TECHNOECONOMIC ANALYSIS OF INDONESIA GENERATION EXPANSION TO ACHIEVE ECONOMIC SUSTAINABILITY AND ZERO CARBON IN 2050

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SATRIA PUTRA KANUGRAHAN

Wayang Windu Geothermal Power Plant

Research Structure

- Indonesia Power System Overview
- Research Background
- Research Question
- Research Objective
- Research Novelty
- Research Scope
- Research Methodology
- Scenario
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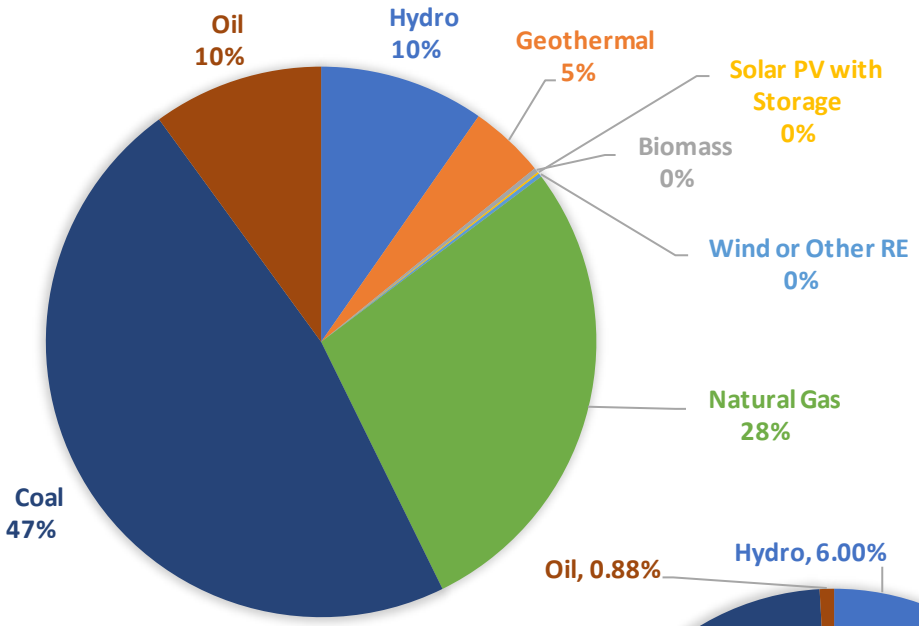
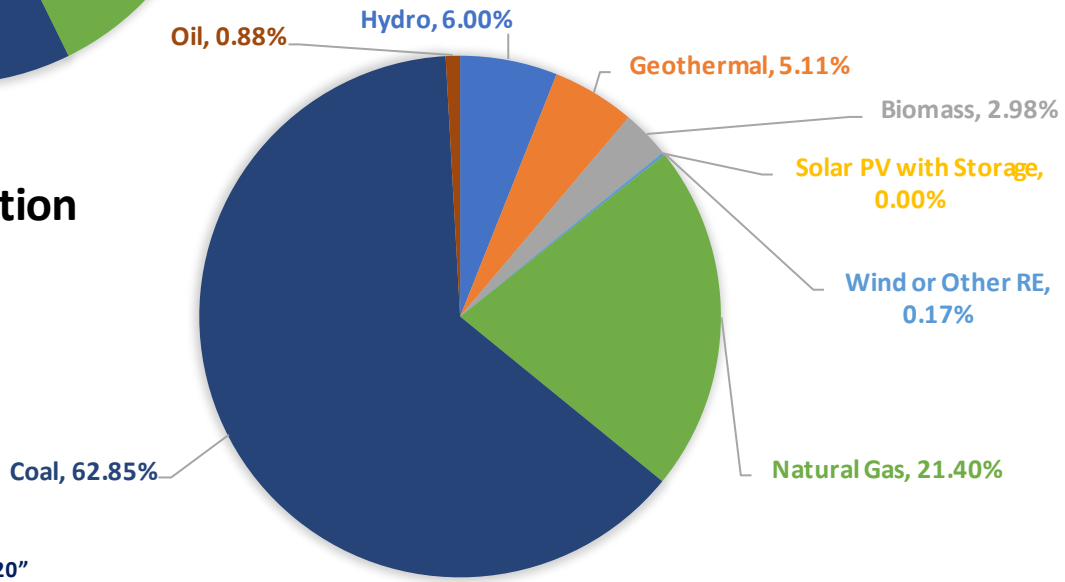
INDONESIA POWER SYSTEM 2020



Power Generation Capacity[1] 63.3 GW



Power Generation Output[2] 274.8 TWh

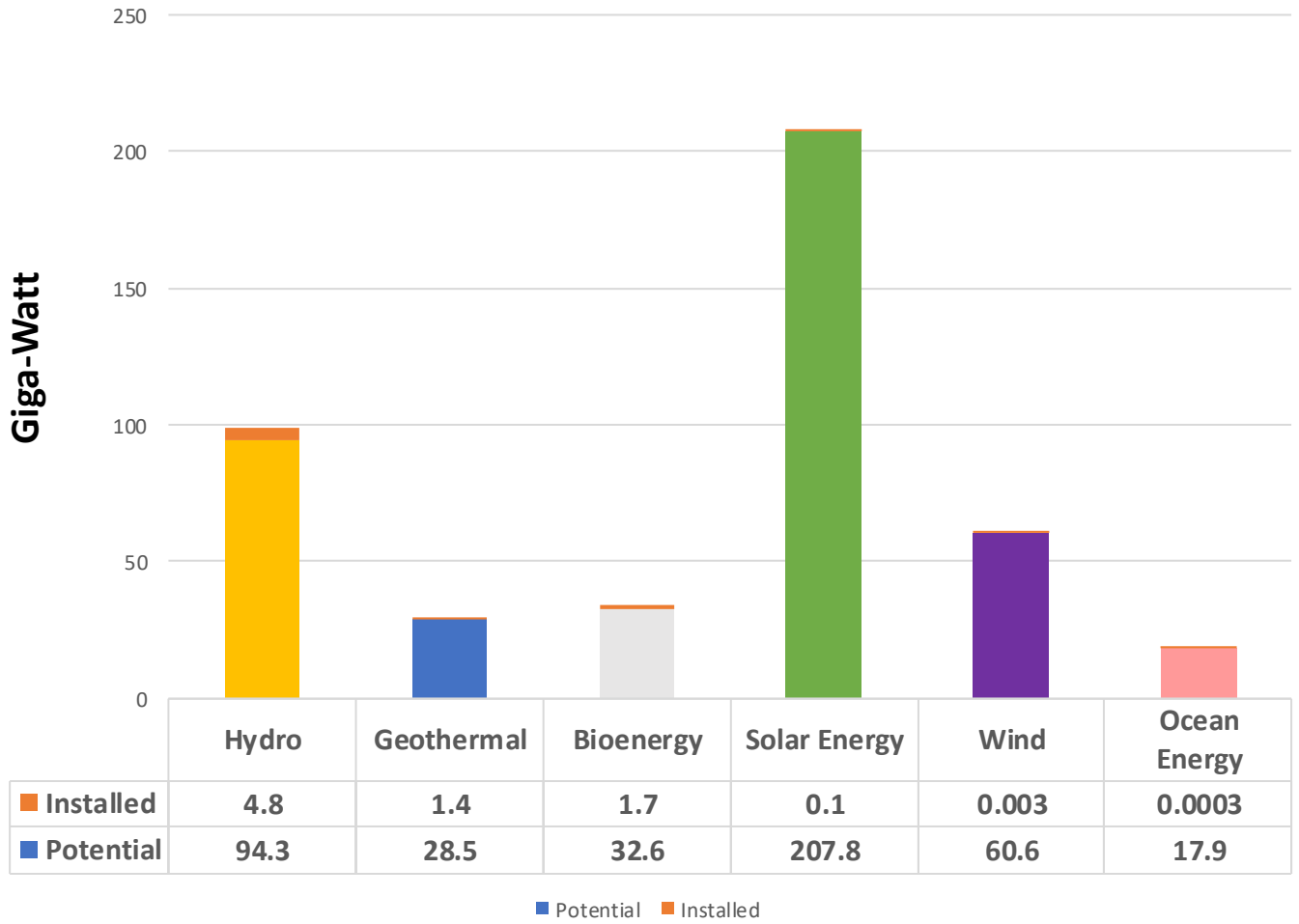
By the end of 2020, Indonesia's total power generation capacity is 63,3 GW. PLN and its subsidiaries power plant operates 45,6 GW and the rest is operated by Independent Power Plant (IPP). The total power output generated in 2020 is 247.8 TWh with the energy mix consist of coal (62.8%), Natural Gas (21.4%), oil (0.88%), hydro (6%), geothermal (5.1%), wind and other RE (0.17%), and PV (0%). Indonesia's electricity generation energy mix is dominated by coal-fired power plant due to the significant amount of available reserves, causing the dominance of coal as a low-cost fuel that is easy to extract and transport with existing infrastructure[3].

Sources:
[1], [2] PLN(2021)"PLN Statistic 2020"
[3] PwC (2017) 'Power in Indonesia', (November), p. 191. Available at: https://www.pwc.com/id/en/energy-utilities-mining/assets/power/power-guide-2017.pdf.

INDONESIA POWER SYSTEM 2020

Indonesia has many potentials of new and renewable energy but renewables energy are still become an expensive sources of electricity[3] . In 2020 it is estimated that Indonesia has a potential of Renewable Energy with total capacity up to 441 GW of Renewable Energy which consist of 94.3 GW Hydro power, 28.5 GW Geothermal energy, 32.6 GW Bioenergy, 207.8 GW Solar energy, 60.6 GW wind energy, and 17.9 GW ocean energy. But even though Indonesia has a large number of renewable energy potential, renewable energy is only used by less than 5%.[4]

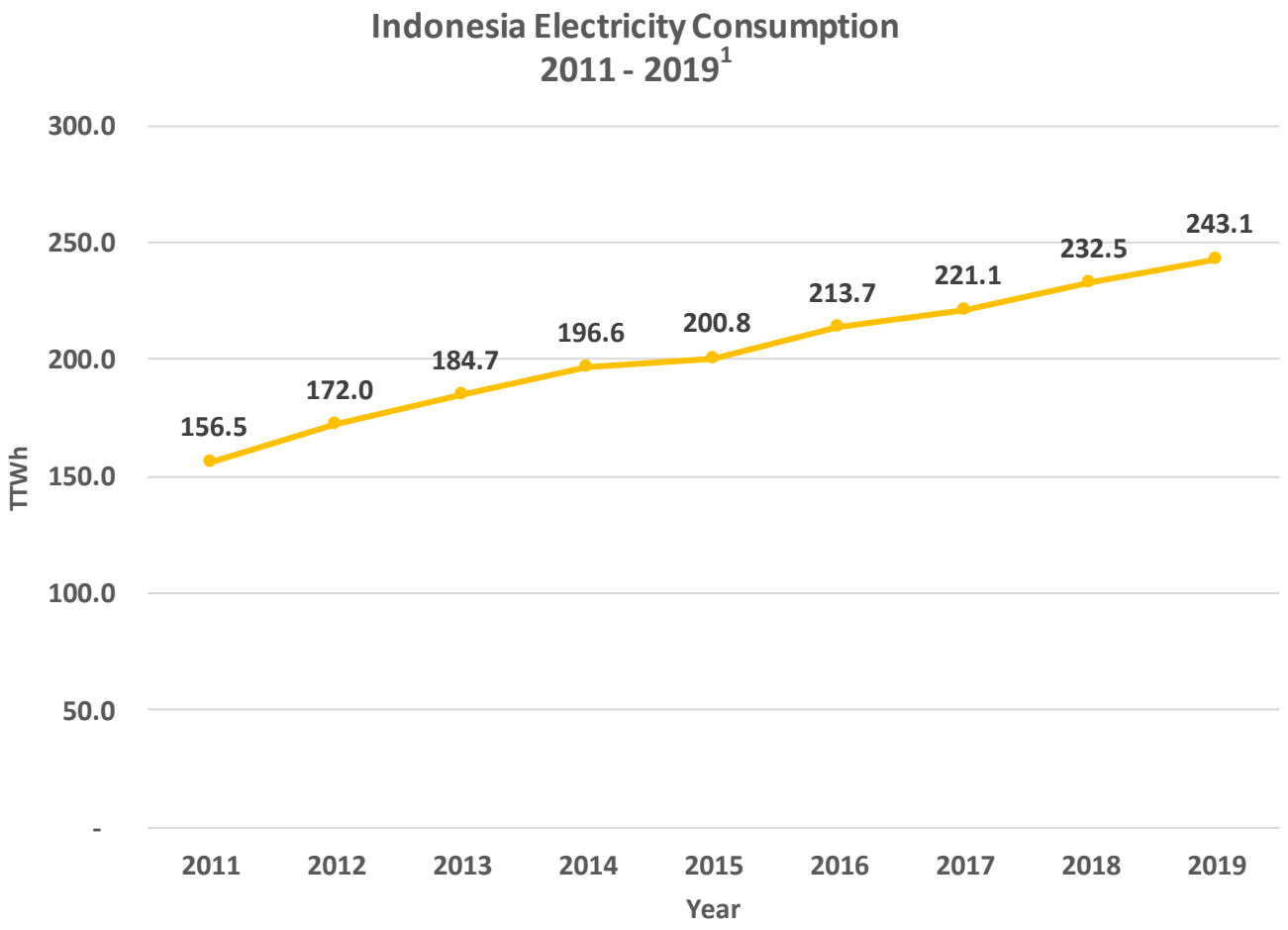
Indonesia's Renewable Energy Potential[1][2]



	Hydro	Geothermal	Bioenergy	Solar Energy	Wind	Ocean Energy
Installed	4.8	1.4	1.7	0.1	0.003	0.0003
Potential	94.3	28.5	32.6	207.8	60.6	17.9

Sources:
[1] Secretariat General National Energy Council (2020) *Indonesia Energy Outlook 2019*. Edited by DEN. Indonesia: DEN.
[2], [4] PLN (2019) 'Electric Power Supply Business Plan (2019-2028)'. Available at: http://gatrik.esdm.go.id/assets/uploads/download_index/files/5b16d-kepmen-esdm-no.-39-k-20-mem-2019-tentang-pengesahan-ruptl-pt-pln-2019-2028.pdf.
[3] Halimatussadiah, A., Amanda, A. and Maulia, R. F. (2020) 'Unlocking Renewable Energy Potential in Indonesia: Assessment on Project Viability'. Jakarta, Indonesia: LPEM - UI, pp. 1–10.

RESEARCH BACKGROUND



For the last 8 years Indonesia's electricity demand has growth for 5.7% on average[1]. The Indonesian government since 2015 has implemented a 35,000 MW program to address the ever-increasing demand for electricity. Through The 2019–2038 National Electricity Plan, the Indonesia's government also aims to have energy mix 23%, 28%, and 31% from renewable energy in 2025, 2038, and 2050 [2], respectively, and even there is a discussion for Indonesia to be zero carbon by 2050[3]. The future Indonesia's energy target is so ambitious that Indonesia will need accurate long-term energy planning to achieve it.

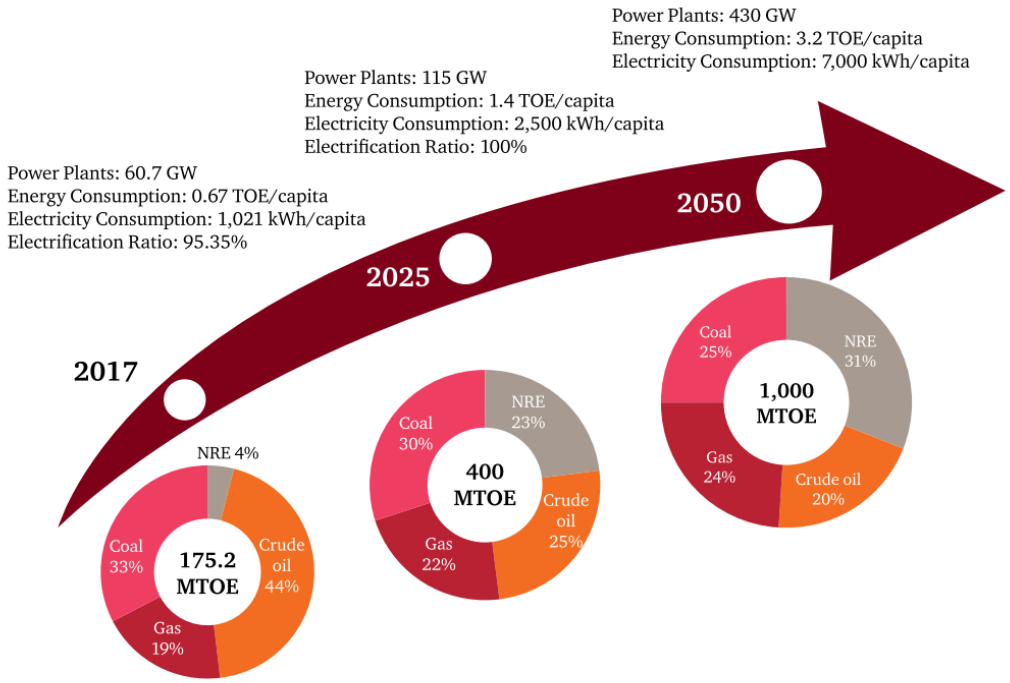
This research provides the techno economic analysis for the future power generation expansion plan by analyzing the future of electricity demand, the energy mix characteristics, and the resulting impacts on the cost of the future capacity generation expansion in Indonesia.

Sources:
[1] PLN(2019)"PLN Statistic 2011 – 2019"
[2] Ministry of Energy and Mineral Resources (2019) "Rencana Umum Ketenagalistrikan Nasional Tahun 2019 sampai dengan Tahun 2038"
[3] Rahman, D. F. (2021) *PLN pledges carbon neutrality by 2050 - Business - The Jakarta Post*, *The Jakarta Post*. Available at: https://www.thejakartapost.com/news/2021/05/07/pln-pledges-carbon-neutrality-by-2050.html (Accessed: 10 May 2021).

RESEARCH QUESTION

This research aims to provide techno-economic analysis of future generation expansion in Indonesia for 2020 - 2050. This research addresses the following two core question:

a. How will the future of Indonesia's power generation energy mix if Indonesia aims to achieve the Renewable Energy target[1] without neglecting the economic aspect?
b. How will the Indonesia power generation energy mix if Indonesia aims to achieve Zero Carbon in 2050 [2]?



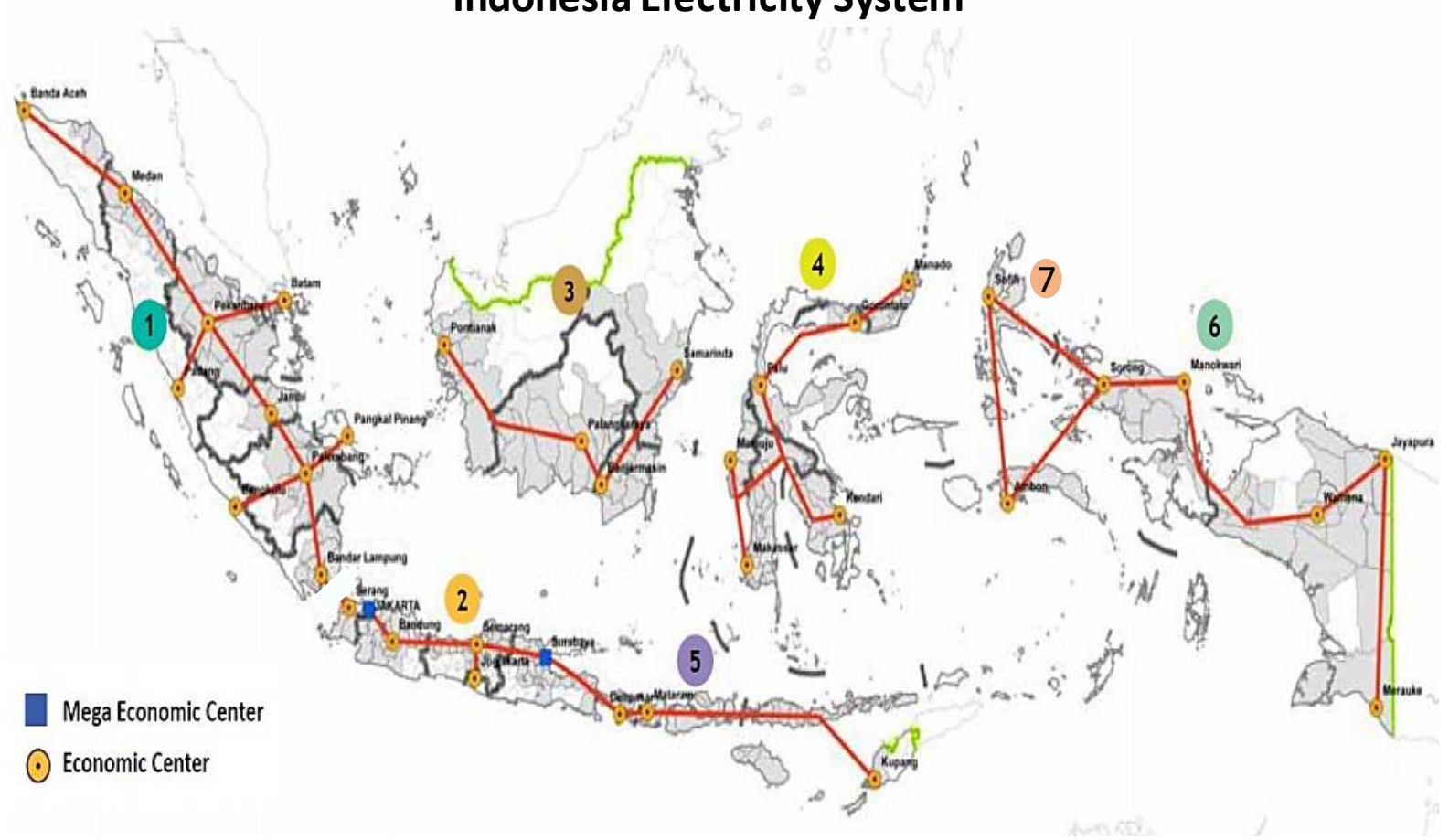
Source: 2014 NEP, BP Statistical Review of World Energy 2018, PwC Analysis

Source:
[1] Renewable Energy target: 23% in 2025, 28% in 2038, and 31% in 2050 based on National Electricity Plan 2019 – 2038 (RUKN 2019 – 2038)
[2] Rahman, D. F. (2021) PLN pledges carbon neutrality by 2050 - Business - The Jakarta Post, The Jakarta Post. Available at: https://www.thejakartapost.com/news/2021/05/07/pln-pledges-carbon-neutrality-by-2050.html (Accessed: 10 May 2021).

RESEARCH OBJECTIVE

This research aims to produces a planning model for Indonesia's electricity system in Post COVID-19 condition by considering the economic and energy sustainability to achieve the renewable energy target. Therefore, this study provides a new contribution to the academic literature. The optimal energy and power generation plan will reduce the power generation investment and production costs, which means a more competitive electricity price for the customer.

Indonesia Electricity System[1]



1 Sumatra 2 Java - Bali - Madura 3 Kalimantan 4 Sulawesi 5 Nusa Tenggara 6 Papua 7 Maluku

Source:
[1] MEMR (2012) INDONESIA ELECTRICITY INFRASTRUCTURE Posture of Indonesia Economic Corridor in MP3EI. Jakarta, Indonesia.

RESEARCH NOVELTY

Previous LEAP Research about Indonesia Power System

Author	Title	Research Scope	
Suhono and Sarjiya	Long-term electricity demand forecasting of Sumatera system based on electricity consumption intensity and Indonesia population projection 2010-2035	Area:	Sumatra system
		Demand Data:	Pre-COVID19
(Energy Procedia, 2015)		Renewable Target:	No power generation projection
		Time Period:	2010 - 2035
Kumar, S.	Assessment of renewables for energy security and carbon mitigation in Southeast Asia: The case of Indonesia and Thailand	Area:	Indonesia and Thailand
		Demand Data:	Pre-COVID19
(Applied Energy,2016)		Renewable Target:	2025 = 23%, 2038 = 28%, 2050 = 31%
		Time Period:	2010 - 2050
Windarta, J. et al	Application of LEAP model on long-term electricity demand forecasting in Indonesia, period 2010-2025	Area:	Indonesia
		Demand Data:	Pre-COVID19
(SHS Web of Conferences,2018)		Renewable Target:	No power generation projection
		Time Period:	2010-2025
Kresnawan, M. R. et al.	Long term projection of electricity generation sector in east kalimantan province: LEAP model application	Area:	Kalimantan system
		Demand Data:	Pre-COVID19
(12th South East Asian Technical University Consortium (SEATUC), 2018)		Renewable Target:	23%
		Time Period:	2015 - 2035
Nugrahanto, C.A. et al.	Analysis of Causality Relationship Energy Consumption and CO2 Emissions to Economic Growth based on the LEAP Model Case Study of Energy Consumption in Indonesia 2010-2025	Area:	Indonesia
		Demand Data:	Pre-COVID19
(E3S Web Conf.,2018)		Renewable Target:	No power generation projection
		Time Period:	2010 - 2025
Kamia Handayani	Seeking for a climate change mitigation and adaptation nexus: Analysis of a long-term power system expansion	Area:	Java - Bali system
		Demand Data:	Pre-COVID19
(Applied Energy, 2020)		Renewable Target:	2025 = 23%, 2038 = 28%, 2050 = 31%
		Time Period:	2020 - 2050
Santika, W. G. et al.	Implications of the Sustainable Development Goals on national energy demand: The case of Indonesia	Area:	Indonesia
		Demand Data:	Pre-COVID19
(Energy, 2020)		Renewable Target:	No power generation projection
		Time Period:	2015 - 2030
Nur'aini, E. et al.	Long Term Projection of Electricity Generation Sector in West Papua Province: LEAP Model Application	Area:	West Papua
		Demand Data:	Pre-COVID19
(ASEAN Journal of Systems Engineering,2020)		Renewable Target:	23%
		Time Period:	2019 - 2045

This study produces a planning model for Indonesia's electricity system by considering the sustainability of energy and the economy. Based on the literature study conducted by the author, previously, there was no Indonesia Generation Expansion Planning modelling using a case study of Indonesia's power system in Post COVID19 era. Furthermore, this research provides an overview of Indonesia future power generation energy mix for zero carbon in 2050.

Area : Indonesia

Demand Data : Post-COVID19

RE Target : 2025 = 23%, 2038 = 28%, 2050 = 31% & 100%

Time Period : 2020 - 2050

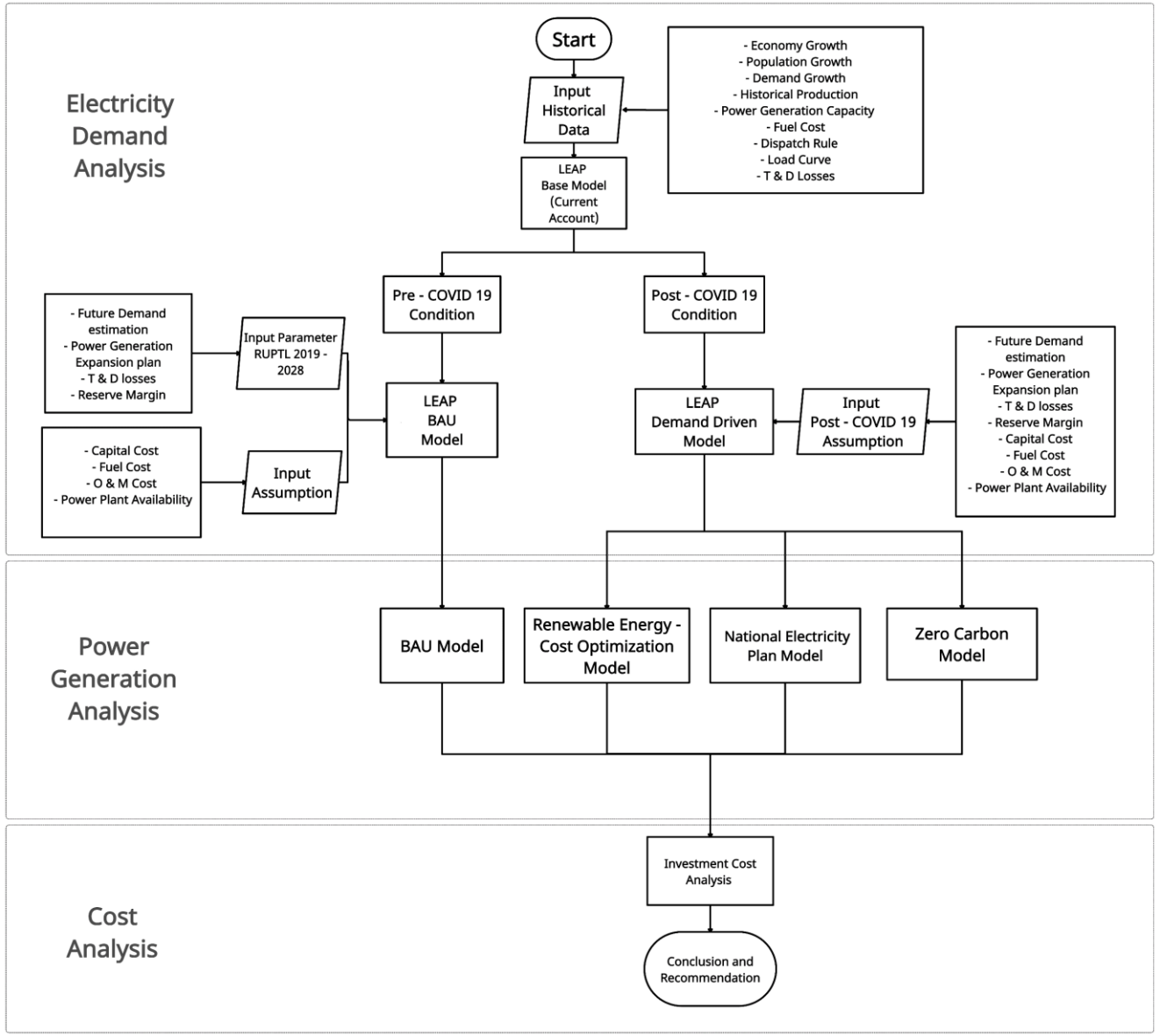
RESEARCH SCOPE

a. The Indonesia's electricity system is modeled as an single electricity system based on the data that available up to May 2021.

b. This research provide an overview of Indonesia future power generation for the period of 2020-2050.

c. The cost analysis in this research cover the investment cost analysis, presented as the total net present value in 2020 during the period of projection.

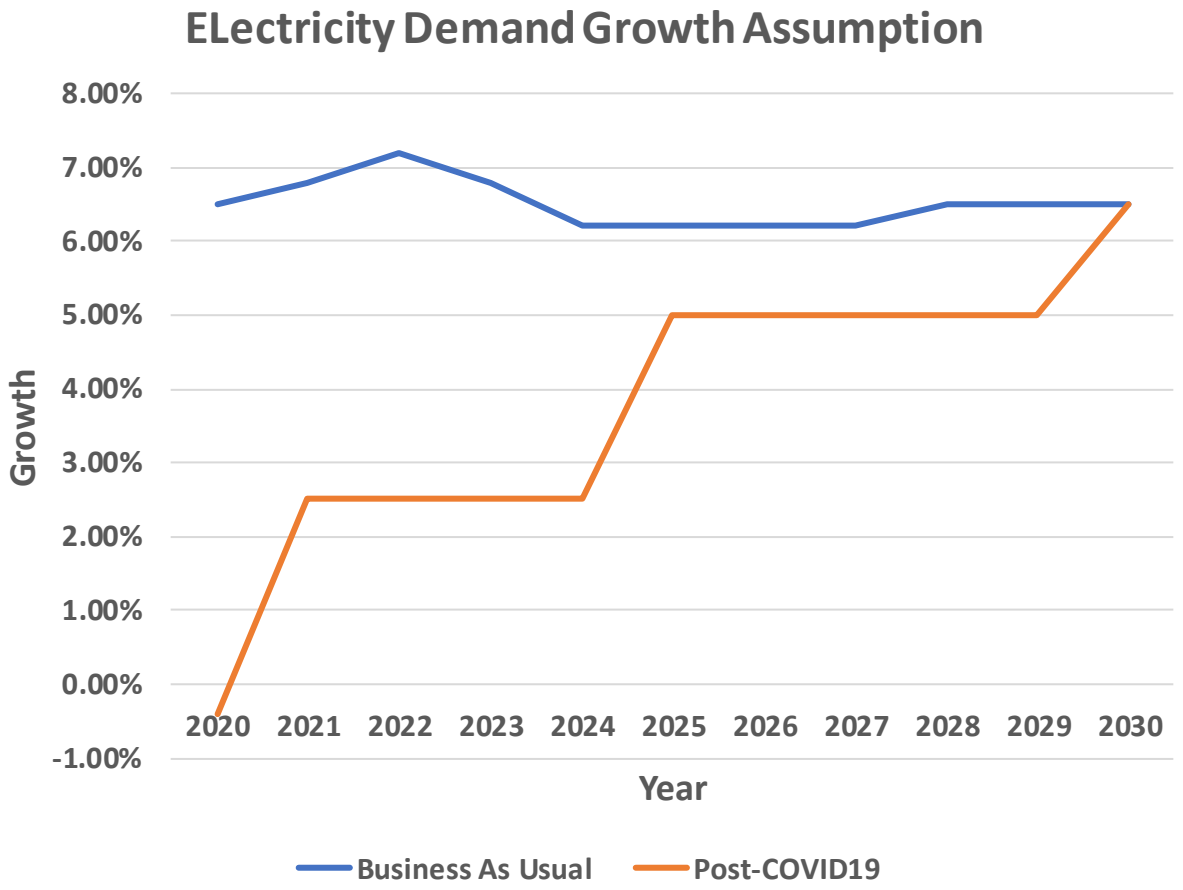
RESEARCH METHODOLOGY



LEAP follows an end-use, demand-driven approach, which means that the analysis starts from the end-use of energy. The demand factor dramatically influences the projection results for every the scenario. There are two demand models projected in this research, Business as Usual demand which based on the PLN Electricity Business Plan 2019 – 2028 and the Post-COVID19 demand which based on the Indonesia Energy Outlook 2020 – Special Edition The Effect Of Covid19 On Indonesia's Energy Sector. The projected demand will then affected the projected power generation for 4 scenarios, which is Business as Usual, National Electricity Plan, Renewable Energy with Cost Optimization Scenario, and Zero Carbon 2050.

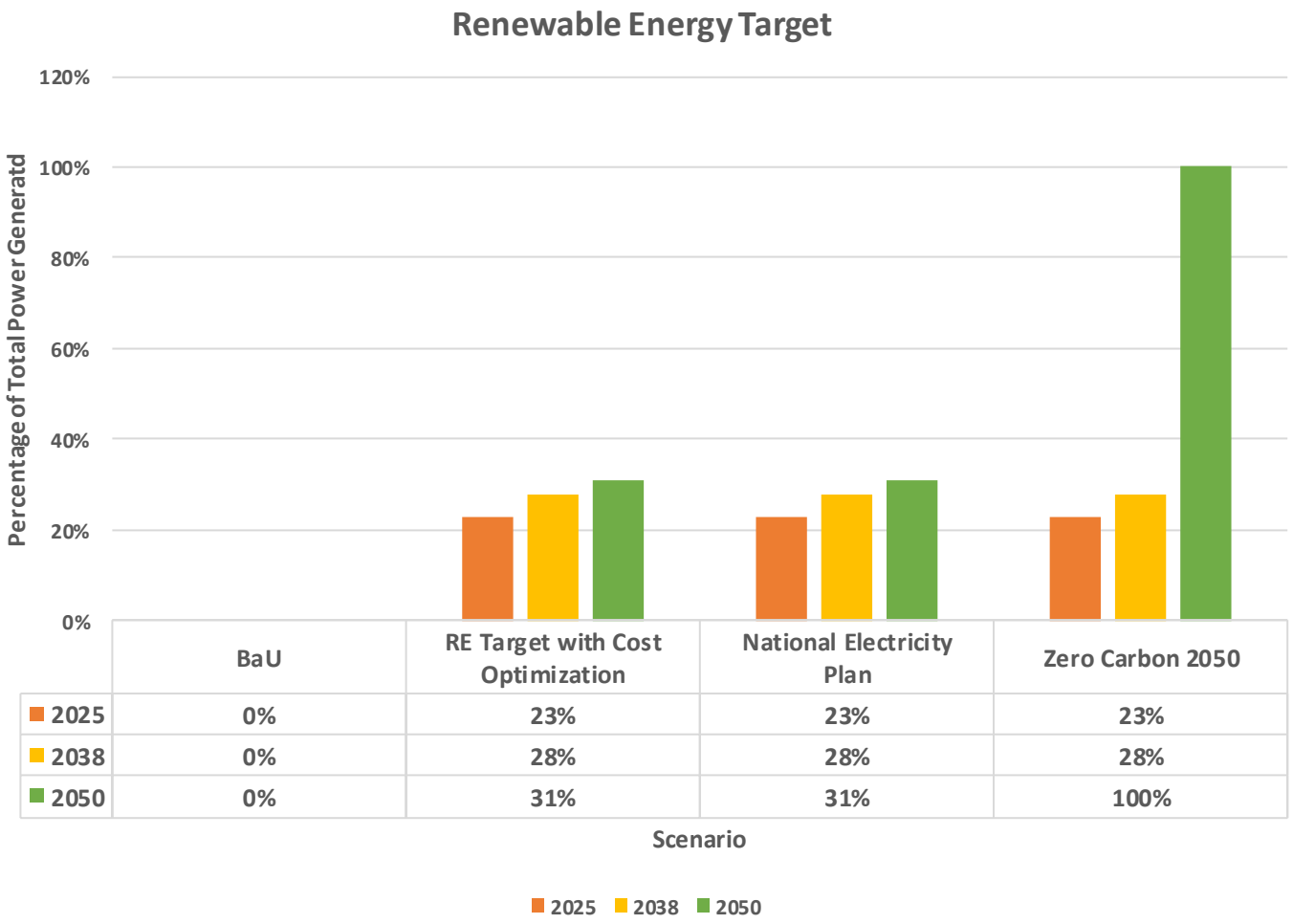
SCENARIO

Business as Usual demand is based on the PLN Electricity Business Plan 2019 – 2028 growth projection[1]. The BAU electricity demand growth will range from 6.2% up to 7.2% per year. Meanwhile, the Post COVID-19 demand is based on the "Indonesia Energy Outlook 2020 – Special Edition: Covid-19 Impact on Indonesia Energy Sector" [2] published by the Agency for the Assessment and Application of Technology (BPPT). The Post COVID-19 demand growth will vary from -0.4% in 2020, up to 6.5% in 2030. From 2030 onward both BAU and Post COVID-19 demand growth is fixed for 6.5% based on the projected average growth for the next ten years in RUPTL 2019-2028.



Source:
[1] PLN (2019) 'Electric Power Supply Business Plan (2019-2028)'. Available at: http://gatrik.esdm.go.id/assets/uploads/download_index/files/5b16d-kepmen-esdm-no.-39-k-20-mem-2019-tentang-pengesahan-ruptl-pt-pln-2019-2028.pdf.
[2] BPPT (2020) Indonesia Energy Outlook 2020 - Special Edition Dampak Pandemi COVID-19 terhadap Sektor Energi di Indonesia. Jakarta, Indonesia: Pusat Pengkajian Industri Proses dan Energi (PPIPE), Badan Pengkajian dan Penerapan Teknologi (BPPT).

SCENARIO



The total demand which we already determine then will affect the total power that the power generation need to produce. For the Business as Usual scenario, we assume that no renewable energy target should be achieve to fulfill the demand. Meanwhile in the Renewable energy with cost optimization scenario, and Hydro and geothermal optimization scenario we assume that renewable energy should achieve minimum target for 23% in 2025, 28% in 2038, 31% in 2050[2]. For Zero Carbon scenario the renewable energy target is 23% in 2025, 28% in 2038, and 100% in 2050[3].

[1] Minimum renewable energy percentage.

Source:

[2] Ministry of Energy and Mineral Resources (2019) "Rencana Umum Ketenagalistrikan Nasional Tahun 2019 sampai dengan Tahun 2038",

[3] Rahman, D. F. (2021) PLN pledges carbon neutrality by 2050 - Business - The Jakarta Post, The Jakarta Post. Available at: https://www.thejakartapost.com/news/2021/05/07/pln-pledges-carbon-neutrality-by-2050.html (Accessed: 10 May 2021).

SCENARIO

Business as Usual

Demand:
RUPTL 2019 – 2038

Energy Mix:
Renewable Energy:
No RE target

Renewable Energy with Cost Optimization

Demand:
Post COVID19

Energy Mix:
Renewable Energy :
2025 = 23%
2038 = 28%
2050 = 31%

National Electricity Plan

Demand:
Post COVID19

Energy Mix:
Renewable Energy :
2025 = 23%
2038 = 28%
2050 = 31%

Natural Gas:
2025 = 22%
2038 = 25%

Zero Carbon

Demand:
Post COVID19

Energy Mix:
Renewable Energy :
2025 = 23%
2038 = 28%
2050 = 100%

Source:
[1] Ministry of Energy and Mineral Resources (2019) 'Rencana Umum Ketenagalistrikan Nasional Tahun 2019 sampai dengan Tahun 2038', p. 441. Available at: https://jdih.esdm.go.id/index.php/web/result/1973/detail.

ASSUMPTION

Characteristic of Technologies

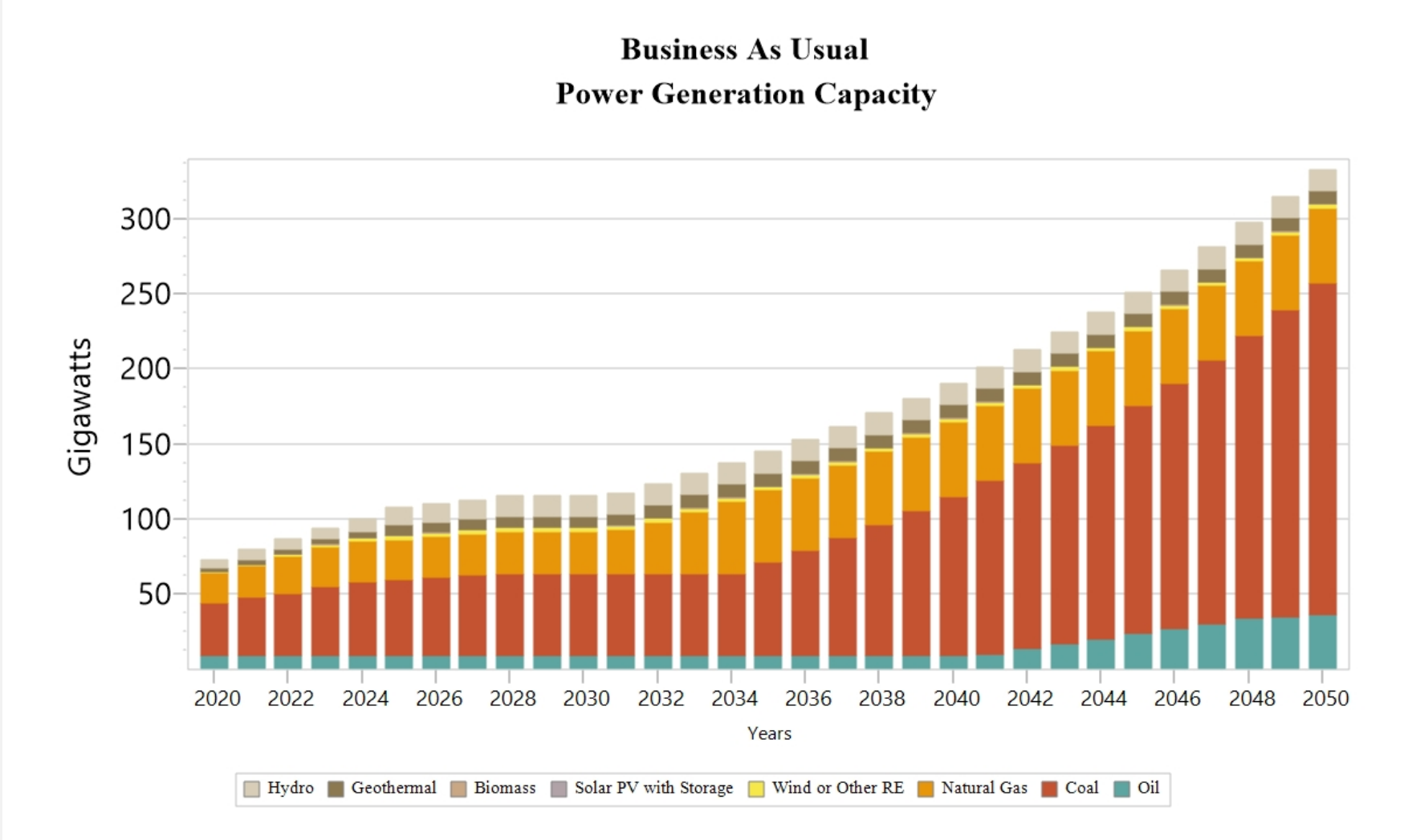
Branch	Lifetime (years)[1]	Efficiency (%)[1]	Maximum Availability (%)[1]	Capacity Credit (%)[1]	Capital Cost[2]		Fixed O/M Cost[3]	Variable O/M Cost[4]
					2020[5]	2050[6]		
Hydro	80	100	41	51	2769	2427	42	1.4
Geothermal	40	100	80	80	2772	2740	137.5	1.17
Biomass	20	100	80	100	4077	1725	126.3	4.85
PV[7]	25	100	22	27	1612	1052	32.3	0
Wind or Other RE[7]	25	100	28	35	1846	1280	26.5	0
Natural Gas	30	55	80	100	1082	926	14.2	2.56
Coal	40	40	80	100	3672	2437	40.8	4.52
Oil	30	35	80	100	1813	476	35.3	3.8

[1] Source: Handayani, K. (2019) Electricity and Climate Change : Seeking for the triple nexus of electrification, climate change mitigation, and climate change adaptation. Available at: http://purl.org/utwente/doi/10.3990/1.9789036548908.
[2], [3] in Thousand USD $ / MW
[4] in USD $ / MWh
[5] Source: Administration, U. S. E. I. (2021) 'Cost and Performance Characteristics of New Generating Technologies , Annual Energy Outlook 2021', 2021(February), pp. 1–4.
[6] Source: Intelligent Energy Systems Pty Ltd (2016) Thailand Power Sector Vision 2050. Bangkok, Thailand. Available at: https://wwfasia.awsassets.panda.org/downloads/thailand_power_sector_vision_full.pdf.
[7] With Battery Storage Cost

Business as Usual

Demand:
RUPTL 2019 – 2028

Power Generation:
RUPTL 2019 – 2028,
No Renewable Energy Constraint

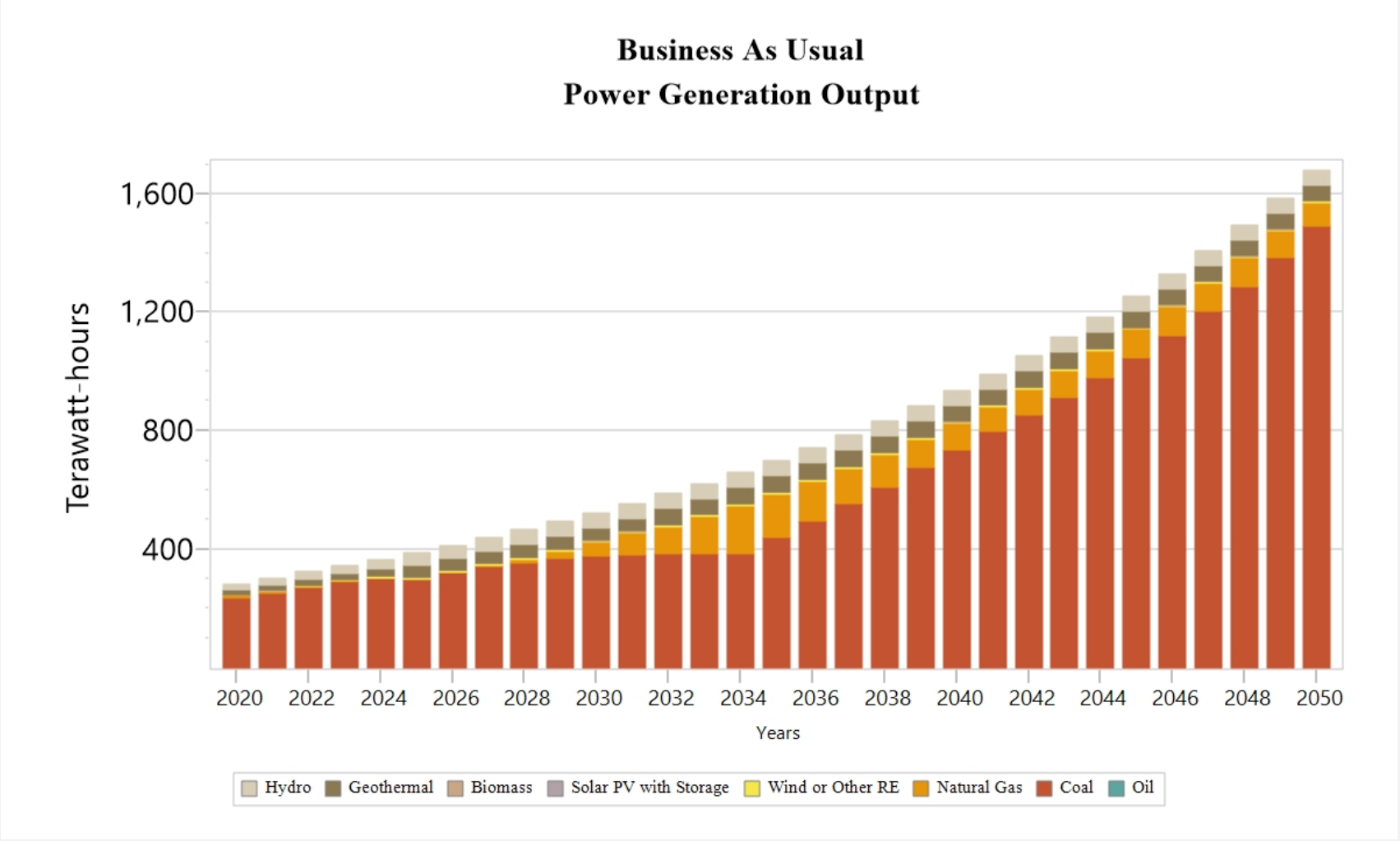


The Indonesia's total power generation capacity will be 107.6 GW in 2025, 170 GW in 2038, and 333.3 GW in 2050. In total up 2050, Indonesia need $124 Billion USD investment in power generation.

Business as Usual

Demand:
RUPTL 2019 – 2028

Power Generation:
RUPTL 2019 – 2028,
No Renewable Energy Constraint

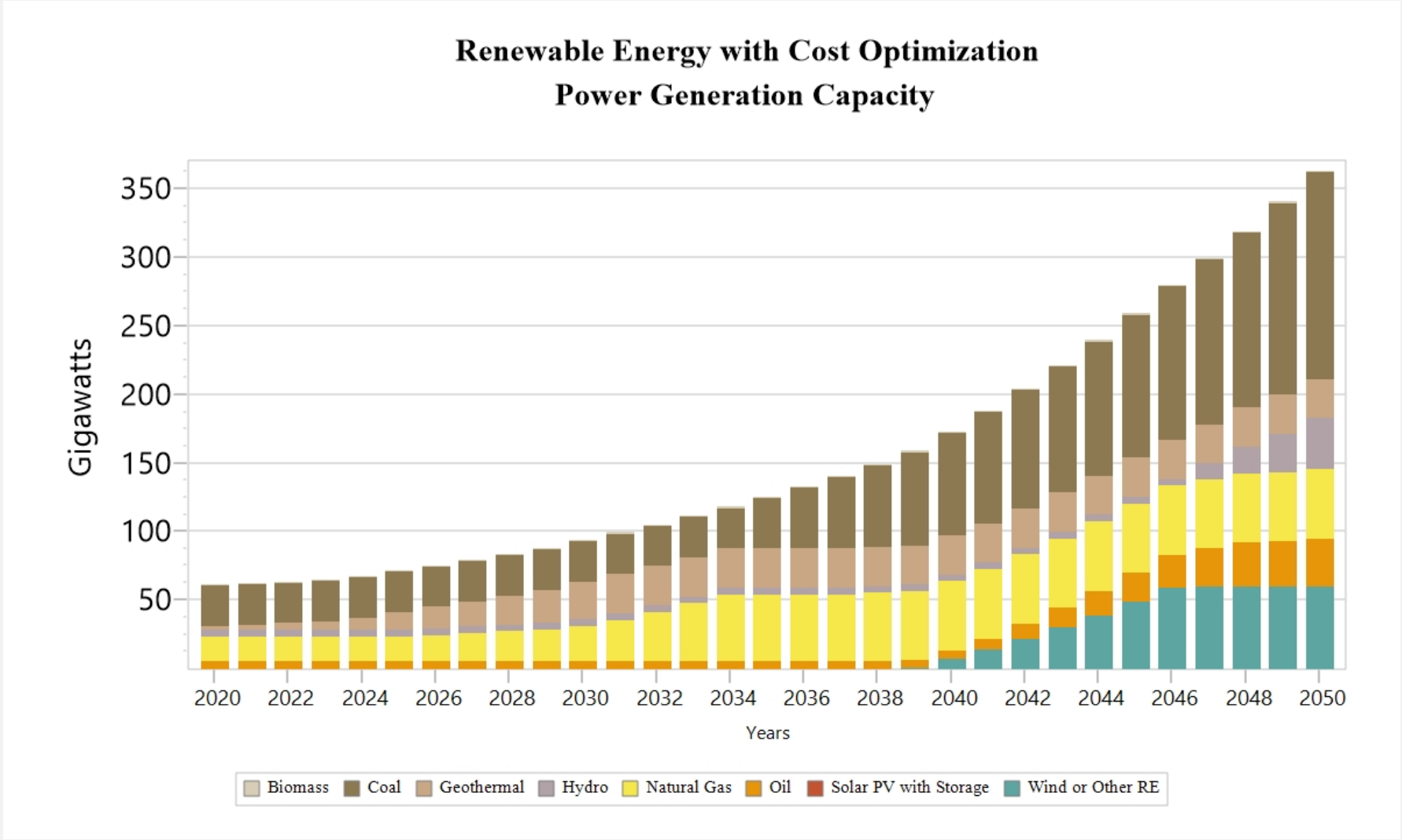


The total power generated in in 2025 is 390.2 TWh with the energy mix consist of, 23% Renewable energy, and the rest is from coal and natural gas. In 2038 the total power generated is 832 TWh, which consist of 13% renewable energy, 13% natural gas, and 74% of coal. And in 2050 the total power generated is 1678.6 TWh, with the energy mix consist of 6.6% Renewable energy, 4.7 % natural gas, and 88% coal.

Renewable Energy Target with Cost Optimization

Demand:
Post-COVID19

Power Generation:
Least Cost to achieve Renewable Energy 23% in 2025, 28% in 2038, and 31% in 2050

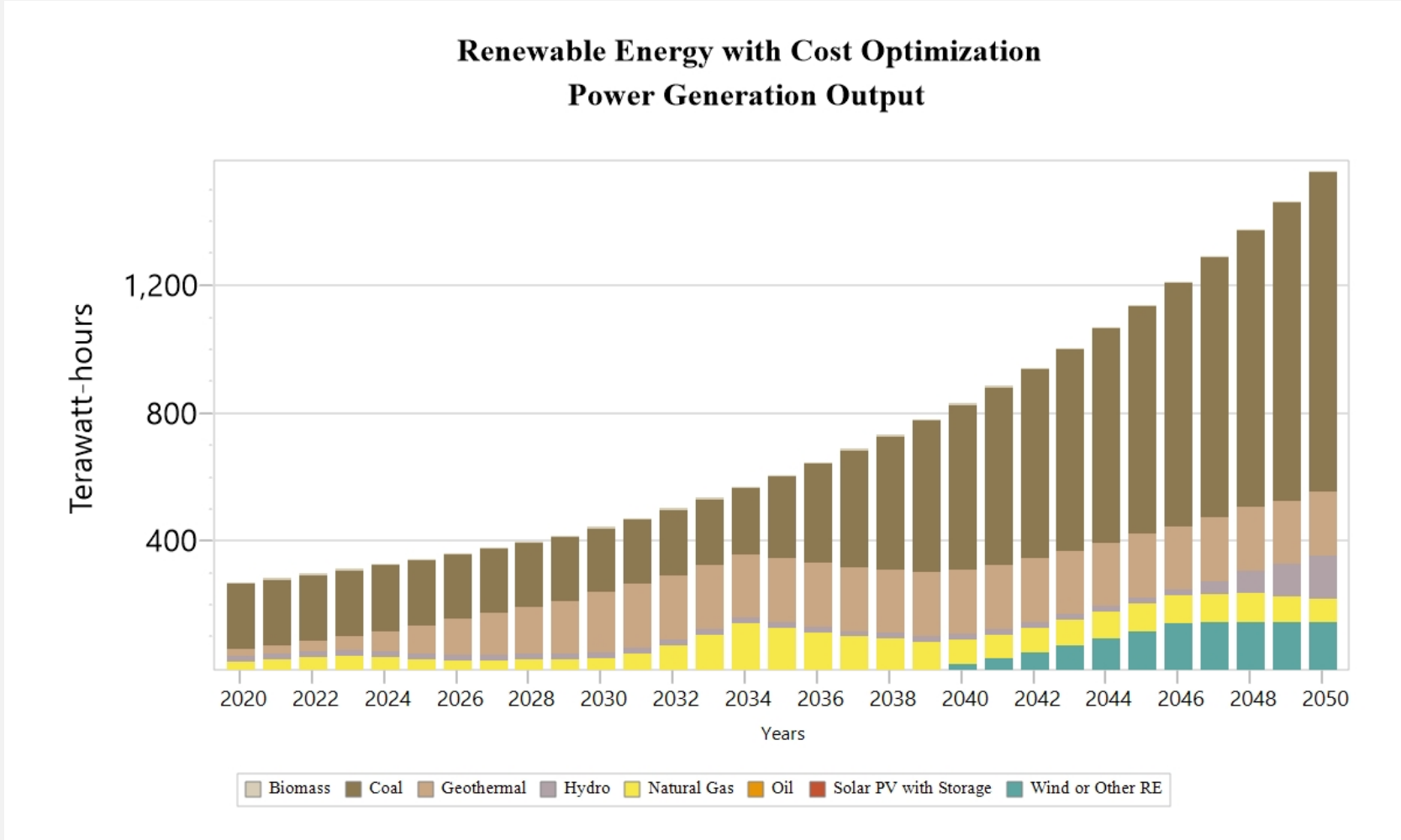


The model showed that, Indonesia total power generation capacity will be 71.25 GW in 2025, 149.1 GW in 2038, and 363.3 GW in 2050. The total power generation investment cost for the period of 2020– 2050 will be $72.8 Billion USD.

Renewable Energy Target with Cost Optimization

Demand:
Post-COVID19

Power Generation:
Least Cost to achieve Renewable Energy 23% in 2025, 28% in 2038, and 31% in 2050

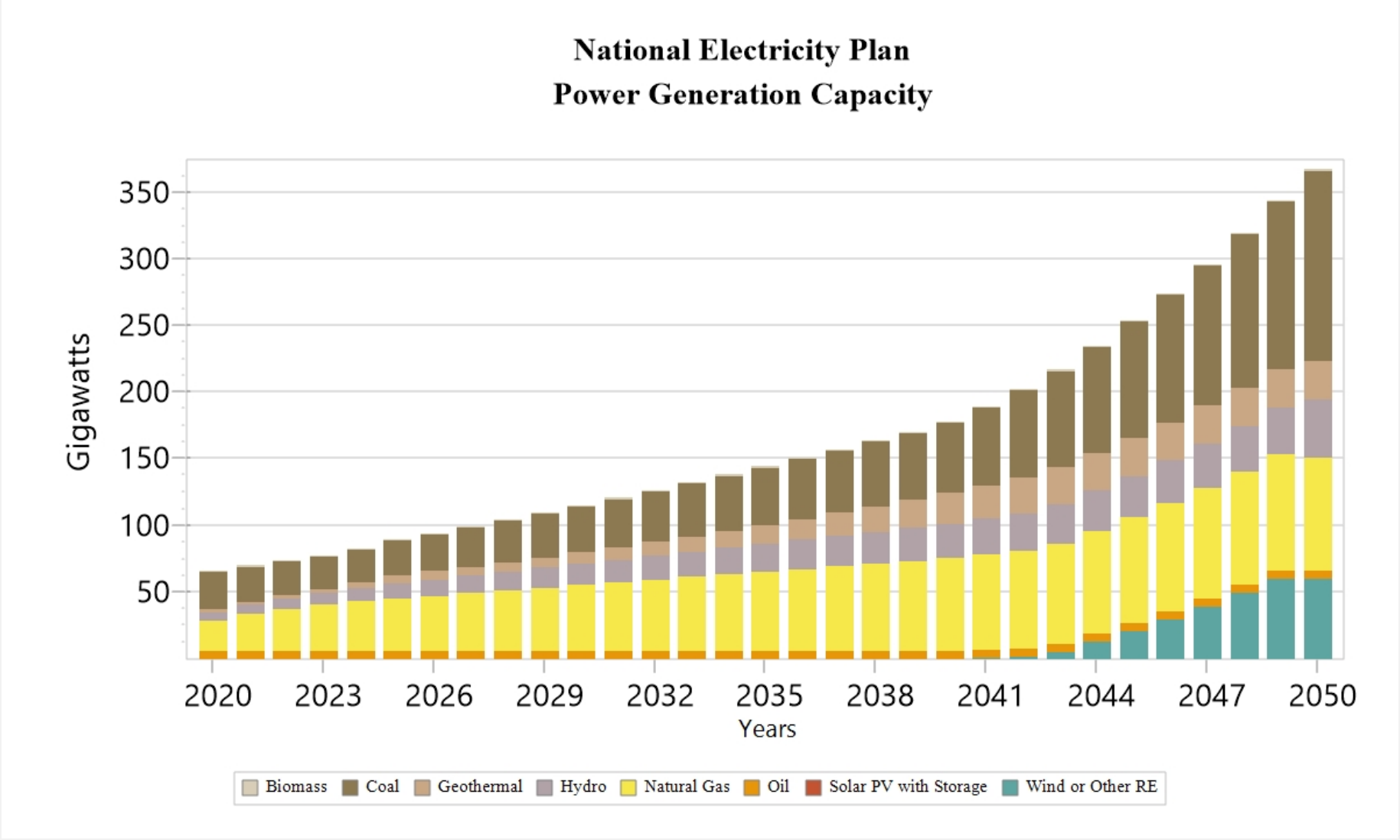


Indonesia total electricity production is 343.76 TWh in 2025, with the energy mix in 2025 consist of renewable energy 31%, natural gas 9.2%, and coal 58.9%. In 2038 the total electricity production is 732.5 TWh, and consist is 29.9% Renewable energy, 13.2% Natural Gas, and coal 56.9%. Next in 2050, the total power generated will be 1559.54 TWh, with 31% of Renewable energy, 4.8% of Natural gas, and 64.2% of Coal.

National Electricity Plan

Demand:
Post-COVID19

Power Generation:
2019 – 2038 National Electricity Plan Power Generation Energy Mix Target

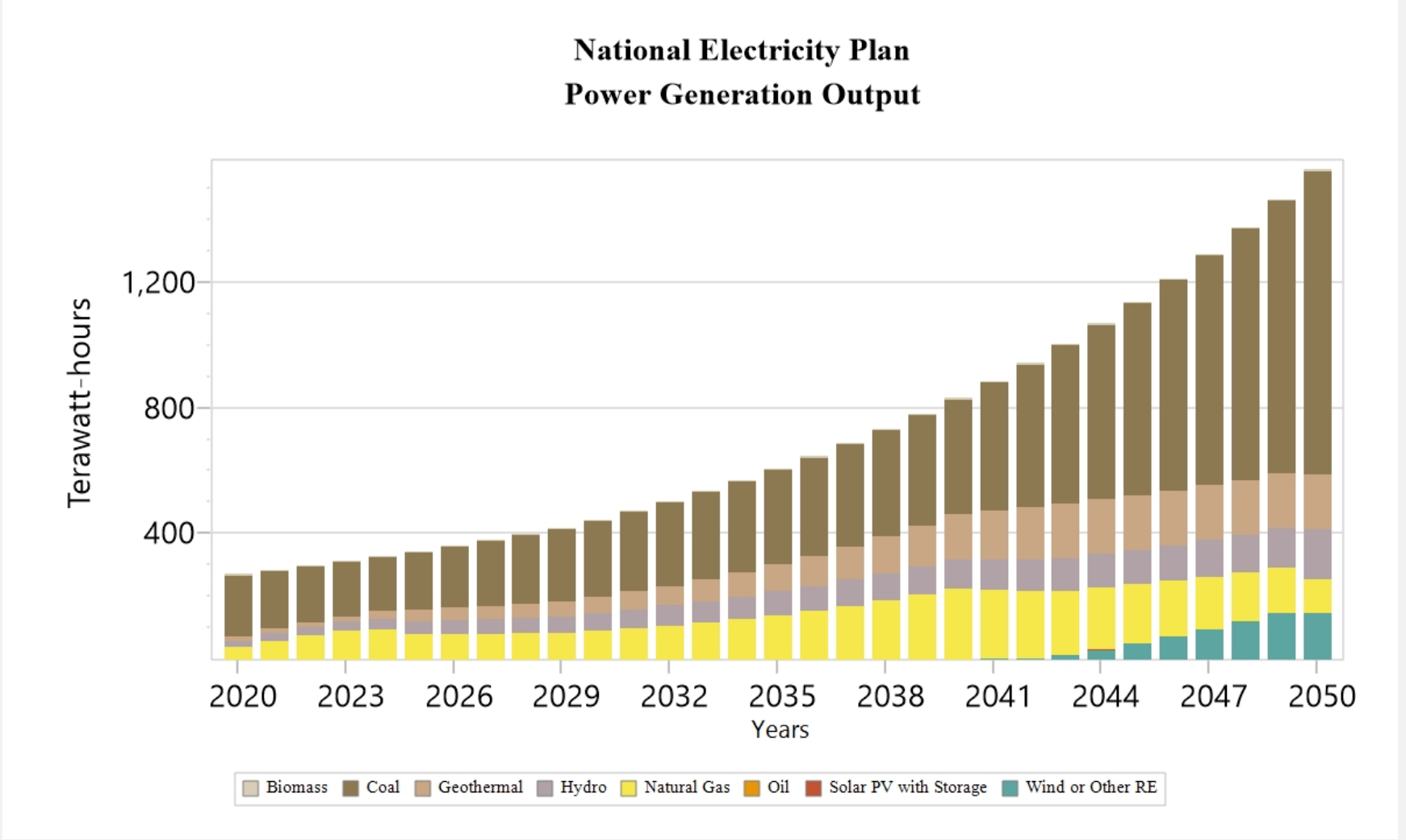


In 2025, Indonesia total power generation capacity is 79.5 GW. while in 2038 the capacity is 157.6 GW, and in 2050 will be 366.7 GW. The total investment cost in power generation up to 2050 will be 91.4 Billion USD

National Electricity Plan

Demand:
Post-COVID19

Power Generation:
2019 – 2038 National Electricity Plan Power Generation Energy Mix Target

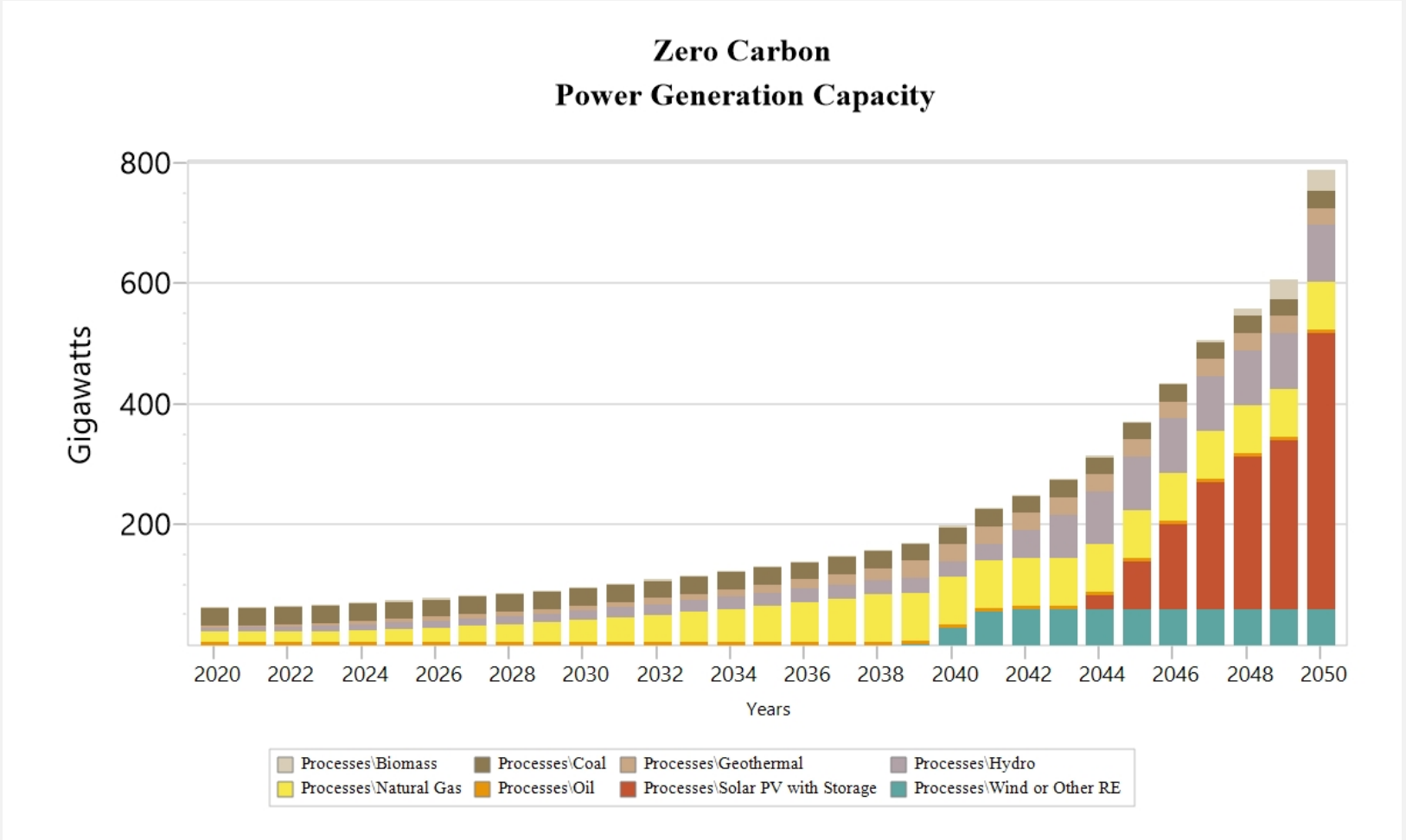


The Indonesia total power generation output is 343.75 TWH in 2025, 732.5 TWh in 2038, and 1559.5 TWh in 2050. The energy mix in 2025 consist of 23% renewable energy, 22% natural gas, and 54% of coal. While in 2038, is 28.6% from Renewable energy, 24.9% from Natural Gas, and coal 46.4%. In 2050, the energy mix consist of 31%of Renewable energy, 6.9% of Natural gas, and 62% of Coal.

Zero Carbon

Demand:
Post-COVID19

Power Generation:
100% Renewable Energy in 2050

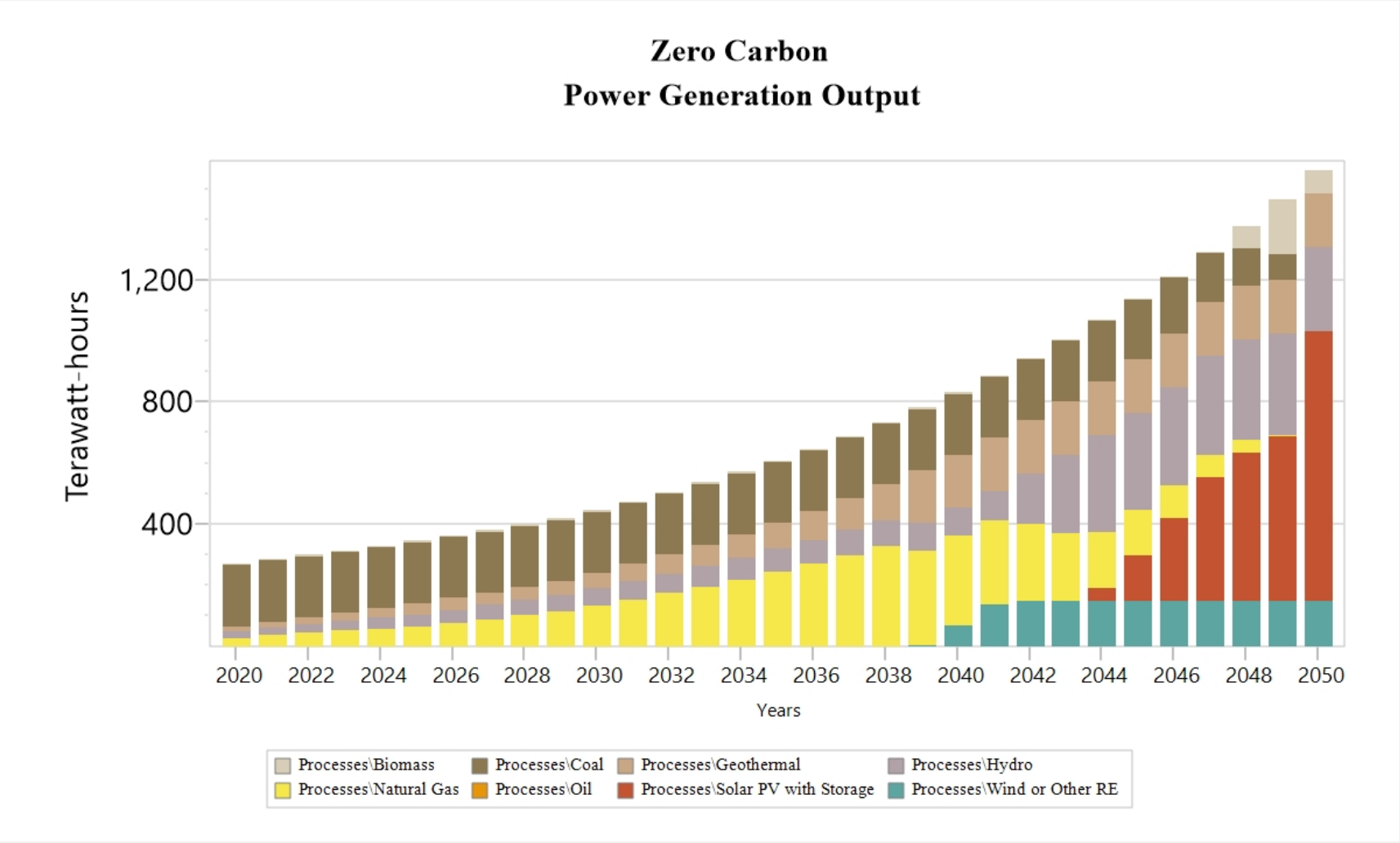


Currently there have been several discussions about Indonesia zero carbon in 2050. The zero carbon scenario aims to provide an insight what the most feasible Indonesia 2050 power generation condition if Indonesia aims to achieve 100% renewable energy at the cheapest cost. The model showed that Indonesia total power generation capacity is 72.85 GW in 2025, 156.55 GW in 2038, and 788.57 GW. The total investment cost up to 2050 is 94.1 Billion USD.

Zero Carbon

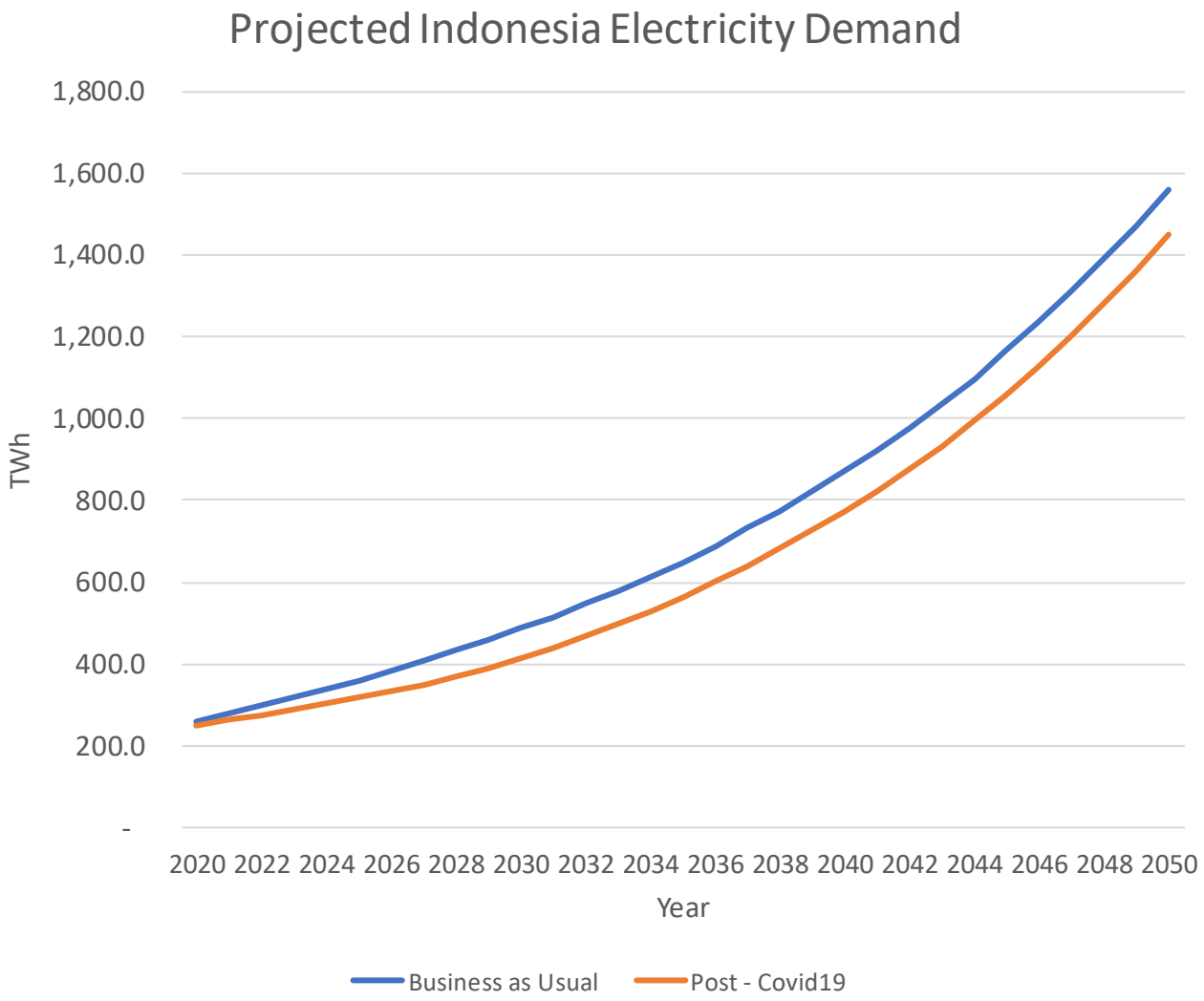
Demand:
Post-COVID19

Power Generation:
100% Renewable Energy in 2050



in 2050, The energy mix will consist of 100% of Renewable energy. The renewable energy mix will consist of, 17.8% hydro, 11.2% geothermal, 4.7% biomass, 56.7% PV, and 9.5% of wind and other type of renewable energy.

Electricity Demand in Indonesia

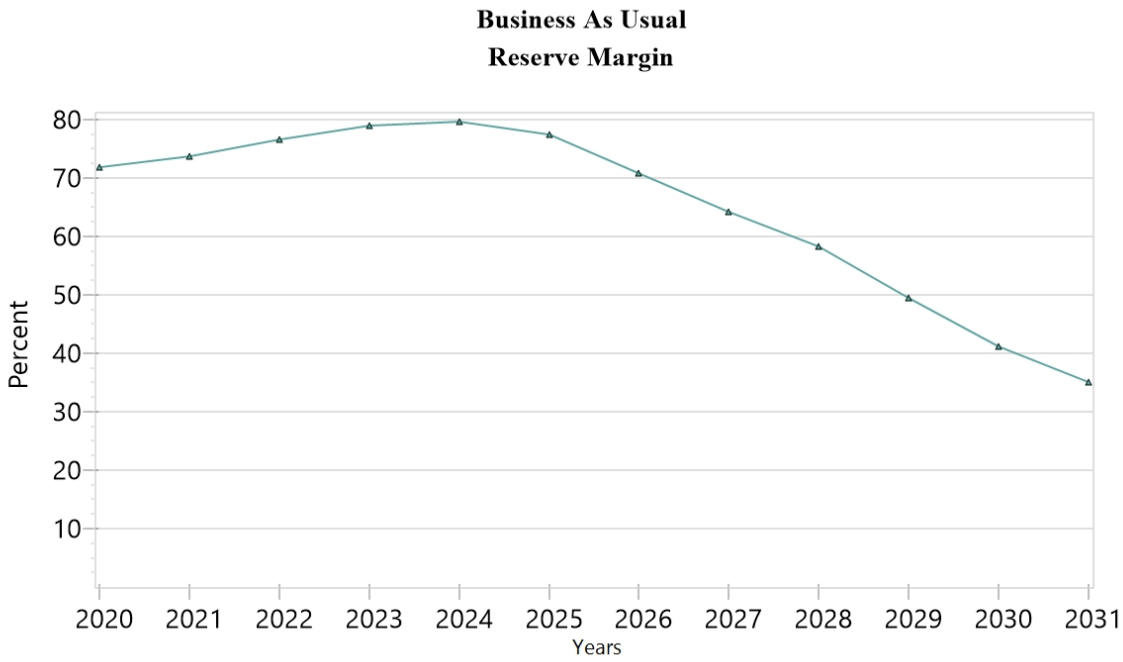


In Business as Usual condition electricity demand in Indonesia will be 360.9 TWh in 2025, and it will continue to grow up to 1561 TWh in 2050. But, due to COVID19 the demand for electricity is declining. In 2025 the demand will be 318 TWh which mean -12% compare to BAU scenario in the same year. If after 2030 the demand can recover to average growth 6.5% per year, then in 2050 the demand will be 1450.5 TWh.

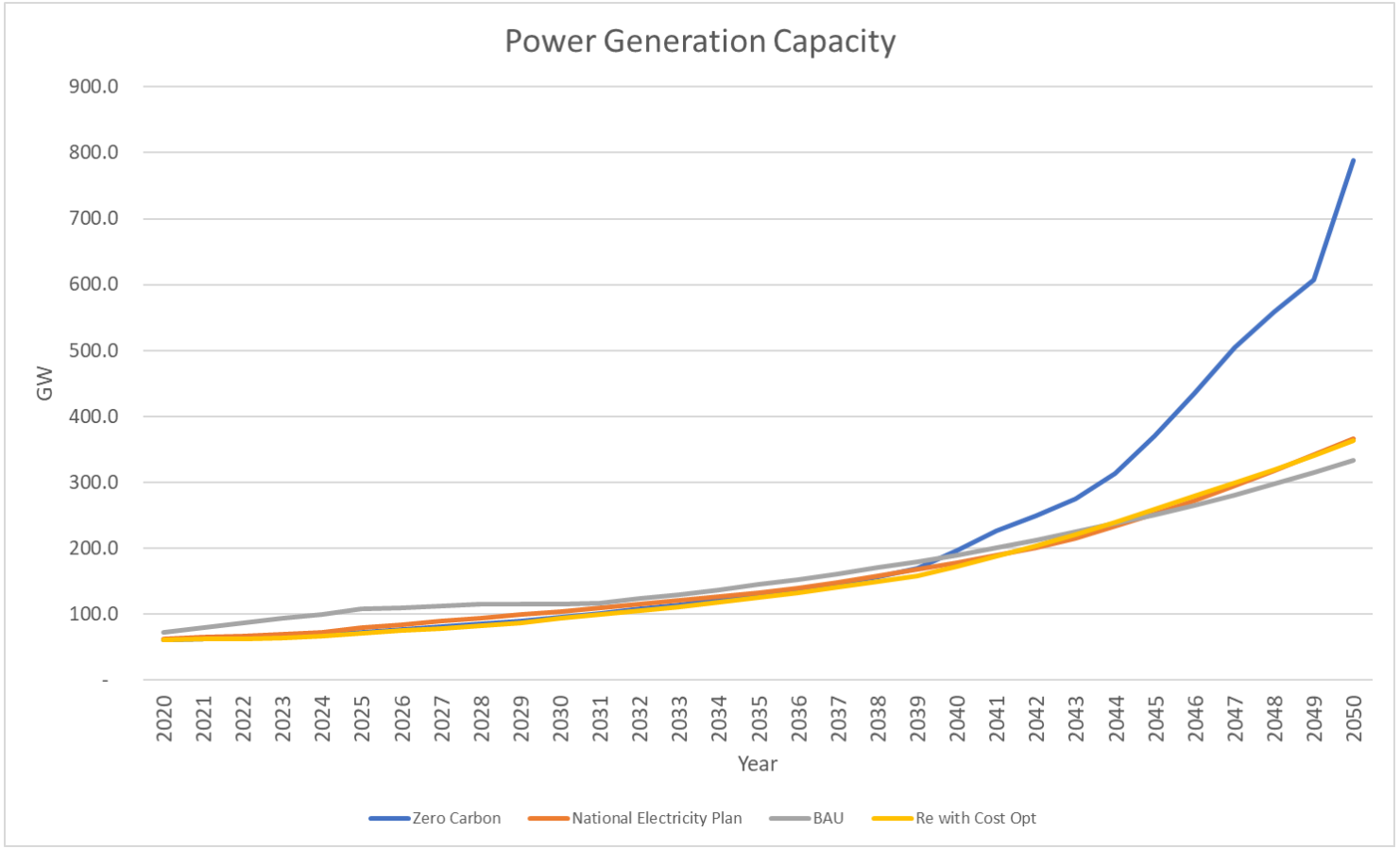
CONCLUSION

The BAU Scenario shows that the capacity of the existing generators and that has been planned in PLN's Electricity business plan 2019-2028 is sufficient to meet the demand in normal conditions until 2031. If the decline in demand due to COVID-19 continues for the next few years, then the reserve margin for Indonesia's generating capacity can reach 80%, or in other words, there is an overcapacity. Of course this is not efficient in terms of operating costs and investment costs. For PLN, this is worsen by the Take or Pay agreement with the IPP, this agreement forces PLN to pay for the electricity produced by the IPP even though PLN does not need the electricity.

PLN's Electricity Business Plan 2019 - 2028 is on the right track to achieve Indonesia's energy mix target of 23% renewable energy by 2025. However, because the energy mix in 2025 relies heavily on coal, Indonesia’s coal power plant will need biomass co-firing or early decommission so that the energy mix target of 28% renewable energy in 2038 and 31% in 2050 can be achieved.



CONCLUSION

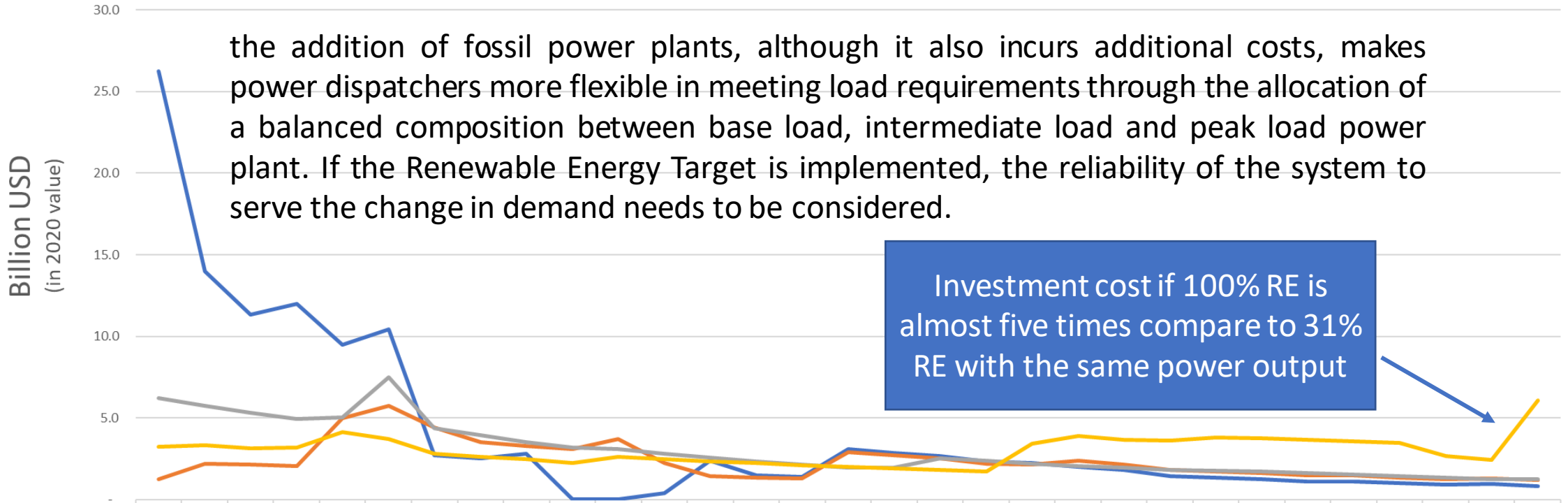


Indonesia could achieve zero carbon or 100% renewable energy by 2050. However, this scenario shows that even if all the renewable energy potential currently available is utilized, the amount of energy produced is still not sufficient to meet the existing demand in 2050. To overcome this problem, advances in renewable energy conversion technology are needed so that we can produce more power from smaller generating capacities. In addition, it is also necessary to explore new renewable energy sources to increase the potential of renewable energy. Utilization of nuclear technology can also be considered to cover the deficit of renewable energy generating capacity.

CONCLUSION

Investment Cost

the addition of fossil power plants, although it also incurs additional costs, makes power dispatchers more flexible in meeting load requirements through the allocation of a balanced composition between base load, intermediate load and peak load power plant. If the Renewable Energy Target is implemented, the reliability of the system to serve the change in demand needs to be considered.



Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Business As Usual	26.2	14.0	11.3	12.0	9.5	10.4	2.7	2.5	2.8	-	-	0.4	2.4	1.5	1.4	3.1	2.9	2.7	2.3	2.2	2.0	1.8	1.4	1.3	1.3	1.1	1.1	1.0	0.9	1.0	0.8
RE Target with Cost Optimization	1.2	2.2	2.1	2.1	5.0	5.8	4.4	3.5	3.3	3.1	3.7	2.2	1.4	1.4	1.3	2.9	2.7	2.5	2.2	2.1	2.4	2.1	1.8	1.7	1.6	1.5	1.5	1.4	1.3	1.3	1.2
National Electricity Plan	6.2	5.8	5.3	4.9	5.0	7.5	4.4	3.9	3.5	3.2	3.1	2.8	2.6	2.3	2.1	2.0	1.9	2.5	2.4	2.2	2.1	1.9	1.8	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.3
Zero Carbon	3.2	3.3	3.1	3.2	4.1	3.7	2.8	2.6	2.5	2.3	2.6	2.5	2.3	2.2	2.1	2.0	1.9	1.8	1.7	3.4	3.9	3.7	3.6	3.8	3.7	3.7	3.6	3.5	2.6	2.4	6.1

discount rate = 12%

inflation rate = 3.8%

Investment cost are calculated based on the net present value of the annual capital cost added in the given year.

THANK YOU!

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