importantly by regional heating due to magmatic activity at relatively shallow depth. Indonesian coal which supplies the CFPP mostly originates from Sumatra and Kalimantan.

The Sumatra coals currently exploited comes from three coal fields mined in the opencast system in South Sumatra, West Sumatra and Bengkulu. The Sumatra coals are generally subbituminous ones with low ash and sulfur contents and seam thickness up to 12 m. There are also a few thick seam of high volatile bituminous. Some bituminous coals are present in close proximity to igneous intrusion. These coals are used primarily for electricity generation and cement manufacture. In the future, coals will be used for iron ore processing. There are small occurences of subbituminous coal in the Bengkulu region which are mined as small scale mining.

The Kalimantan coals deposits are found mostly in the eastern and southern part of Kalimantan. Coal ranks dominated by bituminous and subbituminous have a thicknes of up to 10 m and have extremely low ash and sulfur content. Some of East Kalimantan coals are exported as prime quality steam coal. South Kalimantan coals are used both as export commodity and for local power generation use. Within the northeastern Kalimantan area, coal is characterized by its high sulfur content.

There are 47 coal samples originating from several Indonesia CFPPs which were analyzed by the TEKMIRA laboratory in Bandung. The proximate and ultimate results of the coal samples are almost available for all of them. The proximate and ultimate analysis of coal obtained from the 3 CFPPs where the emission of mercury were carried out are shown in Table 4.3 and Table 4.4.

Table 4.3 Coal Proximate Analysis from 3 CFPPs

Parameter	Suralaya		Cirebon		Indramayu		Unit
	Ad	Ar	Ad	Ar	Ad	Ar	
Total Moisture		27.80		28.68		31.99	Weight %
Inherent Moisture	12.98		14.71		14.03		Weight %
Ash Content	7.02		2.72		6.01		Weight %
Volatile matter	39.46		42.43		40.59		Weight %
Fixed Carbon	40.55		40.15		39.38		Weight %
Total Sulphur	0.82		0.12		0.30		Weight %
Gross Calorific Value	5,753.75		5,584.50				Kcal/Kg
Net Calorific Value		4,367.75		4,670.00		3,975.00	Kcal/Kg

Note: Ar = As Received Basis; Ad = Air Dried Basis;

Table 4.4 Coal Ultimate Analysis from 3 CFPPs

Parameter	Suralaya	Cirebon	Indramayu	Unit
Ultimate Analysis (Air Dried Basis)				
Carbon	60.23	58.94	58.015	Weight %
Hydrogen	5.77	5.72	5.575	Weight %
Nitrogen	0.88	0.80	0.92	Weight %
Oxygen	25.30	31.71	29.18	Weight %
Ash Analysis (Dried Basis)				
Calcium (Ca)	2.16	0.34	7.155	Weight %
Natrium (Na)	0.48	10.84	0.765	Weight %
Sulphur Trioxide (SO3)	3.89	4.41	6.33	Weight %
Trace Elements (Dried Basis)				
Mercury (Hg)	0.047	0.103	0.112	µg/g
Selenium (Se)	0.10	0.10	0.10	µg/g
Arsenic (As)	3.80	1.05	0.90	µg/g
Chlorine (Cl)	0.000	0.025	0.052	%

Range of the analysis result from 47 coal samples is shown in Table 4.3.

Table 4.5 Range of analysis result of coal samples in Indonesia

NO.	PARAMETER	UNIT	RANGE CONCENTRATION	METHOD
A.	**PROXIMATE**			
	Moisture	%, adb	5.37 – 20.98	ASTM D.3173
	Ash	%, adb	1.40 – 18.92	ASTM D.3174
	Volatile Matter	%, adb	35.34 – 43.91	ASTM D.3175
	Fixed Carbon	%, adb	27.21 – 48.89	ASTM D.3172
B.	**ULTIMATE**			
	C	%, adb	44.02 – 68.58	ASTM D.5573
	H	%, adb	4.97 – 6.70	ASTM D.5573
	N	%, adb	0.10 – 1.47	ASTM D.5573
	S	%, adb	0.12 – 1.11	ASTM D.4239
	O	%, adb	14.19 – 38.05	ASTM D.5573
C.	**Calorific Value**			
	GCV	Cal/gr, adb	4122 – 6729	ASTM D.5865
	NCV	Cal/gr, ar	3314 – 6330	ASTM D.5865

The coal quality describes the chemical and physical properties of coal that will influence its potential use. It is important to have an understanding of the properties of coal especially properties that will determine whether such a coal can be commercially used. For proximate analysis, the parameters determined are moisture, ash, volatile matter (VM) and fixed carbon (FC). The high moisture coal is undesirable since it is chemically inert and absorb heat during combustion. Moisture also makes it difficult during handling and transporting coal. It will also lower the calorific value in steam coal and the available carbon in cooking coal. The ash of a coal is the inorganic residue that remains after combustion. It should be noted that the determined ash content is not equivalent to the mineral matter content of the coal. It does, however, represent the bulk of the mineral matter in the coal after losing its volatile components such as CO_2, SO_2 and H_2O which have been driven off from the mineral compounds such as carbonates, sulfides and clay. In steam coal, a high ash content will effectively reduce its calorific value. Volatile matter represents the component of the coal, except moisture, which is liberated at high temperature in the absence of air. This material is mostly composed by the organic fraction of coal and mineral matter in small amounts. For power generation, the volatile matter should be recommended in low concentration but there is no limitation for other facilities such as in the cement industry. The fixed carbon content of coal is that carbon found in the residue remaining after the volatile matter has been liberated. Fixed carbon is not determined directly but calculated as the difference in an air-dried coal between the total percentages of the other components, i.e moisture, ash and volatile matter.

Ultimate analysis consists of the determination of arbon, hydrogen, nitrogen, oxygen andsSulfur. Carbon and hydrogen are liberated as CO_2 and H_2O when the coal is burned and are most easily determined together. The nitrogen content of coal is significant particularly in relation to atmospheric pollution. During coal combustion, nitrogen helps to form oxides which may be released as flue gases and thereby pollute the atmosphere. Consequently, coals that are low in nitrogen are preferred by industry.

Coals should not as a rule have nitrogen content of more than 1.5–2.0% (d.a.f.) because of the NO_x emissions. As in the case of nitrogen, the sulfur content of coals presents problems with utilization and resultant pollution. Sulfur causes corrosion and fouling of boiler tubes and atmospheric pollution when released in flue gases. In the ultimate analysis of the coal, only the total sulfur content is determined, however, in many instances, the relative amount of sulfur in each form is required. This is carried out as a separate analysis. The total sulfur content in steam coals used for electricity generation should not exceed 0.8–1.0% (air-dried); the maximum value will depend upon local emission regulations. In the cement industry, a total sulfur content of up to 2.0% (air-dried) is acceptable, but a maximum of 0.8% (air-dried) is required in coking coals since higher values affect the quality of steel.

Another analysis which are determined are chlorine and trace elements (arsenic, selenium and mercury). Coals contain diverse amounts of trace elements in the overall composition.

Table 4.6 Mercury and chlorine content in coal sample

NO	SAMPLE CODE	Hg (µg/kg)	Cl (% adb)
1	PT. General Energi Bali	110.9	0.023
2	PT. Bukit Asam Persero. Tbk	155.6	0.012
3	PT. Indonesia Power up Suralaya	176	0.015
4	PT. Jawa Power	63.6	0.024
5	PT. Puncak Jaya Power	60.7	0.003
6	PT. PJB up Paiton	66.8	0.022
7	PLTU Asam-Asam	62.4	0.025
8	PT. Merak Energi Indonesia	43.8	0.02
9	Riau Tenayan 2 x 110 MW	101.2	0.015
10	PT. PLN (Persero) Pembngkit Tanjung Jati (3 &4)	< 0.070	0.026
11	PT. PLN (Persero) Pembngkit Tanjung Jati (1&2)	< 0.070	0.023
12	PLTU Tidore 2 x 7 MW	57.5	0.027
13	PLTU Jeranjang	77.6	0.174
14	PLTU Ketapang	63.4	0.007
15	PLTU Sumsel	< 0.070	0.008
16	PT Paiton Energy (Adaro)	15	0.009
17	PT Paiton Energy (Kideco)	134.1	0.005
18	PLTU Tanjung Balai Karimun	59.1	0.006
19	PLTU Air Anyir	134	0.034
20	PLTU Banjar Sari	62.49	0.006
21	PLTU Galang Batang	92.63	0.045
22	PLTU Teluk Balikpapan	86.71	0.008
23	PLTU Sektor Pembangkit Nagan Raya	102	0.041
24	PLTU Labuan Angin	57.91	0.01
25	PLTU Bukit Asam	23.47	0.015
26	PLTU Indramayu (1-3)	58.72	0.015
27	PLTU Nagan Raya	81.54	0.014
28	PLTU Pacitan	65.98	0.026
29	PLTU Tanjung Awar-Awar	43.11	0.057

30	PLTU Baturaja (PT. Bakti Nugraha Yuda Energi)	107	0.006
31	PLTU Ombilin	21.04	0.003
32	PLTU Tarahan	58.18	0.003
33	PLTU Ropa	53.94	0.012
34	PLTU Lontar Unit 2	26.34	0.021
35	PLTU Teluk Sirih	132.72	0.002
36	PLTU DSSP Power Sumsel 5	19.44	0.002
37	PLTU Ketapang Kalbar Unit 1 & 2	49.34	0.007
38	PLTU Pangkalan Susu Unit 1 & 2	< 0.070	0.014
39	PLTU Sanggau Unit 1 & 2 (Sektor Pembangkitan Kapuas)	< 0.070	0.004
40	PLTU Molotabu	< 0.070	0.005
41	PLTU Tenayan Unit UBJOM	25.19	0.001
42	PLTU Rembang (LRC)	52.5	0.005
43	PLTU Rembang (MRC)	10.81	0.004
44	PLTU Barru	< 0.070	0.005
45	PLTU TJK Power	151	N.A.
46	PLTU 2 NTT Bolok Unit 2	50.75	N.A.
47	PLTU Cilacap (Arutmin)	0.72	N.A.

Data of mercury content in the coal will be used as an input factor for the mercury emission factor calculation in this study.

4.3. MERCURY EMISSION MEASUREMENT

Result of total mercury measurement using 2 (two) methods: SNI 7117.20:2009 / US EPA 29-2000 and ASTM D6784-2002 / Ontario Hydro methods from those 3 CFPPs are shown in Table 4.7 below.

Table 4.7 Emission measurement results

Method	**ASTM D6784 / Ontario Hydro**	**US EPA 29**
	Hg total (µg/m^3)	Hg total (µg/m^3)
Suralaya CFPP	1.07	1.00
Cirebon CFPP	0.60	0.57
Indramayu CFPP	3.02	2.93

The result shows that mercury emitted from the Suralaya CFPP is relatively low although the power plant was built in 1986. This low mercury emission may be due to the regular maintenance of the power plant and also from the low mercury content in the coal supplied to the power plant (see Table 4.6).

The Cirebon CFPP emitted the lowest concentration of mercury in the flue gas in this report. This can be expected since the power plant is still new (built in 2012) and supported with supercritical boiler technology. From the 3 (three) power plants measured, Indramayu CFPP emitted the highest concentration of mercury in the flue gas. The power plant is considered as new since it was built in 2011. However, it still uses subcritical boiler technology and the low-quality boiler may affect the high concentration of mercury in the flue gas compared to the other two plants.

Nevertheless, those emission are below the EU (Germany) regulation standard of 30 µg/m^3 mercury releases from CFPPs flue gas.

4.4. MERCURY CONCENTRATION IN FLY ASH AND BOTTOM ASH

Measurement of the mercury concentration in fly ash and bottom ash from Suralaya CFPP, Cirebon CFPP and Indramayu CFPP has been carried out by TEKMIRA. Samples of each fly ash and bottom ash were collected two times. The results are presented in Table 4.8 and Table 4.9.

Table 4.8 Fly ash sample analysis report from TEKMIRA laboratory

Parameter	Suralaya	Cirebon	Indramayu	Unit
Ultimate Analysis (Air Dried Basis)				
Carbon	3.58	0.22	0.695	Weight %
Ash Analysis (Dried Basis)				
Calcium (Ca)	2.84	0.27	8.375	Weight %
Natrium (Na)	0.69	9.96	0.735	Weight %
Sulphur Trioxide (SO3)	0.61	0.40	0.53	Weight %
Trace Elements (Dried Basis)				
Mercury (Hg)	<0.070	<0.070	<0.070	µg/g
Chlorine (Cl)	-	0.021	0.033	%

Table 4.9 Bottom ash analysis report from TEKMIRA laboratory

Parameter	Suralaya	Cirebon	Indramayu	Unit
Ultimate Analysis (Air Dried Basis)				
Carbon	2.55	0.22	1.225	Weight %
Ash Analysis (Dried Basis)				
Calcium (Ca)	2.40	0.265	4.895	Weight %
Natrium (Na)	0.79	9.96	0.58	Weight %
Sulphur Trioxide (SO3)	0.37	0.395	0.49	Weight %
Trace Elements (Dried Basis)				
Mercury (Hg)	<0.070	<0.070	<0.070	µg/g
Chlorine (Cl)	-	0.0205	0.032	%

Results show that the mercury content in fly ash and bottom ash from Suralaya CFPP, Cirebon CFPP and Indramayu CFPP are below limit detection of TEKMIRA equipment (< 0.07 µg/g).

4.5. FATE OF MERCURY IN COAL-FIRED POWER PLANTS

The fate of mercury in CFPP is obtained based on the mass balance of the onsite test results. The mass balance is calculated based current mercury analysis results and CFPP operation of coal consumption, fly ash and bottom ash generated. The calculation of mercury in fly ash and bottom ash based on assumption that the concentration of mercury is 0.070 µg/g. The result is presented in Table 4.9.

Table 4.10 Fate of Mercury in 3 CFPPs

Fate of Mercury	Suralaya		Cirebon		Indramayu	
	kg/year	%	kg/year	%	kg/year	%
Mercury input in coal	62.69	100.00	254.59	100.00	291.51	100.00
Mercury output in emission	9.15	14.60	20.53	8.06	57.31	19.66
Mercury output in fly ash	3.37	5.38	3.75	1.47	4.77	1.64
Mercury output in bottom ash	0.78	1.25	0.66	0.26	0.19	0.07

The fate of mercury from measurement at 3 CFPPs did not achieve its mass balance. This is due to several factors such as minimum number of samples compared to the huge coal consumption and also fly ash, bottom ash and emission generated. Human error during the sampling and/or analysis may also have contributed to the result although the team already tried to minimize the error by following the standard conducted by certified laboratory in Indonesia. In addition, utilization of Method 30B for the mercury emission is suggested to be conducted for future measurement. In this study the later method was not employed due to the unavailable of laboratory holding national certification for Method 30B.

4.6. INTER-CALIBRATION OF ANALYSIS ON SELECTED SAMPLES

Only sample collected from the Suralaya CFPP is subject to be analyzed for inter-calibration purpose. Geoservices laboratory and Carsurin laboratory were selected as the inter-calibration laboratories. Complete result from both laboratories is presented below.

Table 4.11 Proximate coal analysis report inter laboratory

Parameter	TEKMIRA		CARSURIN		GEOSERVICE		Unit
	Ad	Ar	Ad	Ar	Ad	Ar	
Total Moisture	-	27.80	-	29.76	-	30.04	Weight %
Inherent Moisture	12.98	-	14.09	-	14.18	-	Weight %
Ash Content	7.02	-	8.04	6.57	8.12	6.57	Weight %
Volatile matter	39.46	-	-	-	39.44	-	Weight %
Fixed Carbon	40.55	-	77.87	63.67	38.26	-	Weight %
Total Sulphur	0.82	-	0.48	0.39	0.47	-	Weight %
Gross Calorific Value	5,753.75	-	5,521.00	4,514.00	5,515.00	-	Kcal/Kg
Net Calorific Value	-	4,367.75	-	4,178.00	-	-	Kcal/Kg

Table 4.12 Ultimate coal analysis report inter laboratory

Parameter	TEKMIRA	CARSURIN	GEOSERVICE	Unit
Ultimate Analysis (Air Dried Basis)				
Carbon	60.23	58.13	56.98	Weight %
Hydrogen	5.77	3.9	4.55	Weight %
Nitrogen	0.88	0.94	0.85	Weight %
Sulphur	-	0.48	-	Weight %
Oxygen	25.30	14.42	29.03	Weight %
Ash Analysis (Dried Basis)				
Calcium (Ca)	2.16	0.37	4.64	Weight %
Natrium (Na)	0.48	0.06	0.95	Weight %
Sulphur Trioxide (SO3)	3.89	5.4	3.22	Weight %
Trace Elements (Dried Basis)				
Mercury (Hg)	0.047	0.092	< 0.5	µg/g
Selenium (Se)	-	0.12	<0.1	µg/g
Arsenic (As)	-	1.59	1	µg/g
Chlorine (Cl)	-	0.015	0.015	%

Table 4.13 Fly ash analysis report inter laboratory

Parameter	TEKMIRA	CARSURIN	GEOSERVICE	Unit
Ultimate Analysis (Air Dried Basis)				
Inherent Moisture	0.45	0.50	-	Weight %
Ash Content	95.88	95.10	-	Weight %
Volatile matter	1.30	-	-	Weight %
Fixed Carbon	2.38	4.40	-	Weight %
Total Carbon	3.58	4.11	3.99	Weight %
Ash Analysis (Dried Basis)				
Calcium (Ca)	2.84	3.99	4.82	Weight %
Natrium (Na)	0.69	0.89	1.68	Weight %
Sulphur Trioxide (SO3)	0.61	0.28	0.55	Weight %
Trace Elements (Dried Basis)				
Mercury (Hg)	<0.070	0.13	<0.5	µg/g
Selenium (Se)	-	0.06	0.1	µg/g
Arsenic (As)	-	0.48	14	µg/g
Chlorine (Cl)	-	0.01	327.12	%

Table 4.14 Bottom ash analysis report inter laboratory

Parameter	TEKMIRA	CARSURIN	GEOSERVICE	Unit
Ultimate Analysis (Air Dried Basis)				
Inherent Moisture	1.09	1.15	-	Weight %
Ash Content	95.22	93.84	-	Weight %
Volatile matter	2.64	-	-	Weight %
Fixed Carbon	1.06	5.01	-	Weight %
Total Carbon	2.55	3.57	3.5	Weight %
Ash Analysis (Dried Basis)				
Calcium (Ca)	2.40	3.3	3.9	Weight %
Natrium (Na)	0.79	0.93	1.86	Weight %
Sulphur Trioxide (SO3)	0.37	0.05	0.22	Weight %
Trace Elements (Dried Basis)				
Mercury (Hg)	<0.07	0.04	<0.5	µg/g
Selenium (Se)	-	0.04	<0.1	µg/g
Arsenic (As)	-	0.23	0.5	µg/g
Chlorine (Cl)	-	0.8	376.48	%

Result analysis from 3 laboratories are mostly comparable. All laboratories confirmed that mercury content in the coal is relatively small, hence generated low concentration of mercury fly ash and bottom ash as well.

5. MERCURY SPECIATION AND MERCURY EMISSION FACTOR FROM CFPP IN INDONESIA

5.1. POLLUTION CONTROL EQUIPMENT AND POLICY FOR INDONESIAN POWER PLANTS

The legal framework for environmental management in Indonesia is defined by Environmetal Protection and Management (EPMA), 2009. Enacted in October 2009, it replaced the 1997 Law Regarding Environmental Management, which in turn had replaced a 1982 statue. EPMA 2009 seeks to integrate environmental protection and management across economic activities to ensure sustainable development. The law recognizes the government's responsibility towards controling environmentals pollution and damage by setting out requirements and procedures for obtaining an environmental permit (EP) and by specifying quality and emission standards.[12]

Power plant using coal will produce several impacts to the environment from the increase of CO_2 emission, dioxin-furans, gas emission or air pollution, fly ash and bottom ash. Air pollution emission notably are sulfur dioxide (SO_x), nitrogen dioxide (NO_x) and particulates matter (dust). Fly ash and bottom ash are categorized as hazardous and toxic waste as listed under Government Regulation No. 101 Year 2014 regarding Hazardous Waste Management. The management of hazardous waste management is initiated from the so called cradle to grave process. From the onset, coal which is used as fuel are stored at coal stockyard after being shipped in from unloading berth via conveyor. Dust scattering will be controlled using every possible measure, i.e. closed conveyor, water spraying. Fly ash may be used by cement industries used as supplement of silicate raw material and also may be used as road-based material and for making concrete or landfill.

From the 2013 MOEF data, the total heavy metals in the fly ash from one of the power plants are shown in Table 5.1 and Table 5.2.

Table 5.1 Mercury parameter in fly ash from one CFPP (i)

LABORATORY TEST RESULT							
Job Number : S-131011					Date : November 12, 2013		
Customer : ASDEP VERIFIKASI PENGELOLAAN LIMBAH B3 Position :					Attention : Mr. Yunus		
Lab. Sample	**Customer Sample ID**	**Matrix**	**Date Sampled**	**Time Sampled**	**Date Received**	**Time Received**	**Interval Analysis**
S-131011-2/3	Fly Ash	Ash	24/10/2013	14:20	29/10/2013	09:30	29/10 to 12/11

[12] Indonesia's Coal Power Emission: Lessons From India and China, 2017, ICEL, CSE & REEI, centre for Science and Environment, New Delhi, India.

No.	TEST DESCRIPTION (Total Heavy Metals)	RESULT	REGULATORY LIMIT*		UNIT	METHOD
			A	B		
1	Arsenic, As	10.53	300	30	mg/Kg	US EPA SW 846 3050B-1996 & US APHA 3120B-2012
2	Barium, Ba **	1077.8	-	-	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
3	Cadmium, Cd **	0.57	50	5	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
4	Chromium, Cr **	30.7	2500	250	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
5	Copper, Cu **	23.2	1000	100	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
6	Cobalt, Co **	<0.1	500	50	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
7	Lead, Pb **	10.4	3000	300	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
8	Mercury, Hg **	<0.1	20	2	mg/Kg	US EPA SW 7471 A-1994 APHA 3112 B-2012 SNI 06-6992-2-2004
9	Molybdenum, Mo	102.3	400	40	mg/Kg	US EPA SW 846 3050B-1996 & US APHA 3120B-2012
10	Nickel, Ni **	79.0	1000	100	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
11	Tin, Sn	7.2	500	50	mg/Kg	US EPA SW 846 3050B-1996 & US APHA 3120B-2012
12	Selenium, Se	<0.06	100	10	mg/Kg	US EPA SW 846 3050B-1996 & US APHA 3120B-2012
13	Silver, Ag **	0.2	-	-	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
14	Zinc, Zn **	85.91	5000	500	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012

As per KEP-04/BAPEDAL/09/1995
****Accreditation ISO/IEC 17025***

Note:

Class A, Cat I = If sample ≥ permissible limit column A, Landfill Category I
Class A, Cat II = If sample < permissible limit column A, Landfill Category II
Class B, Cat III = If sample ≤ permissible limit column B, Landfill Category III

This type of fly ash can go into landfill Class II, because of the Molybdenum(Mo) concentration 102.3 mg/Kg < 400 mg/Kg limit of column A and > 40 mg/Kg limit of Column B.

Table 5.2 Mercury parameter in fly ash from one CFPP (ii)

LABORATORY TEST RESULT							
Job Number : S-130994					Date : November 8, 2013		
Customer : ASDEP VERIFIKASI PENGELOLAAN LIMBAH B3 Position :					Attention : Mr. Yunus		
Lab. Sample	**Customer Sample ID**	**Matrix**	**Date Sampled**	**Time Sampled**	**Date Received**	**Time Received**	**Interval Analysis**
S-130994-1/3	Fly Ash power plant	Ash	24/10/2013	10:55	24/10/2013	08:30	24/10 to 08/11

No.	**TEST DESCRIPTION** (Total Heavy Metals)	**RESULT**	**REGULATORY LIMIT***		**UNIT**	**METHOD**
			A	**B**		
1	Arsenic, As	10.31	300	30	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007
2	Barium, Ba **	651.8	-	-	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
3	Cadmium, Cd **	0.48	50	5	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
4	Chromium, Cr **	39.2	2500	250	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
5	Copper, Cu **	20.1	1000	100	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
6	Cobalt, Co **	<0.1	500	50	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
7	Lead, Pb **	14.5	3000	300	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
8	Mercury, Hg **	<0.01	20	2	mg/Kg	US EPA SW 7471 A-1994 APHA 3112 B-2012 SNI 06-6992-2-2004
9	Molybdenum, Mo	14.4	400	40	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007
10	Nickel, Ni **	52.0	1000	100	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
11	Tin, Sn	3.1	500	50	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007

12	Selenium, Se	0.13	100	10	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007
13	Silver, Ag **	<0.1	-	-	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012
14	Zinc, Zn **	17.17	5000	500	mg/Kg	US EPA SW 846 3050B-1996 & US EPA SW 7000 B-2007 APHA 3111 B-2012

As per KEP-04/BAPEDAL/09/1995
*****Accreditation ISO/IEC 17025***

Note:

Class A, Category I = If sample ≥ permissible limit column A, Landfill Category I
Class A, Category II = If sample < permissible limit column A, Landfill Category II
Class B, Category III = If sample ≤ permissible limit column B, Landfill Category III

The general framework for controlling air pollution from mobile and stationary sources is provided by Government Regulation No. 41 of 1999 (PP 41/1999) on Air Pollution Control, issued under Law No. 23 of 1997. These regulation set out the National ambient Air Quality Standards (NAAQS) for thirteen air pollutants. Provisions of PP 41/1999 continue to remain in force under the 2009 EPMA as long as they are not contrary to its contents. While the new law called for notification of a new set of regulations within a year of its enactment, these are still being drafted and notification could take another year.[13]

According to the Environment Ministerial Decree No. 21 Year 2008 regarding Emission Quality Standard from Stationery Source of Electric Thermal Generation, the government requires thermal power plant to manage their emission in meeting the emission standard under the decree. This management can be fulfilled by installing electrostatic precipitator/baghouse filters/fabric filters especially for CFPP. For achieving beyond compliance the CFPP can install flue-gas desulfurizer equipmentsutilizing low-NOx burner/two stage combustion units.

For stationary source pollution including factories, refineries, boilers and power plants, air pollution standards were first introduced by the Ministry of Environmental in 1988 later updated in 1995. The most recent revision in the standards was in May 2007 (for industrial boilers) through Decree No. 7 (PermenLH 7/2007) and in December 2008 (for thermal power plants) through Decree No. 21 (PermenLH 21/2008).[14]

In the 2008 revision the government decided to retain the 1995 standards for old power plants, either operational or under advanced stages of development at the time the decree came into force (1 December 2008). New power plants especially those planned before but commissioned after the decree comes into force were required to maintain the 1995 standards during transition and must fully comply with the new standards by 1 January 2015. All thermal power plants planned and commissioned after

[13] Indonesia's Coal Power Emission: Lessons From India and China, 2017, ICEL, CSE & REEI, centre for Science and Environment, New Delhi, India.

[14] Indonesia's Coal Power Emission: Lessons From India and China, 2017, ICEL, CSE & REEI, centre for Science and Environment, New Delhi, India.

the enactment of the decree have to comply with the new standards. Emissions standards remain considerably weak however especially for NO_x and SO_2.

Table 5.3 Air emissions standards for coal-based power plants, 2008

Parameter	Unit	Old plants	New plants
SO_2	mg/m^3	750	750
NO_x	mg/m^3	850	750
PM	mg/m^3	150	100
Opacity	Per cent	20	20

Note:Reference conditions for testing are 25^{0}C at an atmospheric pressure of 1 atm (or 101 kPa) on a dry flue gas basis with 7 per cent O_2 in the flue gas (except for opacity).
Source: Ministry of Environment and Forestry, Indonesia.

The 2008 regulations allow provincial governments to stipulate emission standards for their respective regions as long as these are more stringent than the national standards. Additional parameters can also be added by the provincial government after obtaining approval from the Ministry of Environment and Forestry (MOEF). Stricter emission standards can also be determined for power plants if the requirement is established during the Environmental Impact Assessment (EIA) for plants with capacity greater than 100 MV, or the lesser Environment Management (UKL) and Environmental Monitoring Effort (UPL) scheme for plants with capacity less than MW.

CEMS implementation

The 2008 regulations also mandated installation of continuous emission monitoring systems (CEMS) for all old and new coal-based power generation plants with an installed capacity of 25 MW and above; as well as for new generation plants with a capacity of less than 25 MW but with sulphur content of over 2%t in the coal. In case of plants with over 25 MW of capacity, old plants are required to install CEMS at the stack that emits the highest emission load (as calculated during early stages of planning). CEMS are required to be installed at all stacks in new power plants. For CEMS operation, plants are required to have a quality assurance and quality control system. For all other power plants that do not require compulsory CEMS installation, emission levels are to be tested at least once every six months by accredited laboratories.

Under this decree every thermal power plant including CFPP are obliged to install the continuous emission monitoring system (CEMS).

Existing air pollution control

At present 95% air pollution control (APC) equipment are installed in CFPP in Indonesia. Among those, electrostatic precipitators (ESP) are the most common installed APC (98%). Other APC utilized in Indonesia are flue-gas desulfurization (FGD), low NOx burner, wet FGD, bag filter, multi-cyclone and cyclone deduster as shown in Table 5.4.

Table 5.4 Installed air pollution control in Indonesian CFPP

Air Pollution Control	Installed Equipment
ESP and Low NOx Burner	36
ESP, Low NOx Burner and FGD	3
ESP, Low NOx Burner, FGD and Bag Filter	1
ESP, Low NOx Burner, Wet FGD	1
Multi Cyclone and Low NOx Burner	1
Bag Filter	1
ESP, Low NOx Burner and Cyclone Deduster	1
Total	44

Source:DGE, MOEMR 2017

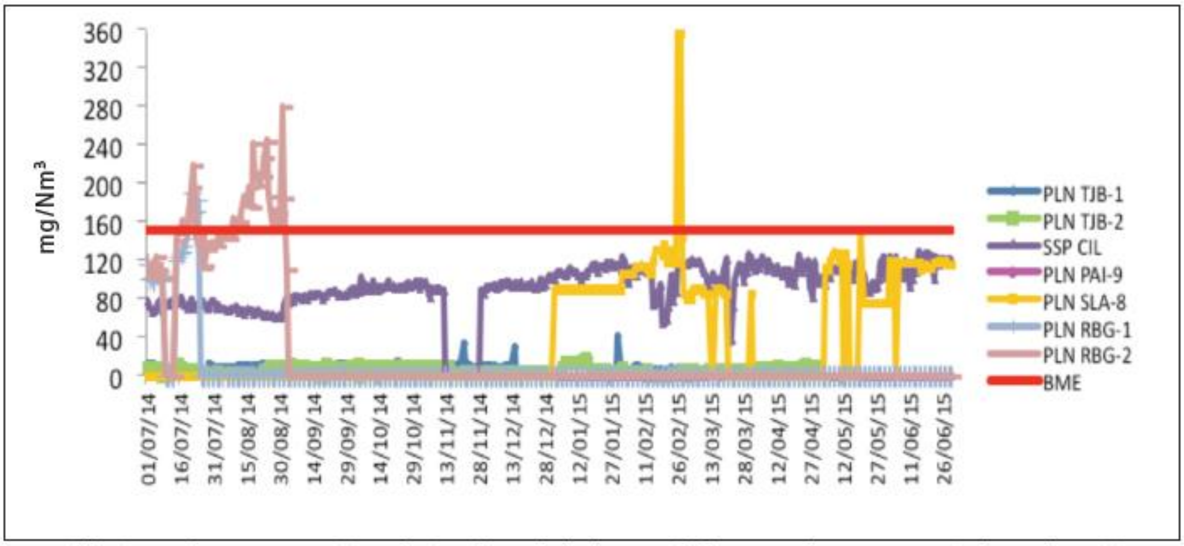
A profile data of air pollution control from CFPP is provided in Table 5.5 showing type of pollution control equipment and the range of emission control for several air pollutants.

Table 5.5 Profile data of air pollution control from CFPP

No.	Company	Capacity (MW)	Operation Year	Production in 2015 (MWh)	Pollution control equipment	Emmision Control		
						Particulant	SO_2	NO_2
1.	PT. A	3400		22.206.075				
	Unit #1	400	1985	2.757.793	ESP	49,69-111,85	508,85 – 716,72	202,09-448,69
	Unit #2	400	1986	2.472.227	ESP	79,92 – 135,79	482,83- 674,74	205,77 – 563,71
	Unit #3	400	1989	2.627.903	ESP	85,42 - 103	405,75 – 416,77	232,06 – 466,37
	Unit #4	400	1989	2.605.534	ESP	58,78 – 121,77	560,42 – 686,98	323,37 -812,38
	Unit #5	600	1997	3.867.258	ESP	67,49 – 123,64	521,45 – 673,64	285,66 – 481,76
	Unit #6	600	1997	4.109.884	ESP	98,92 – 130,68	455,75 – 564,14	353,9 – 418,49
	Unit #7	600	1998	3.765.475	ESP	62,36 – 107,87	503,09 – 637,2	406,84 – 485,95
2.	PT. B	800		5.105.722				
	Unit #1	400	1994	2.751.375	ESP	39,17 – 90,15	130,5 – 617,5	64,3 – 104,5
	Unit #2	400	1995	2.354.347	ESP	62,92 – 111,25	95,35 – 576,5	68,15 – 114,75
3.	PT. C	2840		18.349.824				
	Unit #1	710	2006	4.266.767	ESP; FGD; Low NO_x burner	1,03 – 5,08	97 - 523	215 – 456
	Unit #2	710	2006	4.555.389		0,77 – 6,10	100 - 467	246 - 486
	Unit #3	710	2012	4.603.673		18,7 – 58,2	3,13 – 131,4	66,1 – 280,5
	Unit #4	710	2012	4.923.996		12,94 – 56,6	2,15 – 97,3	83,5 – 443,2
4.	PT. D	600						
	Unit #1	300	2006	1.902.195		78,35 – 149,09	123,08 – 228,97	168,3 – 473,58
	Unit #2	300	2006	1.668.421				
5.	PT. E	660	2012	4.138.488	ESP	51,3 – 63,7	50,4 – 715,7	69,7 – 191,4
6.	PT. F	625	2011	2.101.798	ESP	56,26 – 134,31	409,06 – 578,26	337,69 – 559,1
7.	PT. G	630		4.008.267				
	Unit #1	315	2011	2.195.488	ESP	13,4 – 56,7	138 – 654,5	46 – 377,5
	Unit #2	315	2011	1.812.779	ESP	20,9 – 64,6	275 – 649,7	50,4 - 262
8.	PT. H	1050		4.350.261				
	Unit #1	350	2013	1.645.285	ESP	94,11	445,23	164,28
	Unit #2	350	2014	1.338.080	ESP	89,47 – 97,8	371,92 – 502,24	127,55 – 213,48
	Unit #3	350	2014	1.366.896	ESP	82,6 – 96,15	385,4 – 412,84	134,9 – 149,3
9.	PT. I	815	2012	5.121.242	ESP	0,8 – 37,23	0,01 – 22,36	111,45 – 215,58
10.	PT. J	660	2012	4.942.905	ESP	9,8 – 17,55	72,29 – 177,31	184,4 – 229,07

From this figure emission from old generation units are found to be higher as compared to the new generation units as mentioned in Figure 5.1 and Figure 5.2

For old units, emission of PM ranges from 80 to 120 mg/Nm^3.

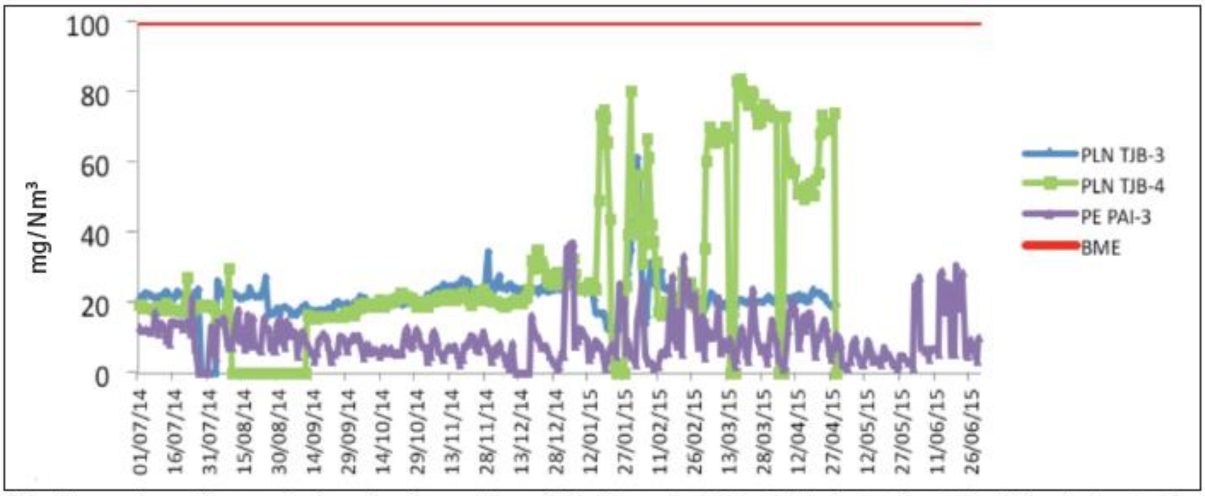


Note: *Old units are the ones commissioned or in advanced development before December 2008. BME indicates the existing PM emission standard of 150 mg/m³*

Source : MOEF on "Policy Brief; Regulating Emission of Coal-Based Power Sector – Proceeding and recommendations of stakeholder roundtable, Jakarta 23-24 May 2017. ICEL & CSE.

Figure 5.1 PM Emission from old generation units

PM emissions from new units appear very low, mostly less than 40 mg/Nm^3.



Note: *New units are the ones developed and commissioned after December 2008. BME indicates the existing PM emission standard of 150 mg/Nm³*

Source : MOEF on "Policy Brief; Regulating Emission of Coal-Based Power Sector – Proceeding and recommendations of stakeholder roundtable, Jakarta 23-24 May 2017. ICEL & CSE.

Figure 5.2 PM Emission from new generation units

Mercury emission standard is not yet included in the decree. Currently, the MOEF is developing the national emission standard for mercury. Efforts are under way to collect data on mercury emission from CFPP to consider the mercury emission being included for future national emission standard. Previous attempt to measure mercury emission from CFPP has been carried out since 2011 as shown in the following Table 5.6.

Table 5.6 Mercury emission from CFPPs in Indonesia

NO	CFPP	BOILER UNIT	YEAR OF MEASUREMENT			
			2011	2012	2013	2015
1	A		0.0007	-		
2	B		0.0002	-		
3	C	Unit # 6	0.0002	-		
4	D	Unit #2	< 0.00006	0.00035		
5	E	Unit # 5	0.0007	0.00036		
6	F	Unit # 6	0.0008	0.00041		
7	G	Unit # 1	0.0006	0.00135		
8	H	Unit # 1	-	0.0013		
9	I	Unit # 6	0.0003	0.0094		
10	J	Unit # 1 Unit # 3 Unit # 4	- 0.00008 0.00006	0.0111		
11	K	Unit # 6	0.0006	0.0098		
12	L	Unit # 1	0.0006	-		
13	M				0.00146	
14	N	Unit # 6	0.00033 - 0.00204	0.0001 – 0.0014		0.0004 – 0.0009

all measurement in mg/Nm^3
Source: MOEF 2011 - 2015

All measurement was conducted using the USEPA Method 29, hence only total mercury was able to be collected. Since no regulation on obligations for power plant to measure the mercury emission are available yet, hence measurement data are only available in several power plants.

Based on available CFPP configuration, coal characteristics and installed air pollution control equipment, the mercury emission removal efficiency can be estimated using the Interactive Process Optimization Guidance (IPOG) software package that was develop for UN Environment by NEA (Niksa Energy Associates) as shown in Table 5.5.

Table 5.7 Estimation mercury removal efficiency of CFPP using IPOG software

No.	Emission Control Technology	Mercury Removal Efficiency (%)	Total Unit in CFPP	CFPP	
1	ESP and Low NOx Burner	26.8	2	Ombilin (Unit 1 & 2)	
		14.2	4	Bukit Asam (Unit 1, 2, 3 & 4)	
		13.8	7	Suralaya (Unit 1, 2, 3, 4, 5, 6 & 7)	
		12.7	2	Indramayu (Unit 2 & 3)	
		4.5	24	1	Labuhan Angin (1 & 2)
				2	Teluk Sirih (1 & 2)
				3	Nagan Raya (1 & 2)
				4	Air Anyir (1 & 2)

				5	Amurang (1 & 2)
				6	Tarahan (3 & 4)
				7	Merak Energi Indonesia (1 & 2)
				8	Pangkalan Susu (1 & 2)
				9	Suge Unit 1
				10	Semarang Unit 1
				11	Baturaja Unit 1
				12	NTT Unit 1
				13	Molotabu Unit 1
				14	Ketapang Kalbar Unit 1
				15	Barru 1 & 2
		4.2	1		Indramayu Unit 1
		3.5	30	1	Asam-Asam (1,2,3 & 4)
				2	Paiton PJB Up 1 & 2
				3	Paiton Unit 9 (PT. PLN/PJB)
				4	Tanjung Awar-awar Unit 1
				5	Galang Batang 1 & 2
				6	Janeponto 1 & 2
				7	Banten 1 Suralaya Unit 8
				8	Banten 2 Labuan 1 & 2
				9	Banten 3 Lontar 1, 2 & 3
				10	Pacitan 1 & 2
				11	Rembang (2x315) 1 & 2
				12	Cilacap 1 & 2
				13	Pelabuhan Ratu 1, 2 & 3
				14	Cogen Power Plant
				15	Sei Batu Unit 1
				16	Tawaeli Unit 1
		16.4	1		Jeranjang
		3.5	1		Cirebon
2	ESP, FGD & Low NOx Burner	54.9	1		Tanjung Jati (PLTU TJB Unit 3)
		54.8	1		Tanjung Jati (PLTU TJB Unit 4)
		32.3	2		Tanjung Jati (PLTU TJB Unit 1 & 2)
		22.8	2		Paiton 5-6 (Jawa Power)
		23.4	3		Celukan Bawang Unit 1, 2, 3
3	ESP, FGD, Low NOx Burner, Bag Filter	47.7	3		PT. Puncak Jaya Tower (Unit 1, 2 dan 3)
4	ESP, Wet FGD	11.6	1		Paiton Unit 3
		11.9	2		Paiton Unit 7 & 8
5	Multi cyclone & Low Nox Burner	3.5	1		Tanjung Balai Karimun Unit 1
6	Bag house (Bag filter)	4.5	1		Sanggau Unit 1

7	ESP & cyclone deduster	3.5	4	BTG Biringkasi Unit A, B, C & D

Based on data obtained from CFPP in Indonesia, IPOG estimated the mercury removal efficiency between 3.5–54.9%. Only 9 CFPP units equipped with ESP and FGD have shown to have higher mercury removal efficiency between 22.8 – 54.9%.

Compliance monitoring

The regency or city government through local environmental boards (LEBs) are responsible for supervising compliance of power plants to the air emission standards (as stated in their EIA). While monitoring should primarily be conducted through CEMS, there is no reliable information on how many of the CEMS are connected to the LEBs or MOEF networks. For instance, at the 380 MW Celukan Bawang coal-based power plant, the LEB neither has a system to connect with the CEMS nor does it receive the CEMS self-monitoring report from the plant.

As per the law, the penalties for violations of air pollution regulations of the terms and conditions of the EP by a power plant vary depending on the degree and seriousness of the violation (which is not clearly defined). The punishments can vary from the LEB sending out a reprimand letter to the plant asking it to take corrective action, to suspension and revocation of the EP of the plant. Repetitive violations can further lead to criminal enforcement.

Data on emissions performance of power generation units is not publicly disclosed in Indonesia. In this report, the analysis of the PM, SO_2, and NO_2 emissions performance of coal-based power plants is based on the data received from the MOEF for the 23 units aggregating 12,080 MW in capacity.

The data shared by the MOEF accounts for nearly half of the country's total installed generation capacity, however, this may not be a representative data set given that the sample covers larger units ranging from 300 to 815 MW in size. A significant number of the installed units in Indonesia are small in size (lower than 300 MW capacity), whose emissions may be higher than the units in the sample. Since large units contribute to around 75% of the capacity, analysis of their emissions is critical in understanding their overall sector performance and to suggest norms. In terms of age, the sample can be considered representative- around 65% of the units were installed after 2006.

5.2. MERCURY SPECIATION IN FLUE GAS

Using the ASTM D6784/Ontario Hydro method, mercury speciation from 3 (three) CFPP was able to be measured and presented in the table below.

Table 5.8 Mercury speciation in emission

	ASTM D6784 / Ontario Hydro		
Location of the sampling	Hg^0(%)	Hg^{2+}(%)	Hg total (µg/m^3)
Suralaya CFPP	55	45	1.07
Cirebon CFPP	72	28	0.60
Indramayu CFPP	94	6	3.02

The result shows that major portion of the emitted mercury is in elemental form. In addition, literature[15] mentioned that the PC and ESP release percentage Hg^0, Hg^{2+} and Hg_p of 57%, 42% and 1% respectively. It is in line with the result obtained from the Suralaya CFPP. However, it is not applicable to th Cirebon CFPP and the Indramayu CFPP. Moreover, although the Indramayu CFPP emitted the highest concentration of mercury as compared to the other two plants, most of the mercury released were in elemental form (94%).

Mercury speciation in emission also was estimated using the IPOG software. Forty-five CFPPs in Indonesia were calculated using this software. It was estimated that around 2.9 tonnes of mercury were emitted through air which consist of 81.72% in Hg^0 form and 18.28% in the form of Hg^{2+}.

5.3. INDONESIAN MERCURY EMISSION FACTOR

The coal samples studied under this project activity revealed a wide variability in terms of ash percent, net and gross calorific value (NCV and GCV), alkali and sulfur content as well as mercury content. The minimum and maximum value of the mercury content is 0.011 mg/kg and 0.231 mg/kg. The average value of mercury content of coal samples from 44 CFPP is 0.056 mg/kg. The average value of 0.056 mg/kg has been considered as the input factor of the coal being used by the power sector and has been used to estimate the mercury emission inventory in this study.

The average mercury input factors (concentration, g/tonne) of the different coal are shown in Table 4.6. To estimate the mercury emissions from the power sector, the methodology provided under the UN Environment Tool Kit and the UN Environment IPOG has been used. In the UN Environment Tool Kit methodology for coal combustion, the default output distribution factor for mercury to air is considered as 0.9 for power plants equipped with an ESP for particulate capture.

[15] Reducing Mercury Emissions from CoalCombustion in The Energy Sector,2011, United Nations Environment Programme, UNEP Chemicals, International Environment House, Geneva, Switzerland. (A Report from Department of Environmental Science and EngineeringTsinghua University for The Ministry of Environment Protection of China and UNEP Chemicals)

The mercury release from the power sector has been estimated using the following equations.

> Emission factor = Input factor x output distribution factor to air
> Estimated mercury release (tonne/year) = Activity rate x emission factor

where:

> Activity rate = Amount of coal fed to power plant (tonne/year)
> Input factor = Mercury input factor of coal (Hg concentration in coal, g/tonne)
> Output distribution factor to air = 0.9 (as per UN Environment Toolkit for CFPP equipped with ESP)

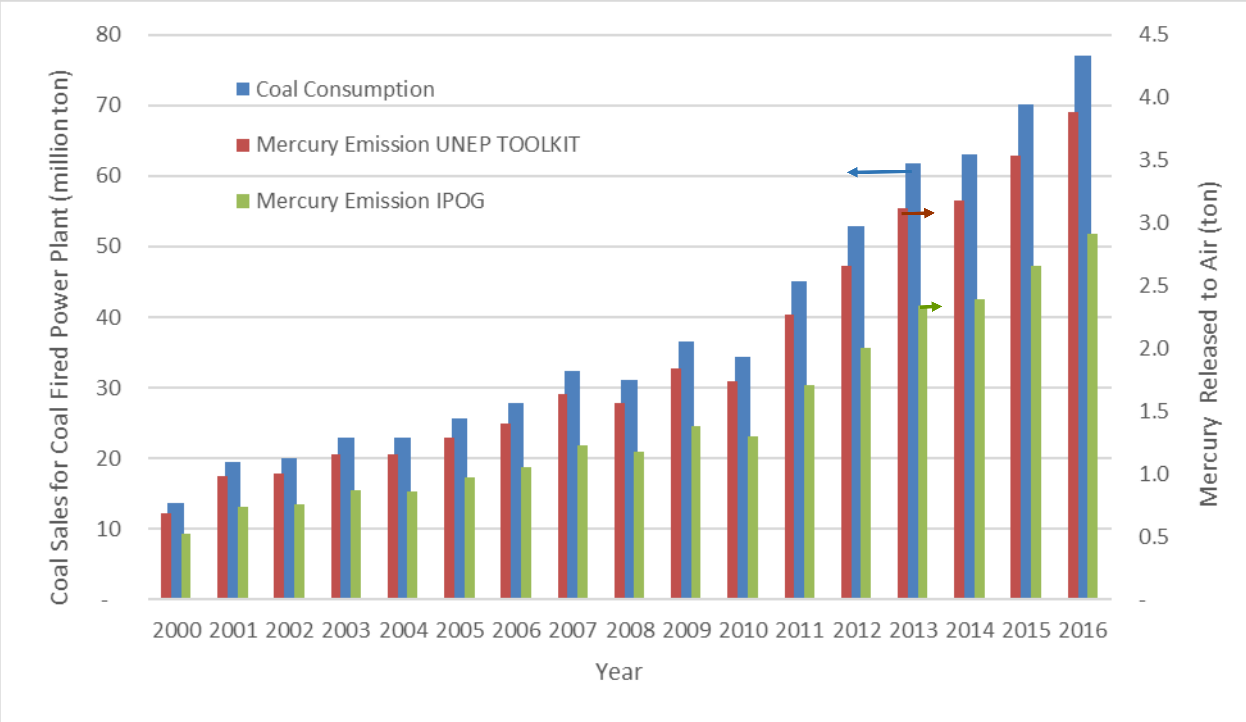
Using the UN Environment Toolkit, the mercury emission factor is 0.05 gram Hg/ tonne coal. The amount of coal consumed in 2016 is 77 million ton, then mercury released can be estimated around 3.9 tonnes/year.

Another scenario to estimate mercury emission factor using IPOG was developed. In order to estimate mercury emission release from each boiler, data on coal characteristics and power plants are needed as parameters in IPOG software. The estimation of mercury released in the air from 45 CFPP based on IPOG calculation is 2.9 tonnes. The operational CFPP data including the coal consumption is collected from January 2016 – December 2016. Once the mercury released data available, the mercury emission factor using IPOG can be calculated at around 0.038 gram Hg/ tonne coal. Mercury emission factor itself can also be defined as of per heat value of fuel as describe in the formula:

> Estimated mercury release = Activity rate x net caloric value x emission factor

With the net calorific value of 19.8 TJ/Ggram, therefore, the emission factor is 1.91 gram Hg/TJ.

The trend of mercury release can also be calculated based of the UN Environment toolkit and based on emission factor from IPOG as shown in Figure 5.3.



Data coal sales from 2000 – 2015 are taken from Handbook of Energy and Economic Statistics of Indonesia 2016.
Data coal utilization for CFPP 2016 is taken from Ministry of Energy and Mineral Resources Decree number 5899 K/20/MEM/2016

Figure 5.3 Trend of coal sales to coal-fired power plant and mercury emission

Figure 5.3 illustrates that calculation of the mercury released using IPOG software are lower than the estimation of mercury released using parameter in UN Environment Toolkit. In addition, 2016 data shows that CFPP consumed more than 5 times higher than in 2000 which resulting 5 times mercury releases accordingly. Rate of mercury release is increasing from 2010 at average of 0.27 tonne/year compared to average of 0.08 tonne/year during 2000 to 2010 as concequences of rapid coal utilization in CFPP in recent years.

5.4. INDONESIAN MERCURY EMISSION 2017-2026 FROM CFPP

Based on Ministry Energy and Mineral Resources Decree No. 1415 K/20/MEM/2017, coal consumption for CFPP has been projected until 2026. Hence the mercury emission projection from CFPP can be estimated as shown in Figure 5.4.

Data Projection Coal Consumption 2017-2026 is taken from Ministry of Energy and Mineral Resources Decree No. 1415 K/20/MEM/2017

Figure 5.4 Projection of coal consumption and projection of mercury emission

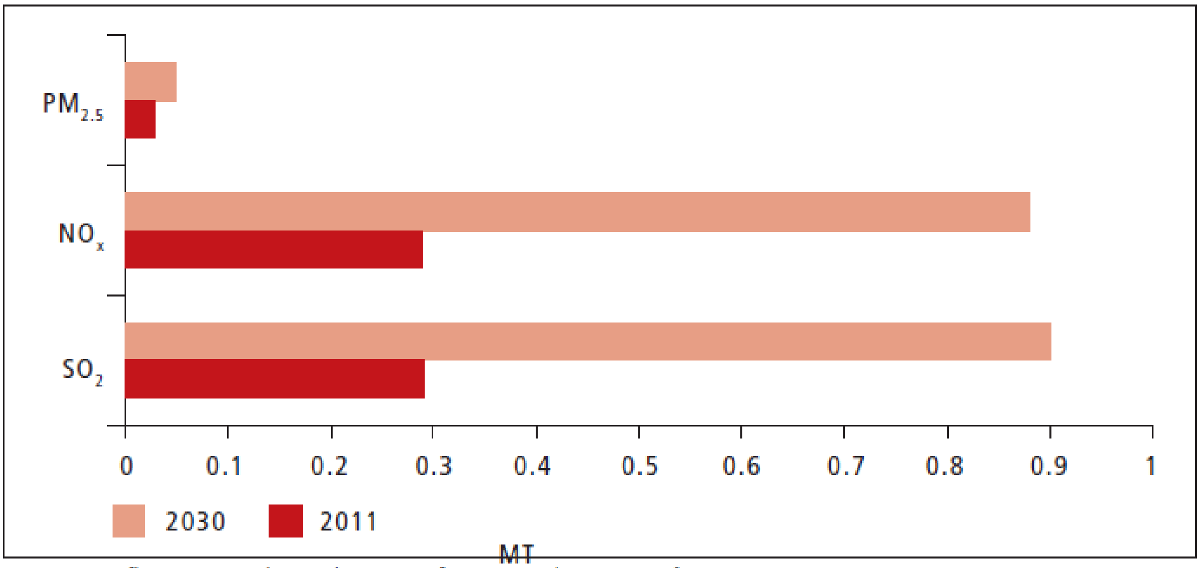
Despite the yearly growth of electricity production, the projected coal consumption decreases in 2025 and continue to increase again in 2026. The coal consumption decrease is due to higher increase of hydropower and LNG as shown in Figure 3.12. Decrease on coal consumption will lower mercury emission on that particular year. It is estimated that in 2026 Indonesia may still contribute 7.7 tonnes (based on UN Environment Toolkit) or 5.8 tonnes (based on IPOG) of mercury to the air from CFPP.

6. RECOMMENDATION

6.1. DEVELOPMENT OF MERCURY EMISSIONS AND RELEASES REDUCTION FOR COAL-FIRED POWER SECTOR

6.1.1 REDUCING POLLUTANT EMISSION FROM POWER PLANT

Independent researchers have estimated that emission from coal-based power sector will total by 0.03 million tonnes (MT) of fine particulate meter ($PM_{2.5}$) and 0.29 MT of SO_2 and NO_x each in 2011. The SO_2 and NO_x emissions from coal power plants will increase three-fold while $PM_{2.5}$ will double by 2030 if no measures are taken to curb their emissio (see Figure 6.1.: Projected Growth In National Inventory of Emissions From Coal-Based Plants). *(source: "Policy Brief; Regulating Emission of Coal-Based Power Sector – Proceeding and recommendations of stakeholder roundtable, Jakarta 23-24 May 2017. ICEL & CSE*)



Note: *Data reflects estimated annual emissions for 2011 and projections for 2030*
Source: *Koplitz, S. N., Jacob, D. J., Sulprizio, M. P., Myllyvirta, L., & Reid, C. (2017). Burden of Disease from Rising Coal-Fired Power Plant Emissions in Southeast Asia. Environmental Science and Technology.*

Figure 6.1 Projected growth in national inventory of emissions from coal-based plants

Under a business as usual (BAU) scenario, pollution emissions from coal-based plants in Indonesia are expected to increase two to three times by 2030.

From this figure it can be shown that the pollution emission from coal-based plants will increase from 2011 to 2013 by two to three times in 2030. This is attributed to the increasing use of coal for power plant generation. The recommendation for these problems are to implementing Government Regulation No. 79/2014 on National Energy Policy requiring the use of new and renewable energy by 23% in 2025 and at least 31% in 2050. If coal impurities are high it will be important to use coal washeries. From coal analysis carried out in the study, mercury content and other impurities are considered low, hence, coal washeries were considered not necessary for the domestic CFPP market.

Pollution control equipment used in power plant can decrease emission if they used ESP, FGD and low NOx burner. New power plants should have the lowest emissions achieved so the power plants will be required to install the newer technologies such as the super-critical boiler.[16]

From the estimation of this study by year 2026 Indonesia may still contribute 7.7 tonnes (based on the UN Environment Toolkit) or 5.8 tonnes (based on IPOG) of mercury to the air from CFPP. To reduce the mercury emission, regulations will have to be developed using ESP, FGD and low NOx burner, Super Critical boilers and having CEMS monitoring and tuneing activities.

6.1.2. ENVIRONMENTAL STANDARD

Indonesia has some of the weakest emission standards for coal-based power plants in the world. The norms for SO_2 and NO_x are quite loose as compared to those in the developed and large emerging economies like India and China[17].as shown in the table below.

Table 6.1 Emission standards for coal-based power plants in major countries

	PM	SO_2		NO_x		Mercury
		New plants	Existing plants	New plants	Existing plants	
EU	50–100	200	400	200 (after 2015)	500 (till 2015)	0.03 (Germany)
US	22.5	160 (after 2005)	160 (1997–2005);	117	117 (after 2005); 160 (1997–2005);	0.001–0.006
China	30	100	200; 400*	100	100 (2004–11); 200 (before 2004)	0.03
India	100 (till 2003); 50 (2004–16); 30	100	600 (< 500 MW); 200 (> = 500 MW)	100	600 (till 2003); 300 (2004–16)	0.03
Indonesia	150–100	750	750	850	750	None

Unit: *mg/Nm^3*
**SO_2 standards of 400 mg/m^3 for four provinces with high sulphur coal*
Source: *World Resources Institute Asia. Environmental Science and Technology.*

Unlike Indonesia, most major countries have adopted very tight emission standards for coal-based power plants. The evaluation of Indonesia standard for PM, SO_2, NO_2 is very low as compared to other countries and Indonesia does not have yet a standard for mercury.

Representatives from the Ministry of Environmental and Forestry have stated that they plan to take into account three aspects when determining the new standards:

- Existing emission performance of plants and their ability to improve it.

[16] "Policy Brief; Regulating Emission of Coal-Based Power Sector – Proceeding and recommendations of stakeholder roundtable, Jakarta 23-24 May 2017. ICEL & CSE

[17] "Policy Brief; Regulating Emission of Coal-Based Power Sector – Proceeding and recommendations of stakeholder roundtable, Jakarta 23-24 May 2017. ICEL & CSE

- Availability of technology.
- Affordability of invesment.

At present the Ministry of Environment and Forestry are doing an inventory on those 3 (three) items in setting out the new standard.

Indonesian coal powered Industries fear that the new norms will result in higher tariff (IDR 80-100 per kWH) (CSE research indicated that the impact would be far lower (IDR 40-70 per kWH).

Table 6.2 Cost of pollution control equipment in India

Technology required	Approximate cost (Rs million/MW)
ESP upgradation	0.5–1.5
FGD	4.0–5.0
Partial FGD	2.5–3.0
De-NOx burners	1.0–1.5
SCR/ SNCR	2.0–2.5

Note: Rs 1 = IDR 207.7
Source: Centre for Science and Environment (CSE), 2016

The data of air pollution equipment that are installed in power plant using coal are using new technoloy of boiler e.g. Super Critical as compared to the technology used in the older Subcritical technology resulting in different pollution emission as shown by the emission of Cirebon using Super Critical boiler 0.60 $\mu g/m^3$ compared to the Suralaya and Indramayu using Subcritical boiler emission of respectively 1.07 $\mu g/m^3$ and 3.02 $\mu g/m^3$. The new technology using pollution technology will reduce pollutant emission. This will require the development of better pollution emission standards that are more stringent for new power plant and will require investment in building better pollution control technology. Since it will require time to install the new technologies, it is proposed that the standards developed will have to be based on the year of the power plant technology and also the pollution control technology as follows.

Table 6.3 Suggested standards based on age distribution of coal-based capacity

Commissioning date	Aggregate capacity (MW)	Suggested standards (mg/Nm^3)		
		PM	SO_2	NO_x
Total existing	24,764	-	-	-
Pre-1990	1,730	150	850	750
1990-2005*	6,284	50–100	300–600	300–600
2006 onwards*	16,238	50	200–300	200–300
Upcoming capacity	34,800	30	100	100

Note: **Range may vary based on size with smaller units having looser norms*
***Age data not available for 512 MW of existing capacity*
Source: *Indonesia's Coal Power Emission Norms: Lesson from India and China, CSE/ICEL/REEI, 2017*

Tighter emission standards should be imposed on new generation units.

At present, Indonesia does not have an emission standard for mercury. From the field measurement made to the three CFPPs, mercury released ranged between 0.0006 – 0.003 mg/Nm^3. These values will easily meet the European (Germany) standard at 0.03 mg/Nm^3. However, not all CFPP in Indonesia generate low mercury emission, hence, it is suggested new emission standard for mercury in Indonesia is 0.3 mg/Nm^3.

In China, the standards are based on the region, where in Beijing the mercury standard is 0.0005 - 0.03 mg/Nm^3, Tianjing 0,0005 mg/Nm^3 and Hebei 0.03 - 0.05 mg/Nm^3. For other areas in China, the mercury emission standard are set at 0.3 mg/Nm^3. Other reference that can be used are the US mercury emission standard at 0.001 – 0.006 mg/Nm^3.

Even though mercury concentration in emission for 3 CFPPs are low ranging 0.0006 – 0.003 mg/Nm^3, the high capacity of CFPPs will generate large volume of flue gas released. Hence the accumulated released mercury is high as shown in Table 4.10. Looking at the data where mercury released from Suralaya, Cirebon and Indramayu are 9.15, 20.53 and 57.31 kg/year respectively, then it is proposed that the Indonesian standard takes into account the mercury emission load.

Another alternative of setting standards is based on the carrying capacity of mercury in the region. As an example, in Java, if the carrying capacity of mercury is low then the standard can be set tighter.

Technology

For reducing mercury emission, availability of technology is very important. From 93 units power plants 72 units are using ESP; 9 units are using ESP, FGD & low NOx burner; 3 units are using ESP, FGD, low NOx burner, bag filter; 3 units using ESP, wet FGD; 1 unit using multi cyclone & low NOx burner; 1 unit using bag filter only and 4 units using ESP & cyclone deduster. For the efficiency in the removal of mercury, ESP + FGD are proposed for new power plants.

The type of boiler that is more efficient is the super-critical which is is used by Cirebon. It is proposed that new power plants use the super-critical and ultra-super-critical.

Tuning activities

From the data available in this study, Suralaya CFPP began operation in 1986 as compared to Indramayu CFPP, a new plant which began operation in 2011 but nevertheless concentration of mercury emission was lower in Suralaya.

From Suralaya Unit 6 it was mentioned that for the simultaneous reduction of pollution, the activities have been focused on reduction, balancing of secondary air (excess air tuning) and on combustion line optimization to improve the thermal efficiency, consequently resulting in reduction of fuel consumption and pollution release to stack.

The reduced excess air conditions resulted in lower fuel consumption in a more homogeneous combustion condition formation and maintenance.

Its environmental benefits are:

- Reduced CO_2 emissions by around t 67,000 tons/year
- Reduced dioxin/furans emissions of about 8.3 mgTEQ/y
- Reduced mercury emissions of about 233 g/year
- Reduced dust emissions of about 42.4 tons/year
- Reduced SO_x emissions of about 458 tons/year

Economic benefits of tuning activity

The economic benefits of reduced O_2 have been measured and quantified.

As boiler operates 2/3rd of the time at full load and 1/3rd of time at 75% load, the combined economic (reduced coal rate) and environmental (carbon credits from reduced CO_2) benefits of O_2 reduction has resulted in[18]:

- About 2,100,000 USD/y (35,200 t/y reduced coal consumptions assuming coal price of $ 60/t).
- About 340,000 USD/y from reduced CO_2 emissions (assuming carbon credits value of 5.13 USD/t as of June 2016 and U$D to €uro exchange rate of 1.13 as of late June 2016.
- About 410,000 USD/y due to reduced power to fans assuming 1 MW more power to consumers at 0.08 USD/kWh.

Old power plant can also carry out tuning activities depending on their individual capacity for tuning activities.

Coal washeries

Coal originating from mines consist of many impurities such as magnesium sulphate, sulphur in form of pyrites, slate and fire clay. These substances have higher specific gravity than pure coal around 1.28 or 1.30. The fact that their specific gravity is higher than pure coal makes separation possible. Coal is purchased according to its rigid specifications with respect s to size, sulphur and ash content, jigging or by heavy-media separation.

Advantages

Cleaning of coal has various advantages. Cleaning the coal at the mine site reduces the fixed carbon, volatile matter and ash content and traces of other elements like sulphur or phosphorus and other extraneous material like mud, clay dirt and parts of soft rock in the coal. By doing so, the following can be achieved :

- Transport and operating cost can be reduced by reducing the burden during transport, handling and processing.
- The real content of coal i.e. the fixed carbon can be increased by reducing its ash content.

[18] Combustion air optimization of unit 6 of Suralaya Power Plant Report, 2015

- There is a slowdown in process of metallurgical change and retard in the pace of chemical reaction due to the presence of such impurities.
- Process can be made efficient and pollution can be reduced.

For most of the coal that are used by power plants in Indonesia, their impurities will not require coal washeries. In this study, coal washery was not identified and supplied to CFPPs in Indonesia. Nevertheless, if impurities are high coal washeries will be required.

Power plant inventory and monitoring

The study only took mercury emission measurements from 3 (three) power plant and coal mercury contamination from 45 power plants. More accurate data will be required by the Ministry of Environment and Forestry through collaboration with other line ministeries to carry out an extensive inventory of mercury emissions from all power plant or if not possible by carrying out such activities from Indonesia's main large islands. This can be conducted by selecting 3 (three) power plants with different yearly activities, type of boiler technology, composition of coal, pollution control technology, air emission, fly ash, bottom ash, etc.

Monitoring is highly important to be carried out in knowing the pollution that is emitted to the air in real time. Hence, it will also be required by government through government regulation compelling power plants for continuous emission monitoring system (CEMS) to be installed. All CEMS data should be connected to the Ministry of Environment and Forestry or local environmental institutions. The Ministry of Environment and Forestry should develop the emission data base to take lead in controlling the emission especially for mercury through close coordinate with local environmental agencies and the Ministry of Energy and Mineral Resources. Leading generation companies should also independently collect the data to verify results.

The Ministry of Environment and Forestry in collaboration with the Ministry of Energy and Mineral Resources should also conduct studies for detailed cost analysis in installment of pollution control devices requiring direct engagement with various stake-holders. It will help in assessing the investment requirement for compliance with emissions standard if possible more higher.

6.1.3 FLY ASH AND BOTTOM ASH

Fly ash and bottom ash are hazardous waste from specific priority source as mentioned in Table 4 with waste code for fly ash B409 and for bottom ash B410. These two hazardous wastes are number 2 hazardous categories. Based on observations made in the Cirebon/Indramayu power plant, they obtained permit for recycling their waste into cement kiln for subtitute of silicate and in landfill class 3. In Article 145 point (4.a) of the Hazardous Waste regulation, the radioactive ≥ 1 Bq/cm should be put into Landfill l Class 2.

The standard of mercury for Landfill Class 1 is300 mg/kg, Class 2 between < 300 mg/kg and 750 mg/kg. For reused hazardous waste in Article 77 of the Hazardous Waste Management Regulation Number 101 year 2014, if the hazardous waste contained 1

Bq/gr for Uranium and Thorium or ≥ 10 Bq/gr of Calium, it will not be allowed for the reduce, reuse, recycling (3R) management.

The recommendation on the handling of fly ash and bottom ash is that , controlling and monitoring are very important for the power plant to compliance with standards in the regulation.

6.2. PROPOSED CAPACITY BUILDING ACTIVITIES FOR STAKE-HOLDER ON PUBLIC AWARENESS OF MERCURY AND CLEAN TECHNOLOGIES FOR REDUCING MERCURY EMMISSION

Capacity building activities will depend on the type of stakeholder addressed to:

1. Public

   Pocket handbooks to introduce the source, usage and impact of mercury will be necessary. This pocket handbook should be disseminated to the public through local government or NGOs.

2. Workers

   The higher risks of mercury impact are the workers. They will also need a pocket handbook on the process, mercury emissions, pollution control technology, environmental standards, safety equipment, storage and the impact to environment and health and emergency response. Workers dealing with coal should be provided the training.

3. Government officials

   Government officials should also need a pocketbook on the regulations, process, environmental standards, pollution control technology, safety equipment, storage, the impact of mercury to environment and health, emergency response, monitoring (CEMS). This pocketbook should be used by government officials and will also require training.

4. Workshops for all stakeholders including NGO, the media, workers, local and central government. Such workshops can be facilitated also by regional offices of the Ministry of Environment and Forestry.
5. The Government of Indonesia should conduct monitoring using the CEMS to inform the public and also carry out law enforcement activites.
6. Civil society must work towards building public support for emission reduction by dissemination information about long-term cost of emissions and its impact on health and livelihood. This will help build support for government intervention as well as adress public apprehension regarding the tariff impact of pollution control.

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APPENDICES

A. SCHEDULE OF WORK

Workplan Project on Hg emissions from coal-fired power plants in Indonesia

Activities	Completion time frame	TIME 2017											
	[months since signing]	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Task 1 Coal information	10												
a) Collect available information coal consumed for electricity production and by coal source, and available information on coal analysis													
b) Collect or estimate information on the coal consumption (projected coal use) for electricity generation through 2025.													
c) Collect and analyse untreated Indonesia coal samples from power plants													
c.1. Coordination													
c.2. Letter correspondent to Coal Mining Companies													
c.3. Coal Samples shipment from Coal Mining to Tekmira													
c.4. Analysis													
c.5. Reporting													
d) Collect and analyse untreated Indonesian coal samples from coal washeries													
d.1.-d.5. Idem c.1.-c.5.													
e) Inter-calibration of analysis													
e.1. Lab Identification													
e.2. Pricing													
e.3. Sample Analysis													
e.4. Reporting													
Task 2. Power plant information	7												
a) Collect available information on installed power plant capacity and electricity generation by coal combustion as of 2016, including the approximate locations of power plants													
b) Collect available information on the configuration of any installed air-pollution control equipment and its typical operational efficiency													
c) Collect available information on measurements of Hg emissions from power plants in Indonesia													
d) Conduct mercury measurements at minimum 3 selected power plants (US EPA Mercury Measurement Toolkit recommended).													
d.1. Confirmation of Laboratories for Emission Sampling and Analysis													
d.2. Selection with MEMR on Coal Power Plant location													
d.3. Coordination between Lab for Emmision and Coal Power Plant													
d.4. Mercury Sampling Campaign at Selected Power Plant													
d.5. Reporting													
Task 3 Mercury emission inventories and future estimates	9												
Task 4 Final report preparation	12												
a) Quarterly report													
Task 5 Capacity building and national action plan	10												
a) Conduct capacity building activities and information seminar													
b) Develop options to reduce mercury emissions from coal-fired power sector													

B. TABLE OF ACTIVITIES

No	Activities	Date	Result / Follow up
1	Meeting to discuss mercury emissions quality standards and revise Environment Ministerial Decree No. 21 Year 2008	January 11, 2017	3 candidate of coal-fired power plants for sampling: Cirebon CFPP, Suralaya CFPP 2, Lontar CFPP. Directorate General of Electricity (DGE) – Ministry of Energy and Mineral Resurce (MoEMR) together with Ministry of Environmental and Forestry (MOEF) will urge all coal-based power plant in Indonesia to measure mercury emissions including mercury analysis of coal, fly ash, bottom ash by mentioning the methods and requirements of testing laboratories.
2	Coordination with Deputy Director of Environmental Protection for Electricity	January 19, 2017	Audience with Head of Sub Directorate of Electricity Environmental Protection to discuss the continuation of activities
3	Submission of letter No. S.111/PB3/PB3/PLB.1/1/2017 regarding the preparation of power plant mercury emissions sampling to the Director of Technical and Environment of Electricity	January 20, 2017	Waiting for MoMER response
4	Directorate of Air Pollution Control (MOEF) submitted a letter No S-37/PPU/P3U/PKL-3/1/2017 to CFPPs	January 31, 2017	Suggestion to measure mercury as part of routine monitoring by the CFPP and to be reported as RKL(Environment Management Plan)/RPL(Environment Monitoring Plan) document, and separately reported.
5	Submission of letter No. S.285/ PB3/PB3/PLB.1/2/2017 about CFPP data requirement	February 9, 2017	Waiting for MOEMR Response

6	Discussion USEPA Method 29 + Speciation in PT. Syslab Indonesia	February 20, 2017	Syslab confirmed to able to conduct the analysis of mercury using USEPA 29 with speciation Ontario Hydro
7	Coordination with TEKMIRA	February 21, 2017	Confimation on TEKMIRA to supervise Syslab on conducting mercury emission sampling using USEPA 29 with speciation Ontario Hydro
8	Coordination with Deputy Director of Environmental Protection for Electricity, DGE-MOEMR	February 22, 2017	The discussion on UNEP Mission and readiness 3 power plant for this activity
9	Discussion meeting progress and follow-up plan	February 23, 2017	Result and Follow up Submission overlay compliance with TOR by Mr. Anton Purnomo to be discussed at the meeting on March 2, 2017. Meeting with representative of MOEF regarding data requirement for project. The measurement method of mercury emissions has been agreed that the EPA 29 with speciation Ontario Hydro. Sampling on March 22 in Suralaya unit 2. *UNEP Mission* on March 20 – 24 *Submit project progress to Director of Hazardous Substance Management and reporting to Director general PSLB3 followed by submit letter to DGE – MoMRE regarding project and workshop plan*
10	Participated in the workshop energy efficiency and expert meeting on mercury emissions from coal combustion in South Africa	February 28 - March 3, 2017	2 members of the mercury team (Mr. Nixon and Mr. Anton)
11	Coordination meeting and data requirement on *Hg emissions from coal-fired power plants in Indonesia*’	March 2, 2017	Follow up *Director of Hazardous Substance Management to send letter regarding data requirement.* *Director Hazardous Substance Management propose additional member for mercury emission team.*

			Workshop preparation coordination
12	Submission of a letter from the Director General of PSLB3 - MOEF to Director General DGE - MOEMR about project activities and support for workshop on March 20, 2017	March 2, 2017	Sent to DGE – MOEMR
13	Coordination meeting with Deputy Director of Environmental Protection for Electricity DGE-MOEMR	March 10, 2017	Workshop preparation
14	Preparation meeting of Workshop *'Hg emissions from the coal-fired power sector in Indonesia'*	March 16, 2017	Result is matrix for workshop progress 1 where opening speech text, welcoming address text, and most of speaker presentasion have been collected and the invitation for workshop participant have been sent
15	Preparation meeting finalization of Workshop *'Hg emissions from the coal-fired power sector in Indonesia'*	March 17, 2017	Venue and consumption have been finalized
16	Workshop *'Hg emissions from the coal-fired power sector in Indonesia'*	March 20, 2017	Guest speaker was Gunnar Futsaeter (UNEP), Lesley Loss (IEA), the Director of Technical and Environment of Electricity (MOEMR), Director of the Air Pollution Control (MOEF), Head of Sub Directorate for Hazardous Substance Handling (MOEF), and Head of Sub Directorate for Waste and Radiation Safety (MOH).
17	Coordination meeting in Lontar CFPP	March 21, 2017	There is no lift for the measurement of emissions
18	Coal and mercury emission sampling in Suralaya CFPP unit 2	March 22, 2017	Sampling of mercury emission conducted by Syslab while the analysis of coal, fly ash and bottom ash samples by TEKMIRA.
19	Site visit to TEKMIRA	March 23, 2017	UNEP satisfied with lab facilities
20	Meeting with Director General of Solid Waste, Hazardous Waste and	March 24, 2017	Reporting UNEP Mission activities

	Hazardous Substance Management		
21	Coordination meeting at MOEF	April 10, 2017	Coordination meeting for 2nd and 3rd mercury emission sampling
22	Coordination meeting at MEMR	June 19, 2017	Coordination meeting for Q1 report
23	Coal and mercury emission sampling in Cirebon CFPP	July 24-25, 2017	Sampling of mercury emission conducted by Syslab while the analysis of coal, fly ash and bottom ash samples by TEKMIRA.
24	Coal and mercury emission sampling in Indramayu CFPP	July 26-27, 2017	Sampling of mercury emission conducted by Syslab while the analysis of coal, fly ash and bottom ash samples by TEKMIRA.
25	Visit to TEKMIRA	July 31, 2017	Meeting and samples delivery
26	Prelimenary workshop	October 27, 2017	Meeting workshop with coal-fired power plant for data verification and shipment of coal samples at Ministry of Energy and Mineral Resources
27	Final workshop	November 9, 2017	Final workshop of the project at Ministry of Environment and Forestry

C. UNEP MISSION 20-24 MARCH 2017

Mission Programme
HG EMISSIONS FROM COAL-FIRED POWER SECTOR IN INDONESIA
Jakarta, 18-24 March 2017

Date / Time	Activities	Venue/Remark
SATURDAY, 18 March 2017		
	Arrival of Gunnar at Jakarta	Soekarno-Hatta (SH) International Airport
	Arrival of Lesley at Jakarta	Soekarno-Hatta (SH) International Airport
	Transfer to Hotel from Airport by Ridwan and Anton	Dafam Hotel Jakarta
SUNDAY, 19 March 2017		
11:00 onward	Pre-meeting with Ridwan and Anton	Dafam Hotel Jakarta
MONDAY, 20 March 2017		
07:00 – 08:00	Transfer to MOEMR	MOEMR, Kuningan
08:00 – 11:30	Workshop	MOEMR, Kuningan
11:30 – 12:00	Lunch break	MOEMR, Kuningan
12:00 – 15:00	Closed discussion with Mercury team	MOEMR, Kuningan
15:00 – 17:30	Transfer to Hotel Aryaduta in Tangerang City	Aryaduta Tangerang

TUESDAY, 21 March 2017		
08:00 – 09:00	Transfer to Coal-fired Power Plant (PLTU) Lontar	PLTU Lontar
09:00 – 12:00	Meeting in PLTU Lontar	PLTU Lontar
12:00 – 13:00	Lunch Break	TBD
13:00 – 15:00	Facility tour in PLTU Lontar	PLTU Lontar
15:00 – 17:30	Transfer to Hotel Royal Krakatau in Cilegon	Hotel Royal Krakatau in Cilegon
WEDNESDAY, 22 March 2017		
08:00 – 09:00	Transfer to PLTU Suralaya	PLTU Suralaya
09:00 – 12:00	Meeting in PLTU Suralaya	PLTU Suralaya
12:00 – 13:00	Lunch break	PLTU Suralaya
13:00 – 15:00	Facility Tour and Mercury Emission Sampling in PLTU Suralaya	PLTU Suralaya
15:00 – 21:00	Transfer to Hotel in Bandung City (TBD)	Bandung
THURSDAY, 23 March 2017		
08:00 – 08:30	Transfer to TEKMIRA	Bandung
08:30 – 14:00	Meeting and Laboratory tour in TEKMIRA	Bandung
14:00 – 18:00	Transfer to Dafam Hotel, Jakarta	Dafam Hotel Jakarta

FRIDAY, 24 March 2017		
08:00 – 08:30	Transfer to MOEF	MOEF, Jakarta
08:30 – 12:00	Wrap up meeting with Director General MOEF	MOEF, Jakarta
12:00 – 14:00	Lunch	MOEF, Jakarta
14:00 – 17:30	Transfer to airport	Soekarno-Hatta (SH) International Airport
17:40	Lesley departure	
21:00	Gunnar departure	

D. PROCEEDING OF THE WORKSHOP 20 MARCH 2017

Workshop on Hg Emission from Coal-Fired Power Plants in Indonesia

Jakarta, Indonesia, 20 March 2017

Workshop Report

Introduction

1. The Workshop on Hg Emission from coal-fired power plants in Indonesia was organized in Jakarta, Indonesia on 20 March 2017 hosted by The Directorate General of Electricity, Ministry of Energy and Mineral Resources (MOEMR), Republic of Indonesia. The workshop is a component of the "*Mercury emissions from the coal-fired power sector in Indonesia,"* a project between the Ministry of Environment and Forestry (MOEF), Republic of Indonesia and the UN Environment supported by the Basel Convention Regional Centre for South-East Asia/Stockholm Convention Regional Centre Indonesia (BCRC-SEA/SCRC Indonesia) as the subcontracting institution in the implementation of the project. The objectives of the workshop are to introduce the project to relevant stakeholders to obtain inputs and comments as well as to exchange information related to the project among the workshop participants.

Participation of the Workshop

2. The workshop was participated by participants from MOEF, MOEMR, coal-fired power plants, the State Electricity Company (PLN), BCRC-SEA/SCRC Indonesia and experts with a total of 109 participants.

Agenda of the workshop

3. The agenda of the workshop is provided in Attachment 1.

Opening Session

4. The opening speech was delivered by Ms. Tuti Hendrawati Mintarsih, Director General for Solid Waste, Hazardous Wastes and Hazardous Substances Management, Ministry of Environment and Forestry, Republic of Indonesia. She highlighted that mercury has become one of the prioritized chemical substances to be handled by MOEF. Currently Indonesia has a road map for mercury management for coal-fired power plants and mercury management in general. The Government of Indonesia is preparing a National Implementation Plan which refers to accurate data and information for mapping locations and potency of mercury use in Indonesia to determine priority measures in mercury management. She mentioned that in order to obtain data on coal use and mercury emission from coal-fired power plants, MOEF in cooperation with UN Environment and Directorate General of Electricity, MOEMR is

conducting activity on mercury emission inventory from coal-fired power plants. Ms. Mintarsih also expressed her thanks and appreciation to the workshop participants and hopes for commitment, cooperation and support from all stakeholders for the success of the activity.

5. Mr. Alihuddin Sitompul, Director of Electricity Programme Supervision, Ministry of Energy and Mineral Resources, Republic of Indonesia, delivered his welcoming remarks. He mentioned that coal use is still required as one of main energy source in national electricity development plan. Hence, measures should be taken on how to obtain the benefit while minimizing the adverse impact on human health and environment from coal use. In October 2013, the Government of Indonesia through the Ministry of Environment and Forestry signed the Minamata Convention in its commitment to manage mercury in Indonesia. He informed that within the electricity sector, mercury emission from coal-fired power plants can be reduced using air pollution control equipment already applied by coal-fired power plants. In future, it is planned to develop it to clean coal technology. Mr. Sitompul informed that UN Environment provided assistance to developing assistance under the Minamata Convention. Indonesia through MOEF has received support in form of small scale funding agreement for "*Mercury Emission from the Coal-Fired Power Sector in Indonesia.*" The objective of this activity is to increase understanding on mercury emission from coal-fired power plant and its reduction particularly as co-benefit programmes of various gas emission pollution controls. He also thanked UN Environment, International Energy Agency/Clean Coal Centre (IEA/CCC) and Ministry of Environment and Forestry, Republic of Indonesia for their cooperation in organizing this workshop and inviting coal-fired power plants in Indonesia and officially opened the workshop.

6. Following the opening session, Mr. Gunnar Futsaeter from UN Environment delivered presentation on implementing Minamata Convention on mercury focusing on technical support for coal emission from coal-fired power plants which comprised background, UNEP Global Mercury Programme, UNEP Global Mercury Partnership, BAT/BEP guidance on control of air emissions and UNEP Coal Project.

7. During discussion session, a question was raised on mercury partnership activities which had been carried out at present and guidelines for optimizing process to reduce emission. Mr. Futsaeter explained that an interactive programme called iPOG (Interactive Process Optimization Guidance) has been developed which will be further elaborated by resource person from IEA/CCC. The partnership on mercury has been carried out in China, Russia, South Africa, India, Vietnam (final stage), Thailand and Indonesia (starting 2017).

8. Ms. Tuti Hendrawati Mintarsih highlighted that the partnership activity will be very beneficial for Indonesia since in the national electricity development plan, coal is still used as one of main energy sources. It is hoped that this activity will continue with inventory, formulation of guidance for emission and development of options on how to

reduce mercury emission from coal power sector. Mr. Futsaeter mentioned that the activity should be finalized in year 2017, however, if continuation of the activity is deemed necessary, proposal for request for support can be submitted at the conference of the parties in the coming September. Many countries also still use coal as their main energy source hence attention and support are still focused on coal use rather than alternative for substitute. Furthermore, a participant raised question on the reason control is carried out in coal-fired power plants rather than in the source by controlling coal exploration from mining. The second question was request for clarification on mercury content based on coal type. If the coal is low-rank type, the mercury content is low and if it is bituminous, the mercury content is high. In response to the questions, Mr. Futsaeter said that mercury control is not feasible to be carried out at mines, however, several methods of impurities reduction are available such as coal washeries or other pre-treatments prior to entering the coal-fired power plants. Other participant also questioned on recommendation provided to China as one of the countries with high mercury emission. Mr. Futsaeter responded on several recommendations for China, which are development of proposal on mercury reduction, optimization of available technology and recommendation on mercury reduction with various alternatives of activities. UN Environment provided inputs and recommendation only but not formulating plans, it will be returned to the governments. Questions were also raised on general solution to control mercury emission according to similar activities already implemented in other countries and whether it is implementable in Indonesia. Other issue was on the high cost for air pollution control equipment while coal is being used as energy source due to its low price, resulting in increase of electricity price as consequence.

9. A panel discussion followed with four resource persons from MOEMR, MOEF and Ministry of Health (MOH). The first speaker, Mr. Munir Ahmad, Director of Technical and Environmental of Electricity, MOEMR, presented on electricity development plan and mercury emission potency. Mr. Dasrul Chaniago, Director of Air Pollution Control, MOEF, the second speaker, delivered presentation on air pollution control policy followed by Mr. Edward Nixon Pakpahan, Head of Sub Directorate of Hazardous Substances Handling, MOEF who spoke of national action plan on mercury emission reduction. Mr. Sonnny Priajaya Warouw, Head of Sub Directorate Waste and Radiation Safety, MOH, continued with presentation on national action plan on health impact caused by mercury exposure in year 2016-2020 (Minister of Health Regulation Number 57 Year 2016)..

10. During discussion session, a question was raised regarding disposal of waste containing mercury since company/institution to receive such waste is not yet available and export is expensive. Questions were also raised on format for mercury emission reporting, information on timeline and road map of national plan on mercury control which involves cooperation of relevant sectors such as environmental, electricity and health. This information is required for development of the coal-fired power plants in the future. A participant questioned on mechanism of mercury emission analysis which is an addition in the revised Minister of Environment and

Forestry Regulation Number 21 Year 2008. There was also a request to obtain results from researchs conducted in surrounding areas of coal-fired power plants in order to better understand on the health impact on community around the power plants.

11. In response to the question, Mr. Pakpahan from MOEF explained that at present there is no institution or company in Indonesia which utilize mercury directly and legally. Information on how to detect and isolate mercury to become Hg^0 or elemental mercury is already available. Details on mercury waste management can be further discussed at other opportunities. On reporting format for mercury emission monitoring, Mr. Chaniago from MOEF responded that since it is not mandatory at present, there is no specific format. Mechanism for mercury emission analysis should be carried out at accredited laboratories and accurate data is required as one of basis to determine standard quality. Mr. Warouw from MOH informed that Research and Development Agency, MOH, has conducted several researches and the result can be informed and disseminated. Regarding road map, the health sector is part of the national action plan on mercury reduction lead by MOEF and ready to support all activities. In health sector, national action plan on health impact caused by mercury exposure year 2016-2020 has been developed comprising seven strategies. At present, guidelines are being prepared on biomarker, identification of substances in biomarkers such as hair and nails in addition to in the environment (air, water, food, fish, et cetera), however, quality standards for the biomarkers are not yet available.

12. The last speaker, Ms. Lesley Sloss from IEA/CCC presented on Best Available Techniques (BAT) and Best Environmental Practices (BEP) and mercury project in Indonesia. Information on iPOG was also elaborated in the presentation. iPOG can be used to suggest potential reduction, estimate emissions and to “test” control technologies at coal-fired power plants. iPOG is a calculation programme based on established modeling and full size power plant data (such as coal type, moisture, ash, sulfure, chlorine, mercury, HHV, in single coal properties, coal blend properties, furnace condition, mercury control parameters and other data inputs. iPOG can be used by novices or experts with available plant data. And best used in conjunction with the POG and BAT/BEP guidance. the iPOG can be used to estimate speciation based on coal characteristics and plant configuration if monitoring does not include speciation of emissions. The iPOG is intended as a simple guide to a complex issue but not meant to replace expert consultancy. The use of POG/iPOG is effective as screening tools..

13. Following the presentation, question was raised on timeline of mercury activities in Indonesia. Ms. Sloss informed that the activity already started in early 2017 and during the week visit will be conducted to a coal-fired power plant for sampling and it is expected that by the end of 2017 the inventory of mercury emission in Indonesia will be finished. Information on sectors involved in the activity and the three selected coal-fired power plants namely PLTU Suralaya, Lontar and Cirebon for sampling and mercury emission analysis was also mentioned by Mr. Anton Purnomo as the moderator and experts in the activity. Method on mercury emission capture and risks

of mercury exposure from coal to operators at the coal-fired power plants were also discussed during this session.

14. At the end of the workshop, Mr. Ridwan D. Tamin, Director of BCRC-SEA/SCRC Indonesia, delivered his closing remarks and expressed great thanks to Directorate General of Electricity, MOEMR as the host of the workshop and to all participants.

Attachment 1. Agenda of the Workshop

Workshop Agenda

Hg emissions from the coal-fired power sector in Indonesia

Date: 20 March 2017

Time	Programme	PIC
08:00 - 08:30	*Registration*	Secretariat
08:30 - 08:40	*Opening Speech*	Directorate General Ministry of Environment and Forestry
08:40 - 08:50	*Welcoming Address*	Directorate General Ministry of Energy and Mineral Resources
08:50 - 09:10	• *Project Background* • *Presentation of the project Hg emissions from the coal-fired power sector in Indonesia in the context of Minamata Convention*	UN Environment, Gunnar Futsaeter
09:10 - 09:25	*Coffee break*	
09:25 - 09:40	*Electricity production from coal-fired power plant-CFPP (Coal types used, properties, demand and projections of coal and electricity from CFPP, efficiency improvement and pollution prevention efforts CFPP)*	Director of Technical and Environmental of Electricity MEMR
09:40 - 09:55	*Monitoring of air pollutants and air quality regulations in Indonesia*	Director of Air Pollution, MOEF
09:55 - 10:10	*Minamata implementation plans*	Director of Hazardous Substance Management, MOEF
10:10 - 10:25	*National Plan on Health Impact from Mercury*	Director Public Health, Ministry of Health
10:25 - 10:45	• *Presentation on BAT/BEP Emission Control and Reduction* • *Live iPOG presentation (iPOG= interactive Process Optimization Guidance. A tool that can demonstrate the effect (quantify emissions reductions) of various types of controls, based on coal type*	IEA CCC, Lesley Sloss
10:45 - 11:15	*Open discussion/questions*	Moderator, Anton Purnomo
11:15 - 11:30	*Closing Remarks*	Director BCRC-SEA
11:30 - 12:00	*Lunch*	

E. PROCEEDING OF THE FINAL WORKSHOP TO DISSEMINATE INFORMATION ON THE STUDY, JAKARTA, 9 NOVEMBER 2017

Workshop on Hg Emissions from the Coal-Fired Power Sector in Indonesia

Jakarta, Indonesia, 9 November 2017

Workshop Report

Introduction

1. The workshop on Hg Emissions from the Coal-Fired Power Sector in Indonesia was held in Jakarta, Indonesia, in November 9th 2017 and hosted by the Director General for Solid Waste, Hazardous Waste and Hazardous Substances Management, Ministry of Environment and Forestry, Republic of Indonesia. The workshop is a component activity of the "Mercury emissions from the coal-fired power sector in Indonesia," a project between the Ministry of Environment and Forestry (MOEF), Republic of Indonesia and UN Environment supported by the Basel Convention Regional Centre for South-East Asia (BCRC-SEA). BCRC was selected as the sub-contracting institution in the implementation of the project. The purpose of the workshop is to update the progress of the project, particularly on the primary data obtained from coal samples and mercury emissions analysis from several coal-fired power plants (CFPP) in Indonesia. In addition, the plants to reduce mercury emission in the coal-fired power plants was elaborated. The workshop also provided opportunities to exchange information on mercury issues from various stakeholders and to collect inputs from the participants.

Participation of the Workshop

2. The workshop is attended by participants from MOEF, Ministry of Energy and Mineral Resources (MOEMR), coal-fired power plants operators, the State Electricity Company (PLN), BCRC-SEA/SCRC Indonesia and experts.

Agenda of the workshop

3. The agenda of the workshop is provided in Attachment 1.

Opening Session

4. The first opening speech was delivered by Mr. Ridwan D. Tamin, Director of BCRC-SEA/SCRC Indonesia. Mr. Tamin informed the purpose of the workshop and the scope of discussion as related to the findings of the project.

5. Mr. Munir Ahmad, Director of Electricity Program Development, Directorate General of Electricity, Ministry of Energy and Mineral Resources, delivered his opening remark. He informed that subject to Nation's General Electricity Plan 2015-2034, electricity demand for the next ten year is estimated to increase around eight to nine percent per

year. The Government of Indonesia has launched a 35,000 MW electricity project as one of its several program to achieve the electrification ratio of 97.35% by 2019. Based on energy mix projection until 2026, the main energy source for power plant in Indonesia still utilize coal, due to the high coal reserve potency in Indonesia. The domestic use is still not optimized and the price is relatively lower compared to other energy sources. Even though coal use will increase, the emission will be controlled and reduced by clean and environmentally sound technology at the power plants. This is in line with the Government of Indonesia's commitment in October 2017 through the Ministry of Environment and Forestry which signed the Minamata Convention with consequences of restricting, reducing and eliminating mercury use in the industry and mining sectors.

6. The next opening remark was delivered by Mr. Sayid Muhadhar, Director for Verification of Hazardous Waste and Non-Hazardous Waste Management, Ministry of Environment and Forestry. He highlighted the importance on the correlation between mercury emission reduction and efficiency increase in CFPPs, whether the reduction in mercury emission will have an impact in efficiency increase in CFPPs which contributes to energy saving, and vice versa. He also mentioned the mercury originating from the cinnabar mining as the current main issue on mercury. The Presidential Regulation is currently being processed as one of the efforts in mercury management in Indonesia. Mr. Muhadhar thanked the UN Environment, International Energy Agency Clean Coal Centre (IEA/CCC), MOEMR and power plant operators for their cooperation in organizing the workshop and officially opened the workshop.

Technical Session and Discussion

7. Ms. Lesley Sloss from IEA/CCC gave the first presentation on the Minamata Convention and mercury emission from CFPPs which includes mercury as global issue, Article 8 of the Minamata Convention, guidelines on *Best Available Techniques* (BAT) and *Best Environmental Practices* (BEP) under the Minamata Convention. Guidelines for monitoring and real implementation of action plans to reduce mercury emission were also presented.

8. During the discussion session, participants discussed on the revision of government policy on new standard emission limits for mercury emission from CFPPs and obligation to measure mercury emission at Continuous Emission Monitoring Systems (CEMS). Participants also discussed on gathering information on available technologies to control mercury from the Minamata Convention website and the effect of bromine and chlorine injection and their use.

9. Panel discussion on the project progress followed with four resource persons involved in the national mercury team. The first panelist is Mr. Ilham from Directorate General of Electricity, MOEMR, who presented on overview of CFPPs in Indonesia related to mercury emission. Ms. Retno Damayanti from Research and Development Center of Mineral and Coal Technology, MOEMR, presented on overview of coal in Indonesia and analysis results. The third speaker is Dr. Anton Purnomo from BCRC-SEA/SCRC Indonesia. He spoke of mercury emission from CFPPs in Indonesia. Ms. Masnellyarti Hilman from BCRC-SEA/SCRC Indonesia, concluded with presentations on options to reduce mercury emission from coal-fired power plants.

10. During discussion session, participants discussed on renewable energy distribution in Indonesia, technical implementation of coal washeries and its investment and the analysis result of mercury emission from the coal-fired power plants in the project. Participants also discussed the information of listed institution that are capable in measuring mercury emission accurately as well as impact of government's measures plan to reduce coal use in 2012-20125 on the sustainability of coal-fired power plants in Indonesia. MOEMR responded that electricity demand will increase due to renewable energy source and in 2026 coal use will also increase due to the 35,000 MW electricity project in Indonesia. Furthermore it is important to maintain the sustainability of coal-fired power plants in Indonesia. Ms. Hilman mentioned that mercury emission standard of 0.03 pm is the recommended value based on current measurement result of the project. CFPPs operators also suggested to measure their mercury emission and submit the result to MOEF for their consideration in determining the mercury emission standard value. For more accurate data, it is also suggested to take into account the appropriate time in sampling mercury emission (gas, fly ash and bottom ash) in accordance with coal input sample being analysed in order to produce mass balance which is more representative between input and output of mercury sample. CFPPs operators are also recommended to obtain detailed information on types of laboratory accreditation from websites of National Standardization Agency of Indonesia or National Accreditation Committee.

11. The next speaker was Mr. Wojciech Jozewicz, a representative from Global Mercury Partnership. He did the presentation on Process Optimization Guidance, which included report on coal combustion in energy sectors covering coal characterization and mercury emission in 3 CFPPs, UN Environment tools (POG & iPOG and BAT/BEP), mercury emission minimization and future potential projects. Following the presentation, participants discussed on comparison of various mercury capture technologies namely *fabric filter* (FF), *electrostatic precipitator (ESP) and electrostatic-bag precipitator* (EBP), as well as discussion on bromine and chlorine injection. Participants also discussed on future potential projects related to mercury emission reduction in Indonesia with funding from Global Environment Facility **(**GEF) and in-kind contribution from the government. Closed cooperation among relevant stakeholders such as CFPPs operators, government and experts is highly crucial for the implementation of mercury emission reduction activities. Mr. Wojciech also informed that iPOG can be downloaded at the following link : http://web.unep.org/chemicalsandwaste/global-mercury-partnership/mercury-control-coal-combustion

12. Mr. Kris Pranata from Kaltim Prima Coal (KPC) presented on emission from CFPP PT. KPC. Participants then discussed on coal washeries conducted by PT. KPC and its coal dust utilization.

13. The last speaker was Ibu Sonia from Balifokus who presented on environmental issues related to mercury. The presentation was followed with discussion on regulation for mercury emission from artisanal small-scale gold mining as the largest contributor to mercury emission and guidelines from government to manage mercury emission from CFPPs. It was informed that the obligation under the Minamata Convention is to reduce emission from CFPPs. Implementation of BAT/BEP in CFPPs sectors is one of the efforts to reduce the mercury emission. From the preliminary analysis result, the mercury emission from CFPPs in Indonesia is indicated to be low. However, further steps will be required to obtain more accurate results and this preliminary analysis

could be used as input for the government to determine measures to reduce mercury emission from CFPPs.

14. At the end of the workshop, Mr. Ridwan D. Tamin, Director of BCRC-SEA/SCRC Indonesia, delivered his closing remarks and expressed his appreciations to all workshop participants.

Agenda Workshop

'Hg emissions from the coal-fired power sector in Indonesia'

9 November 2017

Time	Programme	PIC
08.30 – 09.00	Registration	Secretariat
09.00 – 09.30	Opening Remarks / Welcoming Address • BCRC-SEA • Ministry of Energy and Mineral Resources • Ministry of Environment and Forestry	• Director BCRC-SEA • Director for Technical and Environment of Electrical Power, MOE&MR • Director of Hazardous Substances Management, MOEF
09.30 – 10.30	Keynote address: Mercury Convention and Hg emissions from the coal-fired power sector	Lead - UN Environment Coal Partnership
10.30 – 10.45	Coffee break	
10.45 – 12.00	Presentation report of the Hg emissions from the coal-fired power sector in Indonesia • Overview of Coal-fired Power plant in Indonesia • Overview of Coal in Indonesia and its analysis result • Mercury Emission in Indonesia • Options on mercury emission reduction from power plant	Mercury Emission from Coal-fired Power Plant Team • Ilham • Retno Damayanti • Anton Purnomo • Masnellyarti Hilman
12.00 – 12.30	Open Discussion	
12.30 – 13.30	Lunch	
13.30 – 14.00	Power Plant technology, prospect in Indonesia	PLN National Electric Company
14.00 – 14.30	Process Optimization Guidance	Jozewicz Wojciech, UNEP Expert
14.30 – 15.00	Coal technology, challenges in Indonesia	PT. Kaltim Prima Coal PT. Adaro Indonesia PT. Kideco Jaya Agung
15.00 – 15.30	Environmental Issues on Mercury	NGO
15.30 – 16.00	*Open Discussion*	
16.00	*Closing Remarks*	Director of Hazardous Substances Management, MOEF