An assessment of climate transition risk and opportunities for Indonesia's State-Owned and largest Electricity Company

by

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List of abbreviations and acronyms

ADB	Asian Development Bank
APLSI	Electricity Producers Association of Indonesia
BPS	Central Bureau of Statistics, Indonesia
C	Celsius
CAIT	Climate Data Explorer by World Resources Institute
CCGT	Combined Cycle Gas Transmission
CDM	Clean Development Mechanism
CER	Carbon Emissions Reductions
CO2	Carbon Dioxide
CSP	Concentrating solar power
EBT	New and Renewable Energy
ETS	Emissions Trading Scheme
EU	European Union
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
GHG	Green House Gases
GoI	Government of Indonesia
ICP	Internal Carbon Price
ICER	Indonesia Certified Emission Reduction
IEA	International Energy Association
IESR	Institute of Energy Services Reform
IPCC	Intergovernmental Panel of Climate Change
IPPs	Independent Power Producers
KMC	kilometer circuit
LULUCF	Land Use and Land Use Change from Forestry
LCOE	Low Carbon
MEMR	Ministry of Energy and Mineral Resources
MVA	Megavolt Apmere
MW	Megawatt
N/A	Not Applicable
NDC	National Determined Contribution

NFP	National Focal Point
O&M	Operations and Maintenance
PLN	Perusahaan Listrik Negara
PV	Photovoltaic
PWC	Price Waterhouse Coopers
REC	Renewable Energy Credit
RUPTL	Electricity Business Supply Plan
SEA	South East Asia
SOE	State Owned Enterprise
T&D	Transmission & Distribution
TCFD	Task Force on Climate related Financial Disclosure
TWh	Terawatt-hour
UNFCCC	United National Framework on Climate Change
USC	Ultra-Super Critical
USD	United State Dollars
WRI	World Resources Institute
WWF	World Wide Fund

1. Executive Summary

Electricity sector is an important player in the Climate Change arena. It is one of the major contributors to the global greenhouse gas emissions. Use of fossil fuels such as coal, natural gas and oil are primary cause of the greenhouse gas emissions in the electricity sector. At the same time, the sector is also vulnerable to the potential physical (direct) and transition risks (response to direct risks) of climate change. This is also true for Indonesia, an emerging economy in South East Asia and one of the most populous countries in the world. It is also one of the only few countries relying on coal for electrification.

This study assesses the climate transition risks of Indonesia's largest electricity provider and state owned company, Perusahaan Listrik Negara (PLN). It provides an overview of the transition risks and opportunities for PLN and the associated financial impact.

The first section provides an overview of climate change risk in the electricity sector and its importance. Climate Change comprises of physical and transition risks. Transition risk includes policy and legal risks, technology and market risks, and reputation risks.

The second section provides the background of Indonesia's electricity sector. Power sector is one of the top three contributors to Indonesia's greenhouse gas emissions, which includes electricity and heat generation. PLN is the country's sole provider for electricity supply, owning hundred percent of the transmission and distribution network in Indonesia. However, the power generation is divided between PLN and other private sector companies. Majority of the country's power generation comes from burning of fossil fuels. This includes coal, oil and natural gas. Being a state owned enterprise and the only electricity supplier, PLN's role in contributing towards Indonesia's national targets for greenhouse emissions reductions is potentially significant.

The third section provides description of the research methodology applied for the study. This includes literature review and data analysis using primary and secondary research. Secondary analysis included review of important national planning and policy documents such as the country's energy policy, and the general electricity supply plan. Primary research included conducting a number of virtual stakeholder interviews. This included PLN representatives, regulators, sector specific think tanks, and professional associations. Following the data collection, scenario analysis was performed based on different electricity supply and applied energy mix forecast until 2050. The three scenarios assessed included; a Business as Usual, Adjusted lowered growth in energy demand, and phase-out coal.

The fourth chapter provides the list of identified climate transition risks and opportunities for the company. Key transition risks identified include pressure to reduce greenhouse emissions, reputational risk, and early retirement of fossil fuel based plants following no-coal by 2050 scenario. Besides climate risks, the analysis indicate potential climate transition opportunities which could potentially create new revenue streams for the company. These include battery-based electric vehicles and electric cooking stoves besides others.

The fifth chapter provides the summary of the climate transition risks and opportunities and the associated financial impacts. This includes summary of political and legal risks, market and technological risks, and reputation risks. The assessment concludes climate change to be a material risk to the company, leading to potential financial impact of multi-billion dollars if left unmanaged.

The sixth chapter provides recommendations for PLN to consider for managing climate risk. Adopting an integrated approach towards low carbon energy transition is recommended. This includes taking a number of steps. These are summarized as below;

- Develop a climate policy based on two pillars. First, PLN should manage its own GHG footprint, and develop an emissions reduction target to be in line with Indonesia’s national target to keep the emissions level below 1.5 degree Celsius. Second, it should increase the share of the renewable energy in the energy portfolio and eventually phase out coal by 2050.
- PLN needs to assess climate risks and opportunities at corporate and asset level. This includes assessing both physical and transition climate risks. Risk assessment based on scenario analysis that is in line with the defined climate policy would help to provide PLN with possible energy transition pathways.
- Develop a management approach including a range of adaptation and mitigation measures. This would help PLN to create the required business resilience towards the risks and transition towards the low carbon energy. Potential GHG Mitigation options were explored through a heat map. This was developed to identify most feasible options by comparing potential reduction and mitigation measures for PLN such as energy efficiency, fossil fuels and renewable energy sources. The heat map indicates hydropower and solar power to be the most feasible options for PLN’s future energy mix among other options compared.
- An early stakeholder identification and engagement process would allow an informed strategy development and managing stakeholder expectations for the company.
- Finally, PLN needs to integrate the climate strategy as part of the company’s annual business plan for electricity supply for Indonesia. This means to elevate the responsibility of climate change to strategic business planning level from its current confined level, which is limited to health, safety and environment (HSE) department, responsible to identify only physical climate risks for the company’s selected assets.

Finally, the seventh chapter lists the study limitations.

The list of questionnaires and methodology used for developing GHG mitigation heat map are provided in the appendices.

2. Climate Change Risk and Electricity Sector

The electric utility sector is an important player in the Climate Change domain (Gerlak et. al 2018, pg 1). It is one of the significant emitters of global greenhouse emissions accounting for 35% of global emissions in 2010 (IPCC, 2014a). Burning of fossil fuels such as coal, oil and natural gas are main sources of these emissions. In 2018, coal-fired power plants accounted for 30% global CO2 emissions and were the main reason for global emissions growth (International Energy Association (IEA), Global Energy and CO2 status report, 2019). Majority of these plants are found in Asia with an average age of twelve years. This is much younger compared to their average economic life span of around 40 years. (IEA, 2019)

Climate risk is outlined as "a function of the probable climate event increased by the severity of impacts and therefore the vulnerability to those impacts". (Johnson et.al, 2020, pg 266). This includes 'direct' climate risk i.e. exposure of a power plant to a hazardous climate event (example floods) and 'indirect' climate risks i.e. exposure of power operating companies to actions related to managing the direct climate risks (example, emissions cap and carbon tax).

Climate Change Risks

The TCFD (Task Force on Climate related Financial Disclosure) calls direct and indirect risks of climate change as 'physical risks of climate change itself' and the 'transition risks of shifting to a lower carbon economy' respectively. (TCFD, 2021).

Physical risks

Physical risks include the direct risks leading to a potential change in the physical environment. (Johnson et.al, 2020). These risks can be 'acute' (extreme weather and climate events) and 'chronic' (long term changes in weather and climate such as sea level rise) (TCFD, 2017). Acute risks have the tendency to "disrupt power plant assets and operations, the economic value chains and the communities in which they operate" (Johnson et. al, pg. 267). Whereas chronic risks could impact the availability and reliability of resources required for power production and operation. For example, availability of water resources, and reliability of renewable sources such as irregular wind patterns and solar radiance levels (TCFD, 2017).

A study of climate vulnerability of electricity sector in Asia and the Pacific region suggests the sector being vulnerable to climate risks. (Asian Development Bank, 2012). Table 1 below provides a summary of the potential impacts of climate change by each technology type on electricity generation, transmission and end use in Asia. Flooding is identified to significantly impact most of the technologies except for wind, solar and geothermal technologies.

Table 1 Potential Impacts of Climate Change on Electricity Sector: Generation, Transmission and End Use (Source: Asian Development Bank, , 2012, page 45)

Technology	Λ Air Temp	Λ Water Temp	Λ Water Availability	Λ Wind Speed	Λ Sea Level	Floods	Heat Waves	Storms
Coal	1	2	1-3	-	-	3	1	-
Oil	1	2	1-3	-	-	3	1	1
Natural Gas	1	2	1-3	-	-	3	1	1
Nuclear	1	2	1-3	-	2	3	1	1
Hydropower	-	-	1-3	-	-	3	-	1
Wind	-	-	-	1-3	3	1	-	1-3
Photovoltaic	1	-	-	1	-	1	1	1
CSP/Solar tracking	-	-	2	2	-	1	1	2
Biomass/Biofuel	1	2	2	-	3	3	1	-
Geothermal	-	1	-	-	-	1	-	-
Ocean	-	1	-	-	1	N/A	-	3
T&D grids	3	-	-	1	3	1-2	1	2-3
End use	2	-	-	-	-	-	3	-

CSP= Concentrating solar power,

Λ = change in,

T&D= Transmission & Distribution

Notes: 3= severe impact, 2= medium impact, 1= limited impact, - = no significant impact, N/A= not applicable

Transition Risks

Transition risks are indirect risks related to managing physical climate risks. These include risks from climate mitigation and adaption actions such as government regulations, entry of new competitors and competitor actions for climate risk, and changes due to consumers or citizen's preferences. Transition risks may lead to fossil fuel assets to become "devalued and even stranded". (Johnson et.al, 2020 pg. 267). Assets become stranded when they are declared to be of longer in use due to various reasons.

The TCFD (2017), categorizes transition risks into three types. These are explained below.

- Policy & legal risks
- Technology and market risks
- Reputational risks

Policy and legal risks: These risks are pertinent to any policy or regulatory and potential liability issues related to climate change which potentially impact energy investments. (Johnson et. al, pg 267). Examples of policy risk could include "governments implementing a price for carbon emissions or restrictions on the use of certain energy sources" (SASB, 2018); shifting towards lower carbon energy sources (TCFD, 2017); and promoting sustainable practices such as energy efficiency and land use. Legal or litigation risks could include potential liability issues resulting due to damage arising out of failure of managing climate risk. For example, governments impose penalties for exceeding GHG emissions or for the use of fossil fuels.

Technology and market risks: Technology risks are related to the technological advancement and innovation focused on low carbon economic transition. For example energy efficiency technologies, renewable energy, carbon capture and storage technology solutions. These factors could affect the investment and operations cost of the power plant. Whereas, market risks are related to the changing environment of the power sector. For example market demand and supply, shifting customer behavior due to preference towards low carbon technology, and scarcity of raw materials and fuels. For example, reduced demand of fossil fuel reliant energy due to increased costs of operation and regulatory changes.

Market Reputation: These include perception risks as a result of stakeholder's assessment of company's response towards climate change (e.g. financial institutions, asset managers, shareholders, communities). This results in the form of a pressure for companies to divest from fossil fuel based business into cleaner energy sources. (TCFD, 2017).

Importance of Climate Risk Management in the Electricity sector

Climate risk management can be defined as a process that includes "knowledge and information about climate-related events, trends, forecasts and projections into decision making to increase or maintain benefits and reduce potential harm or losses" (Travis and Bates, 2014, pg 1).

There are three reasons why climate risk management is critical to electric utility industry. (Gerlak et. al, 2019). These are stated in Table below.

Table 2 Why climate risk management is critical to electric utility industry.(Adapted from Gerlak et. al, 2019, p.13)

i.	Electric utilities provide services (e.g. societal, cultural and economic service). Hence, climate risk management ensures the industry's readiness towards the potential disruptions.
ii.	Electric utilities have a financial interdependency as they are linked to support economic development of the country. A major climate change impact could result in the utility loss and possibly increased rates leading to potential financial stress to consumers.
iii.	The complex infrastructure of electric utilities is exposed to a wide range of threats. For example extreme risk due to regional vulnerability of extreme weather events.

3. Case of Indonesia's Electric Utility

Indonesia is one of the fastest growing economies in South East Asia (World Bank, 2019). It is also one of the twenty largest contributors of the Greenhouse gas emissions countries (WWF, 2018). Indonesia is a signatory to the 2015 Paris climate agreement. Under that framework, Indonesia has committed to 29% national emissions reductions by 2030 from the business-as-usual scenario and 41% with international support (Indonesia, NDC, 2016). Indonesia's greenhouse gas (GHG) emissions levels were recorded at 889 Metric Tons CO2equivalent in 2017 (Climate Action Tracker, 2020). Fuel combustion is the largest driver of overall GHG emissions, accounting for 65% of total GHG emissions (Climate Transparency, 2020). The industry sector contributes the most, at 37%, followed by transport (27%) and power sector (27%). (Climate Transparency, 2020). Power sector includes electricity and heat generation. (See Figure 1)

In order to reduce the poverty rate below 4% in Indonesia, the government forecasts an annual average economic growth rate of 6% by 2025 (Government of Indonesia, 2016). At present, around 14 million Indonesians are without electricity access (IEA, 2018). These facts indicate continued growth in demand for electricity in Indonesia in the coming years.

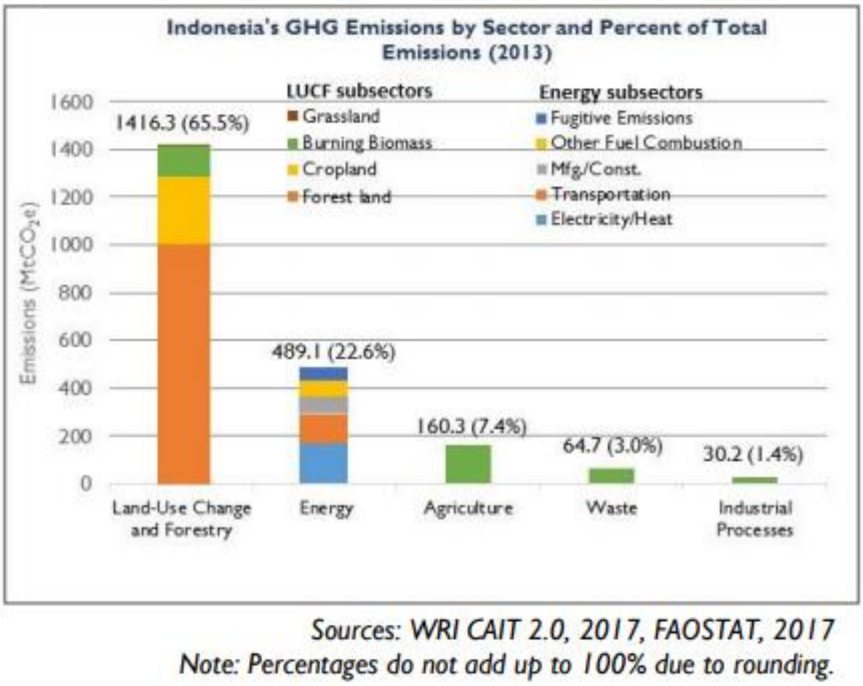


Figure 1 Indonesia's GHG Emissions by Sector and Percent of Total Emissions, 2013, Source: USAID, Indonesia, GHG Emissions Fact Sheet, 2017

Indonesia's electricity sector (See Figure 2 below) is currently monopolized by the state-owned electricity company, Perusahaan Listrik Negara (PLN). In 2020, PLN owns about 69% of total power generation capacity and 100% of the country's transmission and distribution network (PLN RUPTL, 2019). The remaining power generation capacity is owned by Independent Power Producers (IPPs) and by PLN subsidiary companies also called private power utilities (PPUs). The electricity produced by IPPs is sold only to PLN. PLN then provides the electricity supply to the consumers and end users.

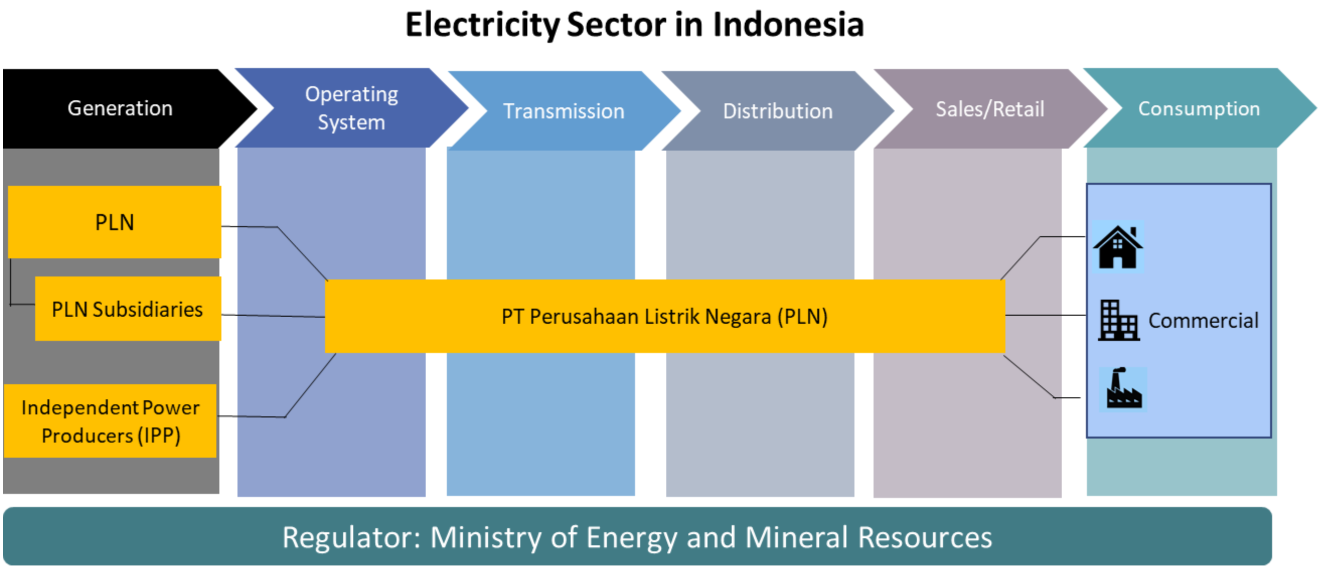


Figure 2 Structure of Electricity Sector in Indonesia. (Source PLN, Carbon Tracker 2019, PWC, 2018)

The electricity infrastructure in Indonesia comprises of eight major electricity grids (Table 3). It also consists of more than 600 isolated grids distributed throughout the country. (PLN Statistics, 2019). In terms of power generation, 65% of the power generators are located in the Java and Bali islands (See Table 4). These are also the most populous islands in the country inhabiting more than half of the country's total population of over 270 million people (BPS, 2018).

Table 3 Transmission lines in Indonesia, (Handayani et. al, 2019 pg 3, and PLN, Statistics, 2019 pg 40-47)

Region/Island	25-30kV	70kV	150kV	275kV	500kV	Total
Sumatera	-	338	11,683	2,727	-	14,748
Java-Bali	97	3,035	14,584	-	5,074	22,790
Kalimantan	-	123	4,698	163	-	4,984
Sulawesi	4	596	4,495	-	-	5,095
Papua and Maluku	-	290	-	-	-	290
Nusa Tenggara	-	653	341	-	-	994
Total	**101**	**5035**	**35,801**	**2890**	**5074**	**48,901**

Table 4 Power generation, transmission, and distribution Capacities in Indonesia and Java-Bali power system. (Source PLN Statistics, 2020, p. 40-42)

Power Generation Assets in Indonesia	**Capacity**		
	Indonesia	Java-Bali	Percentage of the Java-Bali Capacity
Generation capacity (MW)	69,600	45,240	65%
Transmission network:			
Transmission lines (kmc)	44,064	22,553	51%
Substation transformer (MVA)	98,899	78,697	80%
Distribution network:			
Distribution lines (kmc)	887,681	466,686	53%
Substation transformer (MWA)	50,100	32,822	65%
Note: MW=megawatt, kmc= kilometer circuit, MVA= megavolt ampere			

At present, Indonesia uses fossil fuels to power 77% of its electricity needs (RUPTL, 2019). The current energy mix for electricity generation comprises of 55% coal followed by 23% renewables and 22% natural gas. (PLN Annual Report, 2020). It is one of very few countries with coal power plant construction in 2020 (Climate Transparency, 2020). The country also has a huge pipeline of over 30 GW of coal-fired power in development. (MEMR, 2019, and RUPTL, 2019). Indonesia’s Government Regulation No. 49 sets targets for the energy mix by 2030 and 2050. These targets are stated in Table 5 below.

Table 5 Indonesia’s National Energy Mix Targets for 2030 and 2050 (MEMR, 2020)

Energy Source	Current	Expected	
		2030	2050
Coal	55%	30%	25%
Renewable	23%	23%	35%
Oil	-	22%	20%
Natural Gas	22%	25%	20%

PLN develops energy projects to reach these targets including the plan for allocation to IPPs. The company develops a ten year General Plan for Electricity Supply, called Rencana Umum Penyediaan

Tenaga Listrikis or RUPTL in short. This is prepared in alignment with national target set by the Ministry of Energy and Mineral Resources (MEMR). PLN's General Plan for Electricity Supply, RUPTL is revised every year. The last RUPTL was released in 2019 and covers the ten year period from 2020-2029. This plan included updates in the electricity generation plan considering two key factors. First, the movement of Indonesia's future capital to Kalimantan resulting in increased demand particularly in the region, Second the overall decline in the nationwide electricity demand due to slow economic growth of Indonesia. Another update is expected sometime in June this year taking into account the slow economic grown due to pandemic in 2020. (Interview with PLN).

The government of Indonesia plans to increase the contribution of renewables in the energy mix through solar power, geothermal, hydropower and others. However, majority of Indonesia's power mix is dependent on coal, at least up until 2029. (RUPTL, 2019). This becomes a major concern to climate change mitigation efforts not only in the country but globally. A recent study by Tong et. al (2019) explains the world is currently behind its 1.5 degree C target due to the current global fossil fuel infrastructure. Another study by Zhou et. al (2019) pointed out that a significant shift in South East Asia's energy portfolio (including Indonesia) to renewables is required to achieve the global temperature target of 1.5 degree C. For Indonesia to be within within its "fair-share" range compatible with global 1.5°C IPCC scenarios, it needs to reduce its emissions to below 662 MtCO2e by 2030 and to below 51 MtCO2e by 2050. (Carbon Action Tracker, 2020). This means in order to be 1.5°C compatible, Indonesia should phase out coal, and increase its renewable energy targets to be half of total mix in the next two decades. (Climate Transparency, 2020).

In 2019, PLN's revenue was recorded to USD 20.57 billion and installed capacity was 43.85 GW. (PLN Annual Report, p. 37). The company's current total GHG emissions (scope 1) emissions are 1.89 MTCO2e. (PLN Sustainability Report, p. 32). This is currently about less than 1% of the total national GHG emissions of Indonesia.

This Master's Project reviews the case of Indonesia's largest electric utility company, PLN with the objective to assess:

- What are the potential climate risks (primary focus on transition risks) and opportunities for PLN as the country's largest electric utility company, and a state owned enterprise (SOE)? In addition, what are the related quantifiable likely impacts on the business?
- How can PLN integrate climate risk management into its existing operations management framework?

4. Methodology and approach

A Case Study approach was used for the research project (case overview of PLN as Indonesia's largest electric utility company is defined in previous section). A mix of secondary and primary research was applied to collect data and understand potential climate related risks for PLN. As a first step, desk based literature review was conducted using online publications accessible via Duke Library. Besides academic literature, I also captured the following in my search; national planning documents (see Table 7), international frameworks such as Task Force on Climate Change Disclosure (TCFD), consultancy reports, and government presentations or white papers. The literature review guided the framing of the research questions for the stakeholder interviews. Due to travel and engagement limitations, arising because of the pandemic, the scope of primary research was limited to identifying only the transition risks of climate change for the company. Whereas, the review of physical climate risks and impacts on the company's operations was conducted relying on secondary data. A number of stakeholders were identified and interviewed for primary data collection (See Table 8). Semi-structured virtual interviews were conducted with these stakeholders to inform identification of potential political, legal, market, technology and reputational risks. (See questionnaires in Appendix A). Following the data collection, a scenario analysis was conducted considering three different business scenarios for electricity demand and relative energy mix upto 2050 considering ten year period forecasts - 2030, 2040 and 2050. These scenarios are explained below and see Table 8 for Energy Mix for the three Business Scenarios assessed.

i. **Business as Usual (BaU)**

This refers to the business forecast as per PLN's general forecast for electricity generation based on 6% annual growth and following national energy mix target of 23% renewable by 2030. I reviewed the energy forecasts based on RUPTL documents for years 2017, 2018, and 2019 to determine the scenario.

ii. **Adjusted Lowered Demand**

PLN's RUPTL forecast is criticized to be overestimated by leading economic and sector analysts (Institute of Energy Services Reform (IESR), 2019, and Carbon Tracker, 2019). This is based on the actual versus forecasted economic growth and other factors such as COVID 19, global inflation, and fluctuation in oil and gas prices. Hence, this scenario considers adjusted energy demand of 4% per annum. It also includes an increased share of renewable energy.

iii. **Coal Phase-Out**

As shared previously, for Indonesia to be in line with IPCC 1.5 degree C scenario, it needs to eventually phase out coal by 2050 (Carbon Tracker, 2020). This scenario considers coal phase out starting from 2029 with complete phase out by 2050. It estimates a 50% renewable energy mix target by 2050.

Table 6 List of Key National Policy and Planning Documents and Data reviewed for Master's Project (non-exhaustive)

No.	National Policy, Document or Data	Document Type	Source
1	National Energy Policy of Indonesia (NEP)	Central Government Energy Policy with targets.	http://extwprlegs1.fao.org/docs/pdf/ins64284.pdf (last accessed on March, 26, 2021) Summary presentation shared by Ministry of Energy and Mineral Resources representative during interview.
2	RUEN, 2017 (National Energy General Plan)	Central Government policy to achieve the National Energy Policy (KEN) targets up to 2050. This consists of a plan for strategy and implementation across various related sectors. Reviewed every five years unless any change in policy.	Summary accessed from https://iesr.or.id/wp-content/uploads/2020/09/RUEN-Existing-Plan-Current-Policies-Implication-and-Energy-Transition-Scenario-presentation.pdf (Last accessed on March, 2021) Summary presentation also shared by Ministry of Energy and Mineral Resources representative during interview.
3	RUKN, 2019-2038 (National Electricity General Plan)	Electricity Sector Policy document by Ministry of Energy and Mineral Resources (MEMR), Indonesia. This includes a 20-year projection of electricity demand and supply. Besides the forecast, it provides information on the required investment and funding policy for the same. And the approach for utilizing new and renewable energy	https://gatrik.esdm.go.id/assets/uploads/download_index/files/46a85-rukn-2019-2038.pdf (Last accessed on March 26, 2021) Summary presentation also shared by Ministry of Energy and Mineral Resources representative during interview.

		resources. This document feeds into RUPTL.	
3	General Plan for Electricity Supply in Indonesia, RUPTL, 2017, 2018 and 2019	10 year Electricity Business Supply Plan developed by PLN for the period of 2019-2029. This is updated annually to reflect annual changes in national energy (RUEN) or electricity plan (RUKN)	https://web.pln.co.id/stakeholder/ruptl (Last accessed on March 26, 2021) English versions purchased from https://www.petromindo.com/products?page=4
4	PLN Statistics, 2019	Key Performance Statistics of PLN	https://web.pln.co.id/stakeholder/laporan-statistik
5	PLN Annual Report, 2019	PLN's Financial Disclosure	https://web.pln.co.id/stakeholder/laporan-tahunan
6	PLN Sustainability Report, 2019	PLN's Sustainability Performance Disclosure	https://web.pln.co.id/stakeholder/laporan-keberlanjutan

Table 7 List of Stakeholders Interviewed for the Masters Project

No.	Stakeholder	Type	Representative Interviewed
1	PLN	Case Company	Head of Corporate Strategy
2	PLN	Case Company	Head of Environment and Climate Safeguards (Corporate)
3	PLN	Case Company	Head of New Renewable Energy (EBT)

4	Indonesia Power (PLN Subsidiary)	Case Company subsidiary	Head of Environment and Climate Change Management
5	Ministry of Energy and Mineral resources	Regulator	Director General for the Climate Change Mitigation
6	Coordinating Ministry of Economic Affairs	Regulator	Head of Environmental Management and Climate Change
7	Electricity Producers Association (APLSI)	Professional Association	Executive Director
8	Institute for Essential Services Reform (IESR)	Think Tank	Executive Director and Independent Energy Expert
9	Ministry of Environment and Forestry (MoEF)	Regulator	Senior Advisor to the Ministry of Environment and Forestry on Climate Change and International Conventions; and the National Focal Point (NFP) of Indonesia for UNFCCC.
10	BAPPENAS (Ministry of National Development)	Government Agency	Representative
11	Indonesia Joint Crediting Mechanism Secretariat	Independent government agency	Head Secretariat

Table 8 Energy Mix for Three Business Scenarios for Energy Transition assessed for PLN

Scenarios	2030	2040	2050
BaU Scenario (RUPTL, 2019)			
Coal	30%	28%	25%
Renewables	23%	30%	35%
Oil	22%	21%	20%
Natural Gas	25%	23%	20%
Low Carbon Energy Transition Scenario (IESR and Carbon Tracker, 2019)			

Coal	25%	20%	15%
Renewables	23%	30%	35%
Oil	22%	21%	20%
Natural Gas	25%	23%	20%
Coal Phase Out Scenario (International Energy Association 2019, and Carbon Tracker, 2019)			
Coal	20%	10%	0
Renewables	35%	43%	50%
Oil	15%	12%	10%
Natural Gas	30%	35%	40%

5. Climate Change Risks and Opportunities for PLN

The following section discusses physical risks and adaptation opportunities for PLN as identified during secondary analysis.

4.1. Physical Risks

PLN operates over 200 power plants nationally, the majority of which are in Java-Bali Islands as shared previously. A PLN interviewee reported to have conducted a voluntary assessment of climate change (as part of her doctorate studies) at selected 10 power plants in the Java Bali Island including the transmission and distribution networks. The study is available as an academic literature (Handayani et. al, 2019). However, no official study is reported to exist for the operational or planned power plants. There is a plan to conduct the regional vulnerability assessment of the distribution and transmission networks in Western and Central Java in 2021. This is driven by the international financial institution, Asian Development Bank's (ADB) grant funding, rendered to PLN for renewable energy development.

Handayai et. al 2019 have identified a set of acute and chronic risks of ten power plants assessed in Java-Bali Islands. These plants use coal, gas or hydro power as the source of fuel. The study identifies the plants' vulnerability to weather and climate related impact, which is material to PLN's business resulting in reported losses of tens of millions of USD. Table 9 summarizes the list of physical impacts and their estimated Utilities losses for PLN's Java Bali Island's power generation, distribution and transmission network.

Table 9 Impacts of severe weather events on PLN's Java-Bali power generation, transmission and distribution. (Source adapted from Handayani et. al, 2019, pages 6-9)

Power Generation		
Weather and Climate related event	**Identified Impact**	**Estimated Utilities Losses in USD**
Heavy precipitation	-Reduced burning efficiency -Reduced power output - Impeded power plants' water uptake - Flooding	Up to 21.5 million
Heavy wind and high sea waves	Reduced power outputs/shutdowns	1.2 million
Jellyfish inflow	Reduced power outputs/shutdowns	21.3 million
Heatwaves	efficiency reductions of gas turbine, gas and diesel engines	4250
Droughts	Reduced power output	51.5 million USD
Sea Level rise	Daily activity disruption for employees	Not available
Sea surface temperature	cooling water system efficiency reduction	Not available

Transmission Networks		
Weather and Climate related event	**Identified Impact**	**Estimated Utilities Losses in USD**
Lightning	Power failure and transmission equipment damages	~525000
Heavy Wind	Power Failures and transmission equipment damages	22000
Flood	Damaged equipment Plant shutdowns due to safety reasons	9.1 million
Distribution Networks		
Weather and Climate related event	**Identified Impact**	**Estimated Utilities Losses in USD**
Heavy Wind	Power Outages	13.1 million (Customers affected =2.1 million)
Heavy Precipitation	Power Outages	575,152 (customers affected = 3.1 million)
Flood	Power Outages	455,605 (customers affected = 0.1 million)
Landslide	Power Outages	9,234 (customers affected = 0.3 million)

The Handayani et.al, 2019 study of potential physical risks to PLN is limited to assessing direct economic losses of electric utilities resulting from disruption in energy supply and damaged assets and equipment. Hence, it is not a comprehensive assessment of complete financial impact to physical climate risks. For example, it does not account the potential impacts of business interruptions and other cross-sectoral impacts due to physical climate hazards.

4.2. Adaptation Opportunities

As a response to the severe weather events, PLN has implemented some adaptation actions which includes both managerial and technological interventions. (Interviews and Handayani et. al, 2019). However, these measures are reactive as opposed to proactive adaptation.

Some of the adaptation opportunities for PLN include conducting vulnerability assessment and resilience planning for the company. This includes identifying vulnerable assets and implementing relevant risk control measures including technological (hard measures such as flood control system) and managerial measures (such as managing operational hours anticipating fluctuating weather during the day) to proactively manage the key impacts.

Another opportunity for the state-owned enterprise is to integrate adaptation planning as part of the national strategy for the country's adaptation plan. This include assessing the potential impact of PLN's value chain and implementing relevant measures to manage these climate related impacts.

4.3. Transition Risks

In addition to physical impacts of climate change, PLN faces a number of climate transition risks. These risks for the company are discussed below as assessed.

Political and Legal Risks

a. National and International pressure to reduce GHG Emissions

Total GHG emissions from PLN-owned plants is 1.89 million tons (or 1.7 metric tons) CO2e in 2019. (PLN Annual Report, 2019, page 78). This is equivalent to ~2% of national GHG emissions in the country. However, this doesn't include the emissions from the Power Purchase Agreements that PLN has with other Independent Power Producers using fossil fuels for electricity production in the country.

Considering PLN's business as usual scenario, (see page 14). PLN's GHG emissions can be forecasted to be 258 MtCO2e. Indonesia's current climate target for 2030 would only limit its emissions to 1817 MtCO2e (Interview with MoEF). This is not in line with 1.5 degree IPCC scenario for 2030 requiring Indonesia to keep its emissions below 662 MtCO2e. (Climate Action Tracker, 2020). BaU for PLN would mean the company would be responsible for emitting 10% of Indonesia's total national GHG emissions by 2030 as compared to current contribution of 2%. (See Figure 3 and Table 10). This means sooner or later, PLN would be required to develop annual GHG emission reduction targets, this is currently absent in company's business plan.

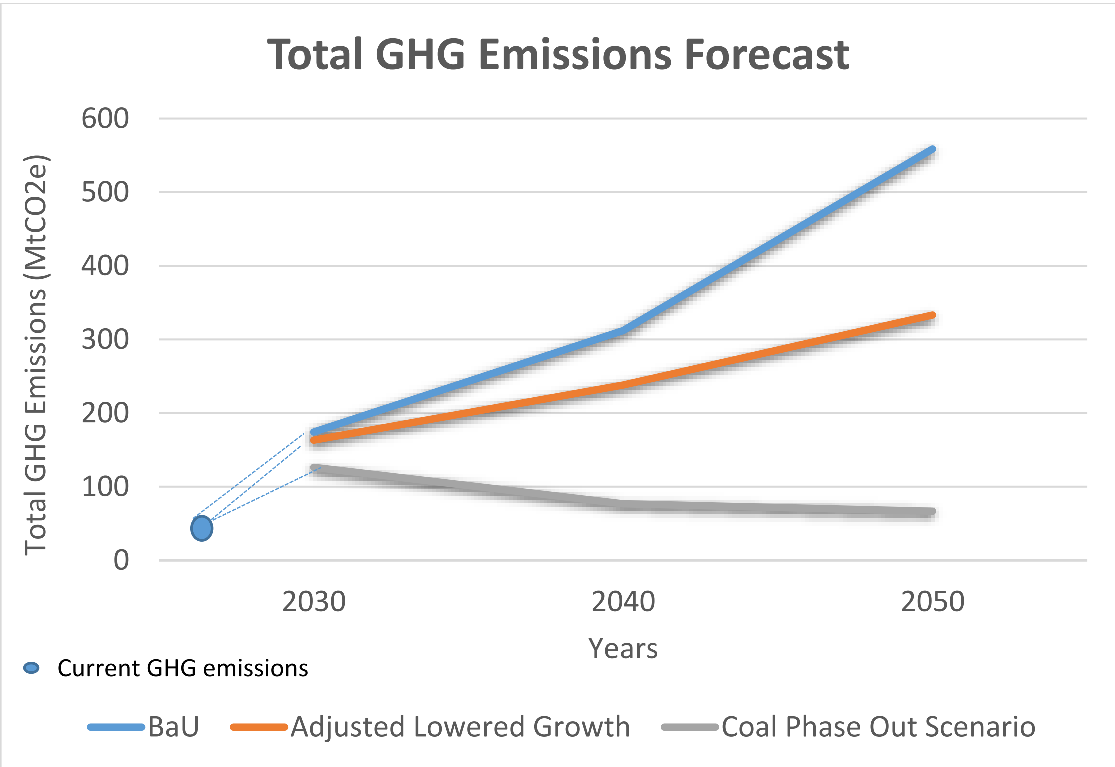


Figure 3 Total Current and Forecasted GHG Emissions for PLN under Three Business Scenarios

Table 10 PLN's GHG Emissions against Indonesia's total GHG Emissions (Source: IEA, Climate Transparency, 2020)

	IPCC 2 degree Scenario	IPCC 1,5 degree Scenario
Total Indonesia GHG Emissions MTCO2e by 2030	1817	662
PLN Emissions %		
BaU	10%	26%
Adjusted Lowered Growth	9%	25%
Coal Phase Out Scenario	7%	19%

Another factor forcing the company to reduce its overall GHG Emissions is potential carbon pricing in Indonesia. Interviews with the regulators identified a government plan to introduce carbon pricing through market based instrument using Emissions Trading Scheme (ETS) and Carbon Emission Reductions (CER) targets. The "Government Regulation on Environmental Economic Instruments, 2017", provides a basis for implementation for ETS. This regulation requires implementation of an emissions and/or waste permit trading system by 2024. The energy sector is considered to be the pilot sector for implementation in 2021. An introduction of carbon pricing would likely have a financial impact on PLN's business, resulting in costs associated with GHG emissions from fossil fuels, which is and will continue to remain the largest source of electricity supply for Indonesia. As Indonesia is yet to announce the internal carbon price, it is difficult is ascertain the actual financial impact at this stage for this.

b. Premature asset devaluations for newly developed coal power plants

As stated previously, Indonesia will need to phase out coal by 2050 and increase its renewable energy targets to at least 50% by 2030 in order to be 1.5°C compatible. Considering PLN's current power generation depending on coal, both in terms of own assets and from PPAs from Independent Power Producers, phasing out coal by 2050 would require closing down the existing and planned coal power plants. The majority of the country's coal fired power plants are less than 20 years old which is considered half of the average age of these plants. This imposes a risk for early shutdowns of coal fired power plants also called "stranded assets". An asset is deemed as stranded when the "economic transition renders a company's assets obsolete or impaired, and leads to premature asset write-downs." (Lloyds, 2017). As a result, these assets would fail to deliver the expected returns on investment to their financiers. (Carbon Tracker, 2017). It is estimated that early retirement of these coal fired power plants would result in costs up to 15 billion USD for PLN which is 17% of current total capital. (Carbon Tracker, 2018).

Technology and Market risks

1. ***Overestimated Electricity Demand resulting in wasted financial investment***

If PLN continues the business as usual forecasts, there is likely to be an overbuild of fossil fuel based power plants. See Figure 4 below for the Annual Energy Demand forecasts under different energy transition scenarios. This means non-feasible investment of up to 12,7 billion USD. (IESR, 2020).In addition to this, it also means increased GHG emissions causing further air pollution and likely adverse health impacts attributed primarily to coal power plants.

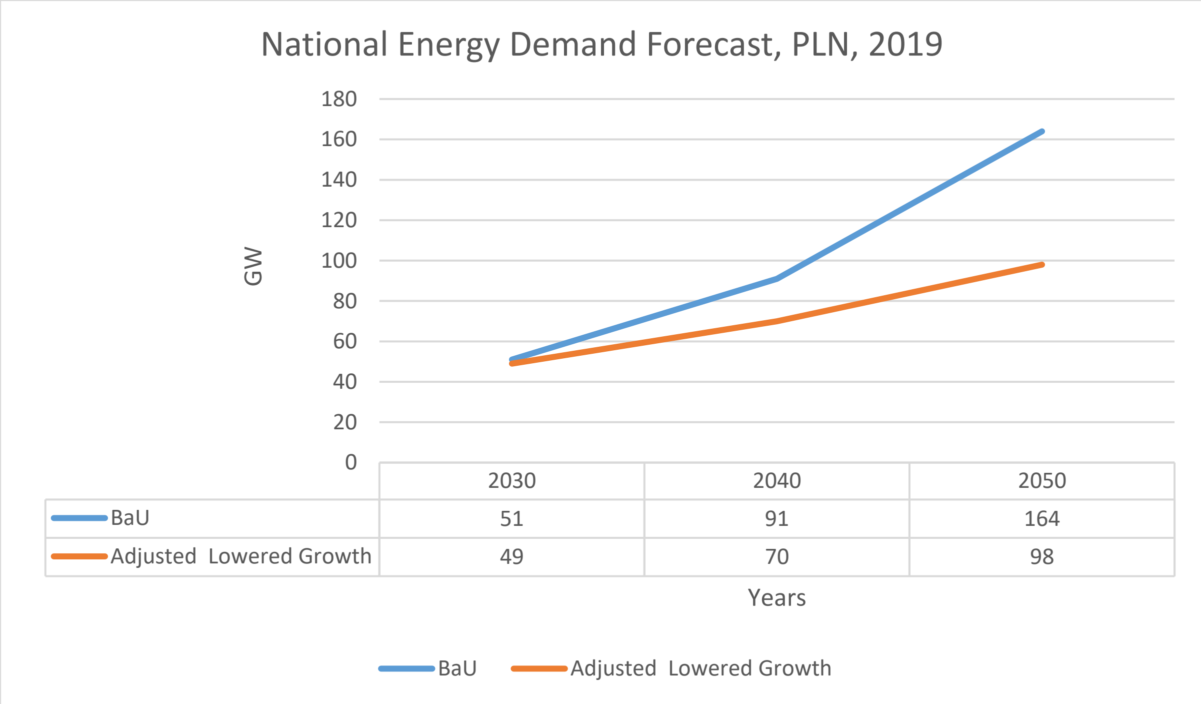


Figure 4 Electricity Demand Forecast for PLN under three Energy Transition Scenarios. (Note Coal Phase out Scenario estimates same energy demand as Adjusted Lowered Growth hence not provided separately)

2. *Increased Operational Costs of fossil fuel plants*

It is estimated that the economics of new coal power will be undermined by declining renewable energy costs in the near term (Economic and Financial Risk of Coal Power in Indonesia, Carbon Tracker, 2019). A study on economics of energy in Indonesia estimates, building a new solar PV could be cheaper to than to build new coal power plant in Indonesia by next year (Carbon Tracker, 2019, pg 7). And by 2028, new solar PV plant could even cheaper than the existing coal power plants. (See Figure 5). This has two implications. First, it will be expensive for PLN to operate at BaU scenario for 2030, with majority of energy mix supply continue to remain on fossil fuels, resulting in increased electricity tariffs or requirement for an increased government subsidy for the state owned enterprise. Second, it will be cheaper for PLN to meet annual energy demand through increased renewable energy production.

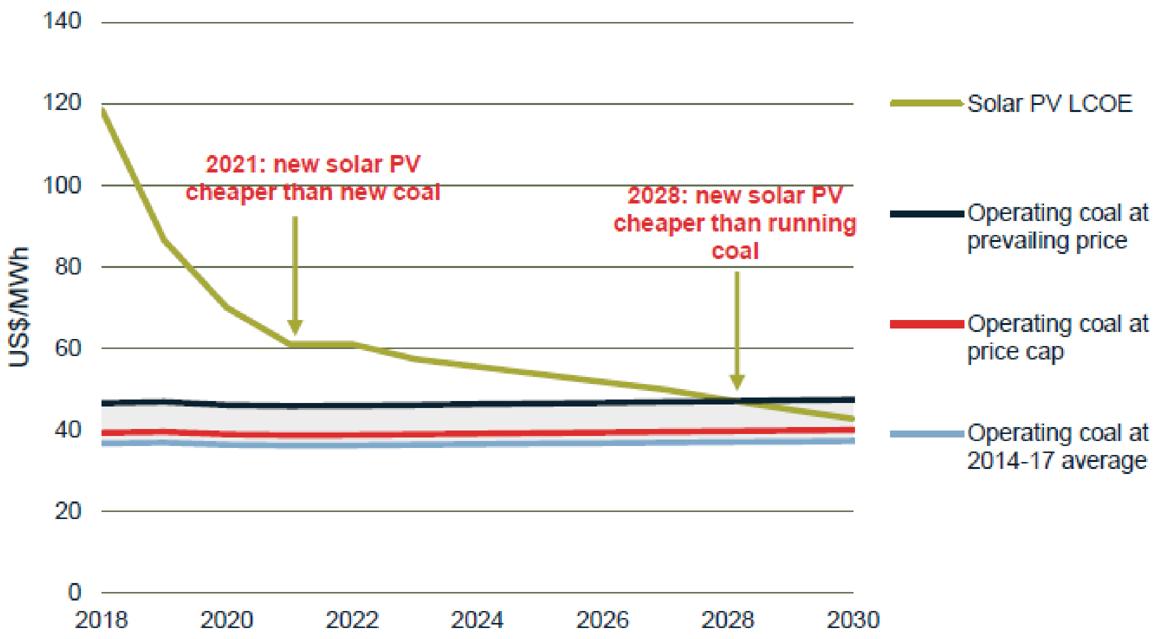


Figure 5 The cost of new renewables versus the capacity-weighted operating cost of coal under different fuel prices. (Economic and Financial Risk of Coal Power in Indonesia, Carbon Tracker, 2019 page 7)

3. *Changing Customer preferences*

As more and more companies commit to renewable energy targets, there is an increased preference and demand for renewable energy versus fossil fuels in the energy sector. Although PLN has plans to utilize its excess capacity from renewable energy to meet the growing demand, an introduction of carbon pricing might accelerate this sooner than required. This could question the company's reputation as a largest electricity producer. Moreover, PLN's reputation could be at stake among global environmental organizations and general public making it difficult for the company to seek stakeholder consents and potential international support (such as technology and funding from financing institution) for future power plant development.

Market Reputation

PLN is dependent on international funding and technological support for its transition towards low carbon economy. According to an interviewee, PLN is 'known among investors as a large contributor to carbon emissions'. (Interview with MoEF). This means investors will likely question the company's commitment towards Environmental, Social and Governance (ESG) aspects and renewable energy development. Such a reputation among international investors and international community could restrict access to international financing and technological support required for future development.

4.4. Transition Opportunities

Regulatory changes in response to climate change creates the possibility of growth and new flows of investment into low-carbon alternatives. These changes could mean cross sector targets for GHG emissions reductions including power sector, introduction of carbon tax, and revised NDC targets resulting increased share of renewable energy supply. Besides the potential the transition risks (as discussed previously), these regulatory changes could also create new marketing opportunities for PLN. These include increased market demand for renewable energy as a result of technology and market shifts and consumer preference, new market/products opportunities and potential rehabilitation of existing coal power plants planned for early retirement.

Increased Market Demand for Clean Energy

Government of Indonesia is developing low carbon economy transition pathways for top emitting sectors including transport, energy, food and beverages and automotive. This would result in more companies demanding clean energy sources and sustainable options. This would lead to subsequent increase in market demand for clean energy to be supply from PLN by 2030 as compared to current planned supply in BaU scenario. An example of opportunities on the technology side is the increase in demand for sector-specific technologies to capture carbon or to build resilient power grids for renewable energy supply, and micro-grids for providing electricity access to small islands in the country through renewable energy.

New Products/Services Opportunities

In order to transition towards a low carbon economy, Indonesia would require implementing measures to reduce GHG emissions for various business sectors. For example, for automotive sector, an increased use of electric vehicles by substituting traditional fossil fuels such as gasoline and diesel. This provides new market and business diversification opportunity for PLN.

Individual consumer demand for electric vehicles is expected to rise in Indonesia (Jakarta Globe, 2020). To understand the potential market, I reviewed an independent study on potential for electric vehicles in low carbon economy transition by IESR (Adiatma & Marciano, 2020). According to the study, "demand for electric passenger vehicles will increase the total electricity demand between the range of 11.6 TWh to 68,2 TWh by 2050" (Adiatma & Marciano, 2020 pg 3-5).

This means an additional market demand for energy for PLN and hence potential revenue streams from electricity vehicles.

In addition to electric vehicles, there is market potential for electric cooking stoves for meeting cooking fuel needs of the mass population of Indonesian archipelagic state. This is especially needed in the small islands with limited access to gas. These communities rely on use of wood and coal as the cooking fuel. This will need to change considering Indonesia's national targets of reduced GHG emissions. Hence, introduction of electric cooking stoves would be a possible substitution. This could be another new opportunity for PLN.

Rehabilitation of Coal-Fired Power Plants

Possible re-use of retiring coal-fired power plants could be considered. Currently, PLN is considering replacing these with Solar PV plants (Interview with PLN) and battery storage facility. This could provide potential cost savings and effective utilization of brownfield sites.

In addition to the above, an introduction of carbon pricing would also enable carbon trading in local and international markets. This could also create opportunities for PLN to consider exploring possible carbon trading from its new renewable energy projects.

6. Conclusion

Clearly, PLN faces formidable climate related challenges, which bring risks as well opportunities for the state-owned enterprise. Adaptation and mitigation measures need to be implemented in line with the long-term horizon of national climate targets. Table 12 presents the summary of the climate change risks. It can be concluded that climate change presents significant risks to the company. If ignored these could result in significant financial risks impacting long term business sustainability of the company. Moreover, the opportunities presented by climate change should be seized. For example almost 50 billion dollars market potential for electric vehicles and cooking stoves. This would help avoidance of future costs while realizing increased revenue potentials from the transition opportunities.

Table 11 Summary of Climate Change Risks for PLN

Climate Change Risk	**Potential Financial Impact – 2030 (in billion USD)**	**Source**
Physical Risks Extreme weather events affecting power generation, distribution and transmissions network.	Approximately 0.1 to 0.3	Handayani, 2019
Transition Risks		
Carbon Tax	Up to 14,5	Author's assessment using data from PLN's ten year Business Plan (RUPTL 2019-2028)
Stranded Risk Coal	Up to 12	Carbon Tracker, 2019
Reduced market demand for fossil fuels and reduced investment costs for renewable energy resulting in additional stranded risk	Up to 15	Author's assessment using data from PLN's ten year Business Plan (RUPTL 2019-2028)
Reputational Risk	Reduced or difficult access to future capital for business expansion	NA
Climate Change Opportunities for PLN	**Potential Financial Impact- Cost savings and additional revenues from climate change impacts (in billion USD)**	**Source**

Adaptation Opportunity		
Integrating climate change adaptation of PLN's vulnerabilities into national strategy for adaptation	Savings of potential loss of Utilities due to severe weather events and climate change impact	NA
Transition Opportunities		
Carbon Revenues	0,6-0,7	Author's estimate using secondary data analysis from various sources
i. Rehabilitation of mining assets to solar PVs and battery storage	0.5	Calculated using data from PLN Business Plan (RUPTL 2019-2028)
ii. Energy efficiency and resilient grid connection	Reduced operating cost and sustainable energy supply	-
iii. Electric Vehicles	0,25-8,1	Author's estimates using available data from secondary sources
iv. Electric cooking stoves	Up to 1,5	Author's estimates using available data from secondary sources

7. Recommendations

An integrated approach is recommended for PLN's climate risk management. The following steps are recommended to be included for climate transition risk management.

- ### Climate Change Policy and Strategy

It was informed during the research interviews that a company policy on Climate Change Management is being developed. The policy will provide an overall guidance for company's climate change management strategy. However, no indication was provided for the company to formulate an internal GHG emissions reductions target. It is recommended that PLN develops the company's climate change policy based on two pillars. First, it should manage its own footprint through GHG emissions reductions target aligned with Indonesia's 1.5 degree Celsius. Second, it should define an ambitious transition towards low carbon economy with an increased share of renewable energy than currently planned and eventually phasing out coal.

GHG Reduction and Mitigation

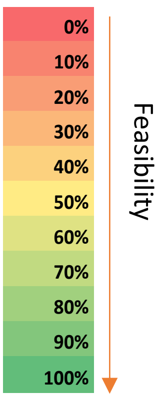
Being a state owned enterprise, the role of the company is critical in national climate action. In order to understand the actual contribution of the company's contribution to the national GHG emissions, it is recommended that PLN establishes the GHG emissions inventory beyond Scope 1 including Scope 2 and Scope 3 emissions. Once the emissions are identified, setting up an annual year on year reduction target is recommended. This will help accelerate investments into sustainable solutions fostering emissions reductions e.g. energy efficiency technology, clean technology and renewable energy development.

Climate Change Mitigation would help PLN prevent potential risks. Developing a mitigation heat map is recommended. This provides an overall chart of various mitigation measures against several key feasibility parameters. The potential of the mitigation measures is compared relatively against each other to set the priority in the overall feasibility. Such chart allows decision makers such as PLN to have a generalized and brief overview on the potential mitigation measures available for their implementation depending on their mitigation strategy. Considering different technology options, a mitigation heat map (Table 12) was produced to provide reference for PLN for potential emission reduction pathways. The heat map provides an opportunity for PLN to review and diversify power generation business to serve end consumers in transformation to low carbon energy future.

Based on the analysis of the desktop data available (see Appendix B). The heat map was developed which compares GHG mitigation measures against several feasibility parameters. The heat map serves as a guide for identification of GHG mitigation priorities, where 100% indicates more feasible and 0% indicates least feasible. Note that the comparison is relative to each other based on the maximum and minimum value of the category.

Table 12 Mitigation Heat Map for PLN

Mitigation Measure	Capacity Factor	Lifetime	Overnight capital cost	O&M costs	Conversion efficiency	LCOE	Overall Feasibilty
Power Generation							
USC Coal	100%	43%	0%	72%	39%	100%	**70%**
Natural Gas (CCGT)	53%	14%	100%	99%	60%	97%	**100%**
Hydro Power	36%	100%	80%	82%	100%	12%	**94%**
Wind Onshore	14%	14%	80%	56%	100%	64%	**59%**
Solar PV (Utility)	0%	14%	99%	100%	100%	91%	**92%**
Biomass power	78%	0%	33%	82%	17%	86%	**45%**
Geothermal	100%	71%	43%	0%	0%	98%	**52%**
Others (Tide, wave, ocean)	38%	0%	5%	50%	100%	0%	**0%**
Energy Efficiency							
Water heating: Solar (thermosiphon)	100%	0%	90%	90%	100 %		**100%**
Space Cooling: Solar	100%	0%	0%	0%	75%		**0%**
Cooking biogas (from AD)	0%	100%	98%	98%	17%		**67%**
Cooking biomass (solid)	0%	0%	100%	100%	0%		**12%**
Cooking bioethanol	0%	0%	100%	100%	17%		**20%**
Industry							
Solar thermal	0%	100%	96%	91%	100 %		**92%**
Biomass boilers	100%	100%	80%	80%	41%		**100%**
Biomass gasification	93%	100%	0%	0%	26%		**0%**
Bioenergy CHP (electricity part)	51%	100%	100%	100%	0%		**72%**



Based on the mitigation heat map, hydropower has been marked as the most feasible option moving forward for Indonesia in line with its BaU scenario for 2028.. The next feasible mitigation option is Solar PV that sees the demand growth around the SEA region.

While the mitigation heat map serves as the general reference for PLN in their emission mitigation strategies, the map also demonstrates potential new low carbon opportunities for PLN to explore to diversify its business model and support the low carbon transformation of end consumers as well.

Note that as transition to renewables occurs, the combined cycle gas power plant would be a feasible solution in the short run.

- Climate Risk Assessment and Management

It is recommended PLN conducts a comprehensive climate risk assessment at corporate and asset level to identify the company's vulnerability to physical climate change as well as the transition risks and opportunities. Once the risks are identified, this would help the company develop an appropriate mitigation strategy. Conducting a scenario analysis in line with 1.5 degree IPP Scenario would help to identify potential low energy transition pathways to achieve the national emissions reduction targets. The analysis should consider the future potential market drivers and changes to have a more accurate energy demand forecasts.

Developing and implementing a management action plan based on adaptation and mitigation measures is required to create the business resilience and climate preparedness for low economy transition. This could include GHG assessment (Scope 1, 2 and 3), monitoring and reduction strategy, renewable energy development, low carbon technologies, energy efficiency and others. (See Table 13 for considered adaptation and mitigation options)

Effective communication of the identified risks and opportunities should also form part of the risk management strategy. An early stakeholder engagement would help to identify key stakeholder interests resulting in informed climate risk management strategy for the company.

Finally, implementing an organizational capacity building program and relevant management systems and processes aligned with international best practice (for example ISO, GRI standards) could serve as enabling factors in managing corporate climate change risks and opportunities.

- ### Climate Governance

Currently, climate change is managed by Health, Safety and Environment (HSE) division of PLN. Given the significance of climate risk and potential impact on business sustainability, it is recommended that PLN elevates responsibility for climate change risks beyond the HSE function. This would mean annual business planning is informed of potential climate risks and opportunities faced by PLN.

Figure 6 below provides an illustration of the proposed integrated approach for climate transition risk management at PLN.

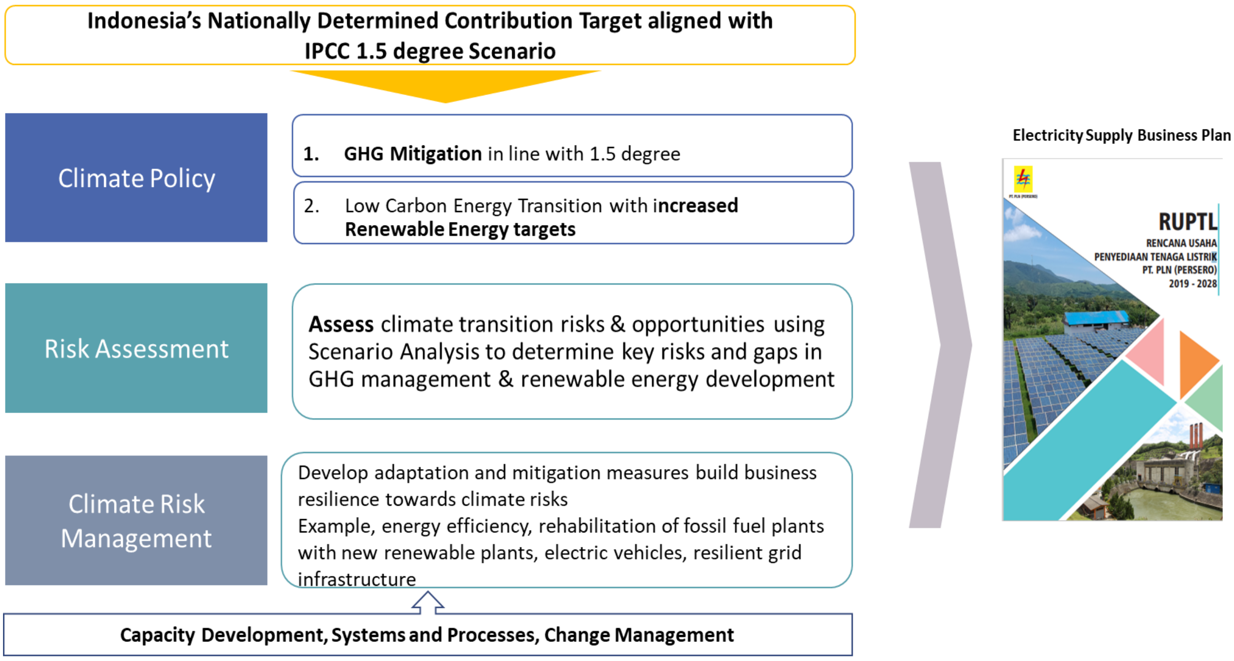


Figure 6 Proposed integrated approach towards Climate Change Management

8. Limitations

The analysis and results are based on the author's assessment as part of the project undertaken during an academic program and may be limited in terms of available data both from secondary resources and information provided during primary research interviews. Hence, this is not a comprehensive assessment of the climate transition risks and opportunities for the case company and may be considered as an initial assessment. Secondly, the financial impact identified is indicative and may require further economic analysis to assess exact impact. Finally, the recommendations for climate change management provided are based on the author's understanding and hence does not necessarily represent the case company or stakeholder's point of view.

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Appendix A – Research Questionnaires

General

1. As per 2019 SR, total GHG emissions from PLN-owned plants reached 1.89 million tons CO2e (which is 4.9% lower compared to the previous year's emissions). How is PLN working to support the national GhG emissions reductions from Energy sector of 315 MtCO2e?

2. Understand from PLN 2019 Sustainability Report, ambition is to have 31% RE mix as part of the energy mix portfolio. How do you plan to achieve this?

3. At the same, we also observe in the energy mix coal to reduce half but gasoline to be five times more. Can you please share the background and how is this supportive of your overall plan of GhG emissions reduction?

4. Why has gas reduced from the energy mix at the same time?

5. Has PLN conducted future projections for the GhG emissions for example what is projected forecast for emissions in 2030, 2050?

6. What is the emissions reductions target of PLN by 2030?

7. Has PLN conducted climate risk assessment of its existing (and planned) assets?

8. What are some of the climate related risks for PLN both in terms of

a. physical risks and opportunities

b. Energy Transition Risks and Opportunities?

9. Are you aware of Indonesia's plan for pilot testing Emissions Trading Scheme on energy sector? What implications would this potential MBI implementation have on PLN's assets?

10. Does PLN have existing or potential risk for stranded assets?

11. What market related transition risks or opportunities PLN foresees?

12. How does climate related risks impact on PLN's value as a company?

13. How does PLN manage its climate risk? Is there a policy, a management procedure that you could share if possible?

14. Does PLN considers or incorporates climate related risks as part of its operations?

15. Could you share an operations risk register of PLN if possible?

16. How do you manage asset level data in terms of operations risk?

17. Can you please share the plan to finance the 35 MW of coal fired pipeline? What will be the split between PLN, its subsidiaries and the IPPs?

18. Could you recommend someone else I could speak at PLN or outside PLN in relation to my research?

Stakeholder specific

Regulator and Independent Associations

1. Could you please share the current and future policy for Indonesia's electricity supply?
2. Why coal is still considered as part of the mix?
3. What is the plan for aligning Indonesia's national target for GHG emissions reductions with electricity generation plan?
4. Is there any national plan or policy in place or expected for controlling GHG emissions for industry particularly power sector (electricity and heat generation)?
5. Is there any plan for coal phase out by the government?
6. How are you looking at increasing the renewable energy deployment in Indonesia? Please be specific in terms of respective roles of PLN and other IPPs.

7. How often does your agency meet and contribute towards PLN's RUPTL planning on annual basis?
8. Are there any sector specific studies that explore potential GHG emissions forecast considering IPCC scenarios for Climate Change (i.e. 2 degree, 1.5 degree)

Appendix B – Methodology for GHG Mitigation Heat Map Assessed for PLN

GHG Mitigation Heat map was developed using the data from the following available sources:

- International Renewable Energy Agency (IRENA), Renewable Energy Prospects: Indonesia, March 2017;
- Institute of Essential Service Reform (IESR), Indonesia's Coal Dynamics: Toward A Just Energy Transition, March 2019;
- Institute of Essential Service Reform (IESR), Levelized Cost of Electricity in Indonesia, Understanding The Levelized Cost of Electricity Generation, December 2019; and
- U.S. Energy Information Administration, Capital Cost Estimates for Utility Scale Electricity Generating Plants, November 2016.

The key comparison of various mitigation measures was relatively gauged based on the following parameters.

- **Capacity Factor (%)**

The capacity factor is a ratio of an actual electrical energy output over a given period of time to the maximum possible output (also called name plate capacity) over that period. It is calculated by dividing the plant's annual power generation by the product of the capacity and the number of hours over a given period. (Pedraza, 2019 pg 1). Several factors can cause a power plant to not operate under its name plate capacity. These include design of the installation, maintenance and reliability issues, the location of the power plant, the type and source of fuel or resource for electricity production, and the local weather conditions.

- **Lifetime (years)**

This refers to the average economic lifetime of each technology type.

- **Overnight Capital Cost (USD/kW)**

Overnight capital cost provides a comparative cost of building a power plant for each technology type. Overnight costs is the sum of all design, engineering and procurement costs of the power plant and the overnight costs (owner's costs). It is the base-years costs expressed in dollars. It is used as a "quick reference for the cost of a plant because it does not take into account the time it would actually take and how prices rise over time for example the interest rate." (J.M.K.C. Donev et al. (2017)

- **O&M Costs (USD/kW/year)**

Operations and maintenance (O&M) costs are costs incurred during the power plant operations. They vary between different types of power generation. These are ongoing costs which form an important part of a power plant's life time cost. These include, "both fixed and variable, day- to-day preventative and corrective maintenance, labor costs, asset and site management, maintaining health and safety, and a host of other important tasks." (Mansano, 2014). High maintenance costs are often offset by advantages in other areas, and vice versa.

- **Conversion Efficiency (%)**

Energy conversion efficiency can be defined as "the useful energy output (benefit) divided by the energy input (cost)" (Mitsushima et. al, 2018, pg 1). Energy conversion efficiency is usually a number between 0 and 1.0, or 0% to 100% without any dimesion. Efficiencies may not exceed 100%.

- **Levelized cost of energy (LCOE)**

Levelized Cost of Electricity (LCOE) can be defined as "an economic measure used to compare the lifetime costs of generating electricity across various generation technologies" (Raikar & Adamson, 2020). LCOE is the net present value of all costs over the lifetime of the asset divided by discounted total of the energy output from the asset over that lifetime. Lifetime costs of a power plants include capital costs during construction, operations and maintenance costs for operating life, and decommissioning costs of disposing off the power plant. LCOE allows comparison of different generation technologies with varying lifetime costs on a consistent basis.

- **Overall Feasibility (%)**

The overall feasibility is an average of feasibility of each parameter considered in the heat map for mitigation measure. This parameter was then normalized between 0% to 100% based on the minimum and maximum feasibility score. The overall feasibility score provides a measure against various mitigation measure relatively how it performs against each other

Table 13 below indicates summary of the compilation from the sources.

Table 13 Compilation of Key Parameter for Mitigation Heat Map

Mitigation Measure	Capacity Factor (%)	Lifetime (Years)	Overnight capital cost (USD/kW)	O&M costs (USD/kW/yr)	Conversion efficiency (%)	LCOE (USct/kWh)
Generation						
USC Coal	80	40	3636	42	45	8.38
Natural Gas (CCGT)	50	30	978	11	64	8.93
Hydro Power	39	60	1500	30	100	27.00
Wind Onshore	25	30	1500	60	100	16.10
Solar PV (Utility)	16	30	1000	10	100	10.28
Biomass power	66	25	2750	30	25	11.40
Geothermal	80	50	2500	124	10	8.70
Others (Tide, wave, ocean)	40	25	3500	67	100	29.56
Energy Efficiency						
Water heating: Solar (thermosiphon)	12	20	150	3.8	100	-
Space Cooling: Solar	12	20	1350	33.8	85	-
Cooking biogas (from AD)	10	25	39	1	50	-
Cooking biomass (solid)	10	20	15	0.4	40	-
Cooking bioethanol	10	20	10	0.3	50	-
Industry						
Solar thermal	14	25	300	9.84	100	-
Biomass boilers	85	25	580	14.5	88	-
Biomass gasification	80	25	2000	50	85	-
Bioenergy CHP (electricity part)	50	25	231	5.775	79.6	-
Data Source:						
International Renewable Energy Agency (IRENA), Renewable Energy Prospects: Indonesia, March 2017;						
Institute of Essential Service Reform (IESR), Indonesia's Coal Dynamics: Toward A Just Energy Transition, March 2019;						
U.S. Energy Information Administration, Capital Cost Estimates for Utility Scale Electricity Generating Plants, November 2016						
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