STUDY REPORT

IESR

National Energy General Plan (RUEN):

EXISTING PLAN, CURRENT POLICIES IMPLICATION, AND ENERGY TRANSITION SCENARIO

www.iesr.or.id

IMPRINT

National Energy General Plan (RUEN):
Existing plan, current policies implication
and energy transition scenario

Author :
Agus Praditya Tampubolon

Reviewers :
Fabby Tumiwa, IESR
Jannata Giwangkara, IESR
Mentari Pujantoro, Agora Energiewende
Saleh Abdurrahman, ESDM

Please cite this report as :
IESR (2020). National Energy General Plan (RUEN) : Existing plan, current policies implication and energy transition scenario. Jakarta: Institute for Essential Services Reform (IESR).

Publication :
June 2020

FOREWORD

Energy planning plays an important role in setting the framework for regulations in the energy sector. In Indonesia, this energy planning is known as National Energy General Plan (Rencana Umum Energi Nasional/ RUEN). It serves as a guideline in establishing the national strategic plans for cross-sectoral energy planning coordination to realize better energy independence and security that support the national development.

RUEN is also used as a reference for sector-specific electricity and energy plans, such as National Electricity General Plan (Rencana Umum Ketenagalistrikan Nasional/RUKN), PLN's Electricity Supply Business Plan (Rencana Umum Penyediaan Tenaga Listrik/RUPTL), and Regional Energy Plan (Rencana Umum Energi Daerah/RUED).

The existing RUEN was developed in 2017 using real data collected up until 2015 for several indicators such as socio-economic, energy, and environmental status. These data then were projected until 2050 by taking into account the existing and future policies. However, looking at the real data of these indicators from 2015 until the first semester of 2019, it is clear that there are discrepancies between the projection and the real data. As a consequence, the projected energy demand, power plants' installed capacity, and energy mix need to be corrected. Additionally, there is a necessity to integrate several new policies, such as those concerning city gas network intensification and electric vehicles, into the RUEN model as they will change the energy shares composition.

As renewable energies begin to bring changes to energy planning around the world, we also see the importance of increasing the shares of renewables. We did this by introducing a scenario called "energy transition". In said scenario, we simulated a situation in which higher shares of coal-fired power plants are replaced by solar PV and wind. The sooner coal-fired power plants are replaced by power plants that use renewable energy, the higher the shares of renewables are.

Through this research paper, IESR intends to inform the policymakers and stakeholders of the alternative scenarios for the existing RUEN. All of which may be used as an input to review the existing RUEN as we expect higher shares of renewables.

June 2020

Fabby Tumiwa
Executive Director

Executive Summary

This study, *National Energy General Plan (RUEN): Existing Plan, Current Policies Implication, and Energy Transition Scenario*, was developed based on the model structure of the existing RUEN, with updated assumptions and techno-economic parameters. We use the Long-range Energy Alternatives Planning (LEAP) to create new Indonesian energy transition scenarios at the national level, the same tool that was used to build the existing RUEN. We investigated three new scenarios that interconnect with each other, which forecast Indonesia's long-term energy demand and supply from 2020 to 2050 based on underlying assumptions, energy demand structure, transformation, and energy supply structure.

The first scenario (Realization Scenario) looks at the new RUEN projection based on the real data on indicators, demands, and transformation and supply (there are twenty in total) from 2015 up to the first semester of 2019. The Realization Scenario is then used as a new baseline to develop the second and third scenarios. In the second scenario (Current Policies Scenario), several new policies launched and promoted by the government since 2019, e.g. city-gas networks, electric vehicles, and biodiesel programs, were integrated in the modelling to show the impact on the projection. Moreover, in the third scenario (Energy Transition Scenario), we proposed a new policy to stop the construction of new coal-fired power plants (CFPPs) from certain years and replace it with renewable power plants. In more detail, the third scenario comprises three sub-scenarios, namely (a) no new CFPP construction from 2029; (b) no new CFPP construction from 2025; and (c) no new CFPP construction from 2025 combined with the latest government policy to phase out combined cycle power plants older than 20 years by 2024 as initially indicated by the Minister of Energy and Mineral Resources.

In the Realization Scenario, the primary energy consumption is lower than the existing RUEN

Table ES1. Primary Energy Mix and Power Plants Capacity

	Primary Energy Mixx (in %)								Plants Capacity (in MW)			
	Fossil Fuels		NRE		Oil		NRE		Fossil Fuels		NRE	
	2025	2050	2025	2050	2025	2050	2025	2050	2025	2050	2025	2050
Existing RUEN	22	25	30	24	25	20	23	31	90	275	45	168
Realization Scenario	26	28	26	19	33	30	15	23	72	172	23	88
Current Policies Scenario	27	31	26	17	29	12	18	40	73	179	24	129
Energy Transition Scenario												
a. No new CFPP construction from 2029 onwards	27	9	26	15	29	10	18	66	73	51	24	408
b. No new CFPP construction from 2025 onwards	27	7	26	16	29	10	18	68	73	41	24	438
c. No new CFPP construction from 2025 plus phasing out combined cycle power plants older than 20 years by 2024	26	7	25	14	29	10	20	69	70	38	36	451

with a yearly energy consumption growth rate at 4% (compared to 4.7%/year in the existing RUEN). Conversely, the 23% target of primary energy mix by 2025 (in the existing RUEN) will also deviate to only 15% in this scenario, and the 31% target in 2050 will only get to 23%. Looking at the capacity, the renewables target of 45.2 GW by 2025 in the existing RUEN will not be achieved. The realization scenario shows that renewables will only get to 22.62 GW in 2025.

In the realization scenario, the electricity demand will decrease from 772 TWh in the existing RUEN to only 447 TWh in 2025. Furthermore, in 2050, the new electricity demand will be at 1,239 TWh or more than 50% less than the projection in the existing RUEN. As a result, with these new numbers, the electricity consumption in this new scenario will also be lower, with electricity consumption per capita in 2025 at 1,582 kWh/capita compared to 2,500 kWh/capita in the existing RUEN. Our analysis indicates that lower socio-economic indicators, such as demography, economic and industrial growth, and the smaller number of vehicles in the realization scenario compared to the existing RUEN are the main reasons why the total primary energy demand, electricity consumption, and power plants capacity in this new scenario are lower than the existing RUEN.

In the current policies scenario, the renewables share in the primary energy mix increased due to the biodiesel program. Based on the government policy target, we set the use of B50, starting from 2021, and B100 (drop-in fuel), starting from 2030. Additionally, the policy to intensify electric vehicles increased the electricity demand compared to the realization scenario, while at the same time reducing the oil consumption. This biodiesel program alone is not sufficient to increase the renewables share in the primary energy mix to more than 50% (it only contributes 14.5% to the primary energy mix by 2050). Additionally, the increasing electricity demand due to electric vehicles also highlighted the need to decarbonize the grid if the EV contribution to a reduction of Indonesian greenhouse gas (GHG) is to be maximized.

The power plants installed capacity in this scenario also increased compared to the realization scenario from 95 to 97 GW in 2025 and from 260 to 308 GW in 2050. The increase is a result of electricity demand growth due to the significant expansion in the number of electric vehicles starting from 2025. Our model shows that the electricity demand in this scenario will slightly increase compared to the realization scenario from 447 TWh to 462 TWh in 2025 and from 1,239 TWh to 1,475 TWh in 2050. Similarly, the consumption per capita will

Power Plant Industrial

also slightly increase compared to the realization scenario.

In the energy transition scenario, the sooner the CFPP moratorium is applied, the more significant the share of renewables in the primary energy mix is, and the earlier the renewables share surpasses fossil fuels. In the first sub-scenario (no new CFPP construction from 2029), the renewables share will be 17.9% (or 46.3 MTOE) in 2025 and will reach 66.3% (or 503.8 MTOE) in 2050. The renewables share will surpass fossil in 2042, when the renewables share in the primary energy mix reached 51%. In the second sub-scenario, the renewables share in 2025 will be similar to the first sub-scenario, while the renewables share in 2050 will increase to 68.1% (or 524.41 MTOE). The renewables share overcame fossil one year earlier in this sub-scenario, wherein 52% of the primary energy mix is already renewable in 2041.

Finally, in the last sub-scenario, the renewables share will reach 20.1% (or 52.56 MTOE) by 2025 and will increase to 68.6% (or 530.5 MTOE) by 2050, making this sub-scenario has the highest share of renewables compared to the previous two. And in terms of overcoming the fossil share, this sub-scenario reaches it in 2040, with renewables at 50.4%.

Overall, with the difference in power plants capacity for each scenario, the share of each power plant will also change. The realization and current policies scenarios show that the existing renewables target with total renewables installed capacity of 45.2 GW by 2025 will not be achieved, without even mentioning the 167.7 GW target by 2050. However, in the energy transition scenario, even though the 2025's target will be missed by all three sub-scenarios, the 2050 target will be far exceeded.

Table ES2. Power Plants Capacity for each type of Renewable Source in all Scenarios

	Power Plants	Year	Existing RUEN	Realization Scenario	Current Policies Scenario	Energy Transition Scenario		
						No new CFPP construction from 2029 onwards	No new CFPP construction from 2025 onwards	No new CFPP construction from 2025 plus phasing out combined cycle power plants older than 20 years by 2024
FOSSIL FUELS (in GW)	Steam (PLTU)	2025	54.28	38.18	39.18	39.18	39.18	39.18
		2050	161.46	128.23	145.43	17.65	7.33	7.33
	Gas (PLTG)	2025	36.07	33.41	33.41	33.41	33.41	30.21
		2050	113.97	43.44	33.40	33.40	33.40	30.20
	Diesel (PLTD)	2025	3.10	1.20	0.36	0.36	0.36	0.36
		2050	3.10	0.00	0.00	0.00	0.00	0.00
RENEWABLES (in GW)	Geothermal (PLTP)	2025	7.24	3.30	3.30	3.30	3.30	3.30
		2050	17.55	10.99	16.00	28.50	28.50	28.50
	Hydropower (PLTA)	2025	17.99	12.48	12.48	12.48	12.48	12.48
		2050	38.00	62.29	76.04	76.04	76.04	76.04
	Mini/Micro Hydro (PLTM/MH)	2025	3.00	1.67	1.96	1.96	1.96	1.96
		2050	7.00	1.67	1.96	19.39	19.39	19.39
	Bioenergy (PLT Bio)	2025	5.50	2.11	3.30	3.30	3.30	3.30
		2050	26.00	9.54	21.81	32.60	32.60	32.60
	Solar (PLTS)	2025	6.50	1.43	1.73	1.73	1.73	14.03
		2050	45.00	2.98	10.00	172.87	203.24	215.54
	Wind (PLTB)	2025	1.80	0.80	0.97	0.97	0.97	0.97
		2050	28.00	0.96	3.00	60.60	60.60	60.60
	Ocean (PLT Laut)	2025	0.03	0.00	0.00	0.00	0.00	0.00
		2050	3.00	0.00	0.00	17.90	17.90	17.90

Key Findings:

- Basic assumptions and indicators used to develop the existing RUEN are already outdated. The existing RUEN was set in 2017, and the majority of the data used was from the real data up to 2015. For 2016 onwards, they were projected based on these existing data and tended to be overestimated, especially in the economic and industrial growth and in the demography. This results in the disproportionate projection in the existing RUEN, for example, in the primary energy and electricity consumption, including in the power plant's capacity.
- Looking at all the three scenarios, the existing RUEN target of 23% renewables share in the primary energy mix and 45 GW installed capacity by 2025 will be missed. However, in 2050, the energy transition scenario will far exceed the existing RUEN target, for both the renewables share in the primary energy mix and the total renewables installed capacity.
- The increased usage of biodiesel, from B50 starting from 2021 to B100 starting from 2030, will increase the renewables share considerably. In the current policies scenario, biodiesel contributes 14.5% to the primary energy mix (out of 40% renewables share) by 2050. However, the biodiesel program alone is not sufficient to increase the renewables share in the primary energy mix to more than 50%. In addition, the feasibility of B50 both technically and economically remains questionable, as the government recently has been pushing to test the production of drop-in diesel fuel from CPO.
- In the energy transition scenario, the sooner the CFPP ban is applied, the more significant the share of renewables in the primary energy mix is, and the earlier the renewables share surpasses fossil fuels. The earliest, when the renewables share overcomes fossil, will occur in 2040 (sub-scenario C from Table ES1) and the latest will occur in 2042 (sub-scenario A from Table ES1).
- To be on-track with the energy transition scenario, the renewables installed capacity by 2025 should be at least 23.74 GW (fossil fuels at 72.96 GW), and should be a minimum 408 GW (fossil fuels at 51.1 GW) by 2050. The majority of the renewables capacity will come from solar, hydropower, and wind.

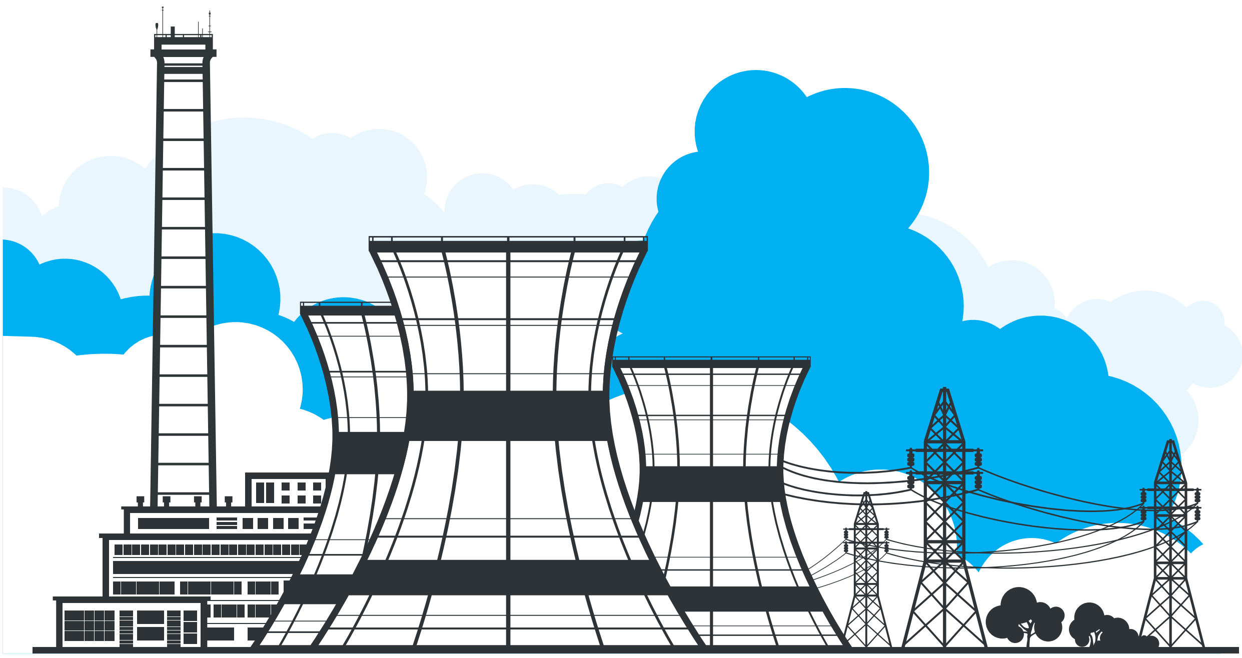


TABLE OF CONTENT

TABLE OF CONTENT

1 Introduction

As the central government's energy policies, National Energy Policy (Kebijakan Energi Nasional/KEN) and RUEN provide guidelines to govern Indonesia's energy for better energy independence and security to support the national development. Being the national plan, RUEN becomes a reference for sector-specific energy and electricity plans such as RUKN, RUPTL, and Regional Energy Plan (RUED). Additionally, RUEN also becomes a directive for ministries as well as national and local government institutions to develop their strategic plan document and conduct cross-sectoral energy planning coordination.

Going forward, in line with the existing 2014 KEN and 2017 RUEN (2015–2050 RUEN), the direction of Indonesia's energy policy shall be based on the new paradigm: that Indonesia should not treat energy sources as export commodities, but as capital for the development of the nation to secure national energy supply and optimize sustainable energy management aiming at ensuring just and equal energy access for all Indonesians; to create and support industries and services focusing on energy; and to create new jobs —all of these objectives also emphasize on climate change and environmental protection.

The existing RUEN, released in 2017 under Presidential Decree Number 22/2017 concerning the National Energy Plan, only targets 23% renewable energy in 2025 for primary energy mix, or around 45 GW of generation capacity and 15 million kiloliters in liquid fuel (biofuel). On the opposite, fossil fuels are still dominating the primary energy mix, with coal at 30%, followed by oil (diesel) and natural gas at 25% and 22% respectively. The uncompetitive price of renewables when the model was developed in 2015 is deemed as one major factor as to why the proportion of renewables is small in this RUEN.

The existing power sector is still highly dependent on coal as coal power plants generate 60 to 65% of the total energy supplied. With coal's price being volatile, electricity generation costs from coal-fired power plants also fluctuate. This is because the cost of fuel makes up 76% of electricity generation costs in the coal-fired power plants. However, renewables are on the opposite. The price of renewables has fallen significantly globally and is expected to continue declining. Additionally, renewables have zero or minimal marginal cost. Renewables-fired power plants will be different from thermal power plants that have ever-increasing marginal cost over time.

With these global trends showing renewables are now competitive and their usage in Indonesia may be increased, we, therefore, investigated new models based on the existing model structure for developing the 2017 RUEN, using the updated assumptions and techno economic parameters. We developed new scenarios that have significantly higher shares of renewables and simulated them using Long-range Energy Alternative Planning (LEAP).

Our model is built based on several scenarios that are all interconnected. The first scenario was developed based on the real data of indicators, demands, as well as transformation and supply (there are twenty in total) from 2015 until the first semester of 2019. After updating these twenty parameters, the new results then were compared to the existing RUEN to see the significant changes generated. Analysis in the section 'Result and Discussion' shows that energy consumption will not grow as high as previously projected. Thus, the primary energy supply, electricity consumption, and power plant capacity–among others–will be significantly reduced. These new numbers, we think, better represent the current condition and projection. They will be used as the new baseline for further analysis.

The second scenario was developed based on the new baseline that was adjusted to several new policies launched and promoted by the government since 2019, like those concerning city gas network, electric vehicles, and biodiesel program. This scenario looked specifically on the impacts of these policies on the same parameters as those in the first scenario, namely primary energy supply and mix energy, electricity consumption, and power plants' capacity. From our study, we found out that the combination of these three policies will slightly increase the renewables shares in the primary energy mix by 2025 and considerably in 2050. Still, it will only contribute a small addition to the total primary energy consumption. However, in this scenario we still cannot have renewables shares higher than fossil fuels'. To realize that, we proposed the third scenario: the energy transition scenario.

The energy transition scenario involves implementing the policies in the second scenario combined with the proposed policy to stop the construction of new coal-fired power plants (CFPP). In our model, we introduced three sub-scenarios: (1) no construction of new CFPPs from 2029; (2) no construction of new CFPPs from 2025; and (3) no construction from 2025 combined with the latest policy to phase out combined cycle power plants that are older than 20 years.

On top of these policies, all CFPPs are limited to thirty years of operation time. When a CFPP reaches this age, the relevant unit must be shut down without any possibility to prolong its operation time. As a consequence, there will be a significant gap in the electricity supply to meet demand. This gap is then filled by the renewables. This action will then increase the renewables shares in the primary energy mix, rendering it to be higher than that of fossil fuels by 2041 or 2042 (depending on the year the cessation of CFPPs construction is applied).

If we set our definition for energy transition solely on the goal to ensure renewables share is bigger than that of fossil fuels, then we shall transform our energy from fossil fuel to renewables from 2041/2042, both for primary energy supply and power plant capacity.

2 Model Overview

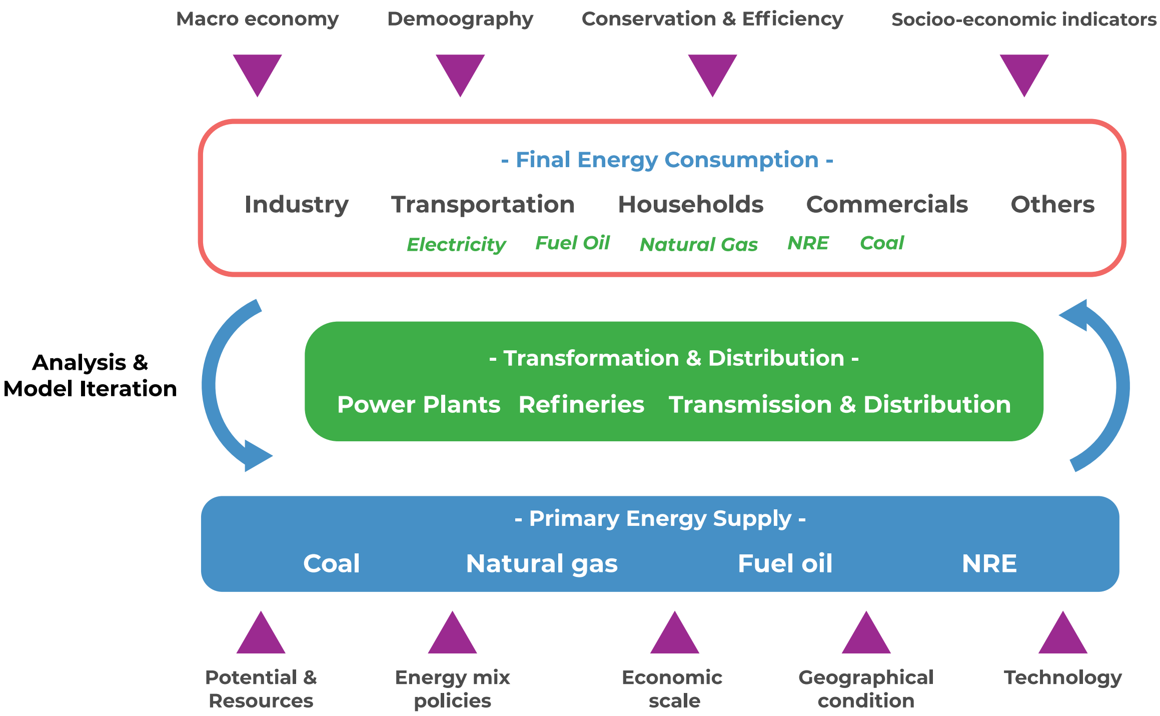


Figure 1 Energy planning structure in LEAP RUEN

RUEN model is built using the understanding of the existing conditions and future expectations. These existing conditions can be categorized into socio-economic indicators, energy indicators, and environmental indicators. Meanwhile, future expectations are set out by considering:

- Targets of KEN;
- Energy development planning from responsible institutions and inputs from stakeholders and experts based on the technology development's prediction in the future; and
- Current condition development of all three indicators: socio-economic, energy, and environmental.

In addition to taking the aspects above into consideration, RUEN modeling also includes current regulations, best practices, studies, official publications, and/or realization of targets.

We used LEAP to create the new Indonesian energy model at the national level, the same tool that was used to build the existing RUEN. This model will predict Indonesia's long-term energy demand and supply from 2020 to 2050 based on the underlying assumptions, energy demand structure, transformation, and energy supply structure.

The existing RUEN was set out in 2017, and the majority of the data used was from the real data collected until 2015. For the data from 2018 onwards, they were projected based on the existing and future policies until 2050.

However, looking at the RUEN's projection from 2015 until the first semester of 2019 and comparing it to the existing data collected until 2019, we can see that the forecast shows a big difference from the actual number such as that of the economic growth, demography, as well as energy demand and supply. As a result, the energy demand requires installed capacity and energy mix to be corrected. Taking this as an example, we assume that the rest of the projection in the existing RUEN needs to be updated and adjusted. For that reason, in this new Indonesian energy model, we updated twenty input data that were used to do LEAP modeling. All of which can be seen on Table 1.

Table 1 Twenty RUEN's input that is updated in the new Indonesia energy model

Macro Indicators	Demand	Transformation & Supply
1. Changes in GDP constant price from 2000 to 2010 2. Realization of nominal GDP 3. Realization and projection of economic growth (%) 4. Realization and projection of population 5. Realization and projection of number of households 6. Assumption of the number ofpeople per household	7. Realization of industrial growth per business sector 8. Industrial growth's projection by adopting draft RPJMN 2019-2024 9. Realization and projection of industrial energy consumption 10. Realization and projection of the number of vehicles 11. Realization and projection of the amount and energy consump tion from the transportation sector 12. Realization and projection of the amount and energy consump tion from the households sector 13. Realization and projection of the commercial sector elasticity	14 Realization and projection data of petroleum supply 15. Realization and projection data of natural gas supply 16. Realization and projection data of coal 17. Realization of the power plants' construction 18. Realization of the power plant mix 19. Realization of the renewable energy development 20. Power plants and renewable energy projection

2.1. Basic Assumption

The basic assumptions used in this model comprise the nominal Gross Domestic Product (GDP), total population, economic and population growth, and number of households.

Table 2 Updated socio-economic indicators in the new Indonesian energy model

No	Indicator	Unit	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
1	Gross Domestic Product GDP	Trillion Rupiah	10,957	11,549	12,184	12,878	13,638	14,470	15,401	20,736	35,859	58,520
2	Economic Growth	%	5.1	5.4	5.5	5.7	5.9	6.1	6.43	5.93	5.43	4.73
3	GDP Per Capita	Million Rupiah	41.05	42.84	44.75	46,85	49.16	51.69	54.52	70.50	114.75	179.43
4	GDP per Capita growth	%	4.35	4.35	4.47	4.70	4.92	5.14	5.49	5.13	4.92	4.31
5	Population	million	266.9	269.6	272.2	274.9	277.4	280.0	282.5	294.1	312.5	325.4
6	Population growth	%	0.72	1.01	0.98	0.96	0.94	0.91	0.89	0.76	0.49	0.45
7	Urban Population	%	56.02	56.7	57.36	58.02	58.68	59.34	60	63.4	67.71	70
8	Number of households	Million households	68.48	66.17	69.85	70.52	71.18	71.83	72.47	75.46	80.18	83.55

*Note: These indicators are used for all modeled scenarios

2.1.1. Gross Domestic Product (GDP) and Economic Growth

In 2018, Indonesian GDP reached Rp14,837.4 trillion based on the current price, with contribution from Java at 58.48%, followed by Sumatra at 21.58%, and Kalimantan at 8.20% (Ministry of Finance of the Republic of Indonesia, 2019).

The economic growth from 2015 to 2018 is lower than the existing RUEN assumption, based on the data published by Statistics Indonesia (BPS) in June 2019. During these years, on average the economy grew 1.6% lower than RUEN's projection.

Looking at the 1st Semester of 2019 realization and moderate projection from the Ministry of National Development Planning (Bappenas) in the 2020–2024 Mid-Term National Development Plan (Rencana Pembangunan Jangka Menengah Nasional/RPJMN), Indonesian economy is estimated to grow between 5.1 to 6.1% from 2019 to 2024. Said estimation is also lower than the economic growth set out in the existing RUEN.

Using the record of economic growth from 2015 to the first semester of 2019 as a reference, we projected the country's economic growth from 2025–2050 to be 1.6% below the existing RUEN assumption, with the peak growth occurring in 2025 at 6.4%. Following the peak, economic growth will decrease slowly to 4.74% in 2050.

2.1.2. Population Growth and Number of Households

Indonesian population in 2018 was around 265 million people, according to the 2019 data published by BPS. The population is expected to grow up to 282.5 million in 2025 and will reach 325.4 million in 2050.

The population's projection from 2019 to 2045 is taken from August 2018's publication by Bappenas and United Nations Population Fund (UNFPA) called 2015–2045 Projection of Indonesian Population. Utilizing these projection data, we looked for the trend and created the Indonesian population forecast for 2046 to 2050. For the number of households from 2019–2050, we calculated it by dividing the number of population with the average number of people in one household from 2015–2018, which resulted in around 3.9 people in one household.

2.2. Energy Demand Structure

2.2.1. Industrial Sector

Industrial sector consumes considerable amount of energy namely electricity to drive the industry and other fuels (e.g., coal, diesel fuel, and natural gas) for the production processes.

It is essential to find out the annual production of each industry in order to calculate the energy demand for this sector.

Additionally, it is necessary to analyze the Gross Domestic Regional Product (GDRP) as it is still considered to reflect the energy demand of an area or region (Tim Pembinaan Penyusunan RUED-P [P2RUED-P], 2017).

According to BPS' classification, industrial sector can be classified into 9 sub-industrial areas namely food, drinks, and tobacco; textile, clothing, and leather; wood, bamboo, and rattan; paper; chemical; metal; non-metal; machinery and tools; and other industries. The categorization can be seen in Figure 2 below. Energy consumption for each of sub- sector will be calculated from its GDRP and fuel consumption.

Realization for the industrial sector's energy needs can be found out from the data published annually by BPS. This realization refers to the economic and industrial growth, which is used to reveal the elasticity of industrial and economic growth. This elasticity will then be used as a reference to project the industrial growth.

Looking at the industrial growth from 2015–2018, the industry sector grew slower than the existing RUEN's projection throughout said years. Reflecting on this condition, we projected that the industrial growth trend from 2019–2050 will also be smaller than the existing RUEN's forecast. This newly updated projection can be seen in Table 3 below.

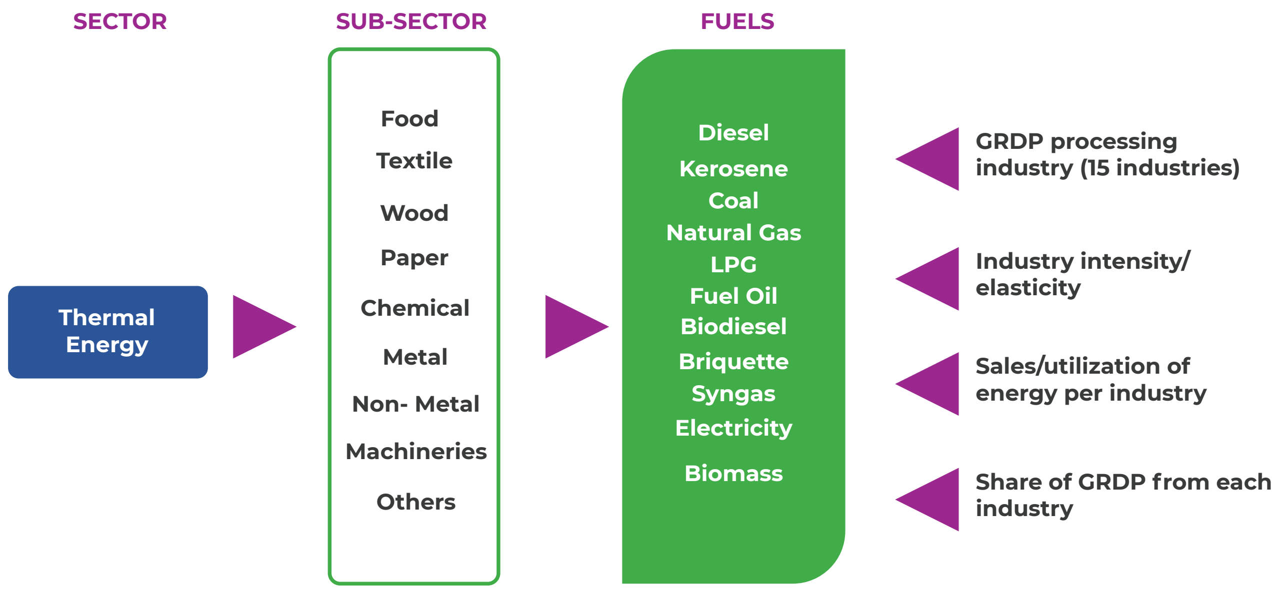


Figure 2 Model Structure of the Industrial Sector

Table 3 Updated industrial demands in the new Indonesian energy model*

	Unit	2020	2021	2022	2023	2024	2025	2030	2040	2050
Food and Beverage	MTOE	7.51	7.87	8.27	8.71	9.19	9.73	13.16	22.61	35.98
Textile	MTOE	5.34	5.16	4.98	4.78	4.58	4.36	5.40	7.68	9.92
Wood	MTOE	1.43	1.46	1.50	1.54	1.58	1.64	2.00	2.76	3.40
Paper	MTOE	4.46	4.62	4.80	5.00	5.00	5.45	6.87	10.22	13.95
Chemical and Rubber	MTOE	11.26	11.68	12.16	12.69	13.27	13.93	18.14	28.95	42.85
Metal	MTOE	3.44	3.55	3.68	3.81	3.96	4.13	5.44	8.89	13.50
Non-Metal	MTOE	12.22	12.71	13.24	13.83	14.47	15.20	19.96	32.37	48.72
Machinery	MTOE	3.82	3.97	4.14	4.32	4.52	4.75	6.27	10.25	15.55
Others	MTOE	0.31	0.31	0.32	0.32	0.33	0.34	0.39	0.44	0.38
Total Industrial Demand	**MTOE**	**49.77**	**51.34**	**53.07**	**54.99**	**57.11**	**59.52**	**77.62**	**124.16**	**184.25**
Industrial Growth	%	5.3	5.6	5.9	6.4	7	7.6	7	6.1	5.3
Industrial Elasticity		1	1.01	1.02	1.03	1.04	1.05	1.04	1.02	1

**Note: These industrial demands are used for all modeled scenarios*

Source: adjustment of the existing RUEN data based on the industrial growth realization 2015-2018

2.2.2. Transportation Sector

Energy demand for transportation sector describes the demand for transportation activities, from land (passenger cars, buses, trucks, motorcycles, passenger and freight trains), sea (ships and ferries), and air (passenger and freight planes), including the fuels for each mode of transportation. Said energy demand can be seen in Figure 3 below.

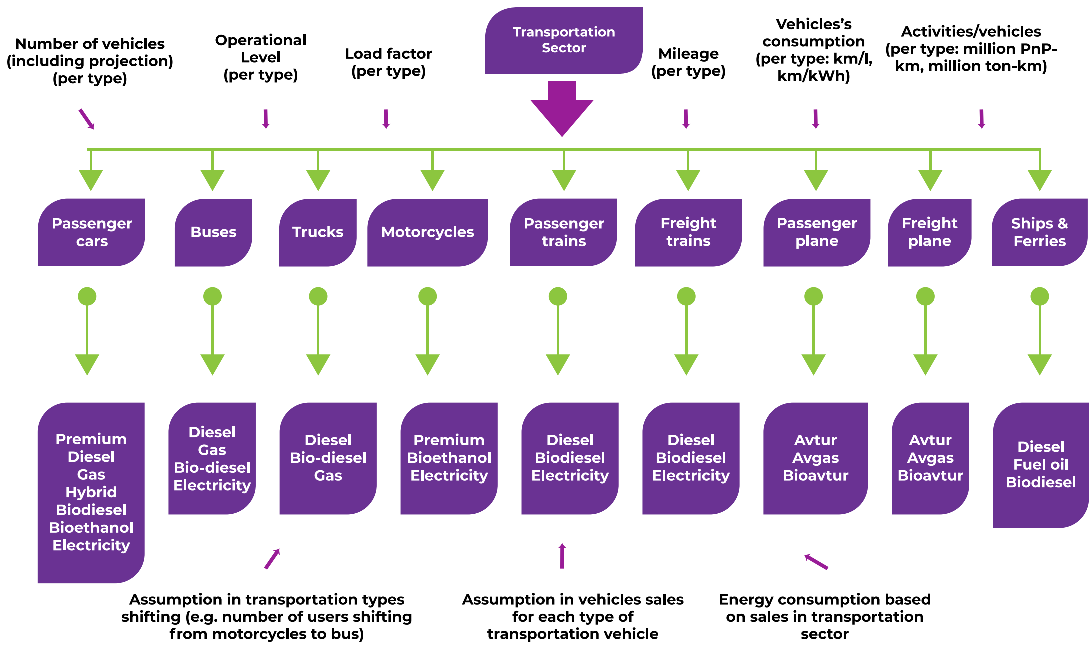


Figure 3 Model Structure of the Transportation Sector

Looking at the 2016-2019 Indonesian Statistics from BPS, the realization of the number of vehicles (i.e. car, bus, truck, and motorcycle) from 2015 to 2018 was lower than the projection in the existing RUEN.

Reflecting on this condition, we projected that the new number of vehicles from 2019–2050 would also be smaller than the existing RUEN's projection. This newly updated projection can be seen in Table 4 below.

Table 4 Updated number of vehicles in the new Indonesian energy model*

	Unit	2020	2021	2022	2023	2024	2025	2030	2040	2050
Car	Million Unit	19	20	21	22	23	24	30.3	45.2	65.4
Bus	Million Unit	2.9	3	3	3	4	4	4.6	6.9	9.9
Truck	Million Unit	9	10	10	11	11	12	14.3	21.3	30.8
Motorcycle	Million Unit	131.3	136.9	142.4	147.6	152.6	157.4	178.0	204.9	218.8

**Note: These number of vehicles are used only for realization scenario; the numbers are cumulative*
Source: adjustment of the existing RUEN data based on the realization number of vehicles from 2015-2018

Table 5 Updated transportation demands in the new Indonesian energy model*

	Unit	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Passenger car	MTOE	16.5	17.4	18	19	20	21	22	26.2	37.8	52.8
Bus	MTOE	4.4	4.6	4.9	5.1	5.3	5.6	5.8	7.0	10.1	14.1
Truck	MTOE	15.0	15.9	16.7	17.5	18.2	19.0	19.7	23.9	34.5	48.2
Motorcycle	MTOE	13.4	14.0	14.5	14.9	15.4	15.8	16.1	17.9	19.9	20.6
Passenger train	MTOE	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.5	0.8
Freight train	MTOE	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3
Passenger plane	MTOE	4.3	4.4	4.6	4.8	5.0	5.2	5.4	6.7	10.1	14.5
Freight plane	MTOE	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.9	1.3	1.8
Passenger ship	MTOE	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.05	0.08
Freight ship	MTOE	2.1	2.2	2.2	2.3	2.4	2.6	2.7	3.4	5.2	7.6
Commuter line (KRL)	MTOE	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.07	0.11
Total	MTOE	56.6	59.4	62.1	64.8	67.4	69.9	72.4	86.7	119.8	160.7

**Note: These number of vehicles are used only for realization scenario; the numbers are cumulative*
Source: adjustment of the existing RUEN data based on the realization number of vehicles from 2015-2018

2.2.3. Households Sector

Energy consumption in a household covers all energy utilizations from cooking, lighting, up to electricity consumption for home appliances. The amount of energy consumption for household sector will be determined by activity level and energy intensity (P2RUED-P, 2017).

The activity level depends on the number and the usage frequency of appliances. Meanwhile, energy intensity is estimated based on the technology of each device and its efficiency level.

The activity level and energy intensity between households in the city and countryside are different.

The difference in purchasing power, for example, will create a difference in the ownership of home appliances between families in the city vs. countryside that can access electricity. Furthermore, with at least 1,700 villages still having no access to electricity, the energy needs between city and countryside will inevitably vary (Sakina Rakhma & Diah Setiawan, 2019).

The number of households from 2019 to 2045, both in the city and countryside, in this model is updated using data from the 2015–2045 Projection of Indonesian Population. Then, based on this data, we then projected the number of households from 2046–2050.

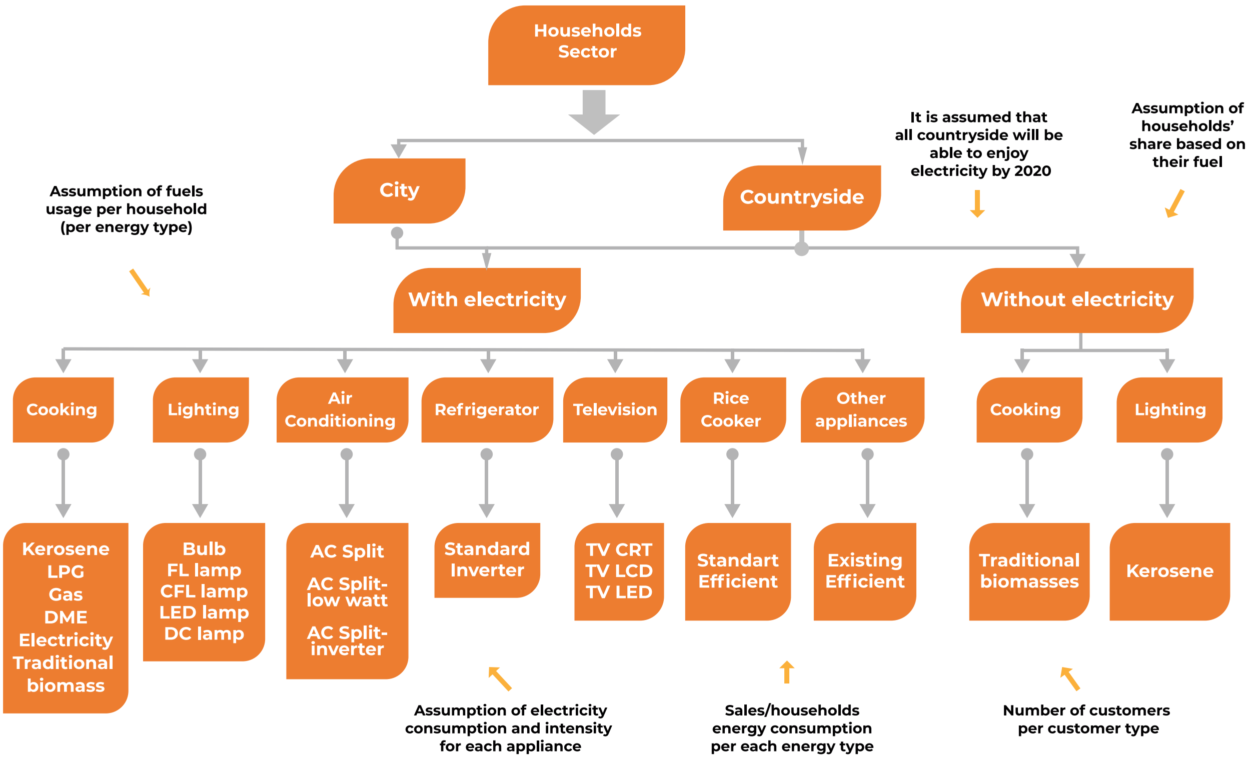


Figure 4 Model Structure of the Households Sector

Table 6 Updated number of households and households' demand in the new Indonesian energy model*

	Unit	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Urban population	million households	38.36	39.22	40.06	40.91	41.77	42.62	43.48	47.84	55.32	61
Rural population	million households	30.12	29.95	29.78	29.60	29.41	29.20	28.99	27.62	24.85	22.56
Total households demand	MTOE	26.73	27.05	27.65	28.30	28.97	29.67	30.40	33.00	38.33	43.19

**Note: These number of households and demands are used for all modeled scenarios*
Source: Survei Penduduk Antar Sensus (SUPAS). (2015). Proyeksi Penduduk Indonesia 2015-2045.

2.2.4. Commercial Sector

The commercial sector can be further divided into two sub-sectors, government and private. Demand from the government sub-sector comprises that from government offices, public street lighting, general hospitals, public school, including social activities, where all energy consumption is assumed to be electricity consumption.

Meanwhile, the demand from private sector comprises that from hotels, restaurants, shopping malls, amusement parks/recreational facilities, and trading centers. This energy demand can be in the form of electricity (e.g., for lighting, air conditioning, elevator) and thermal (e.g., for cooking and water heater) (P2RUED-P, 2017).

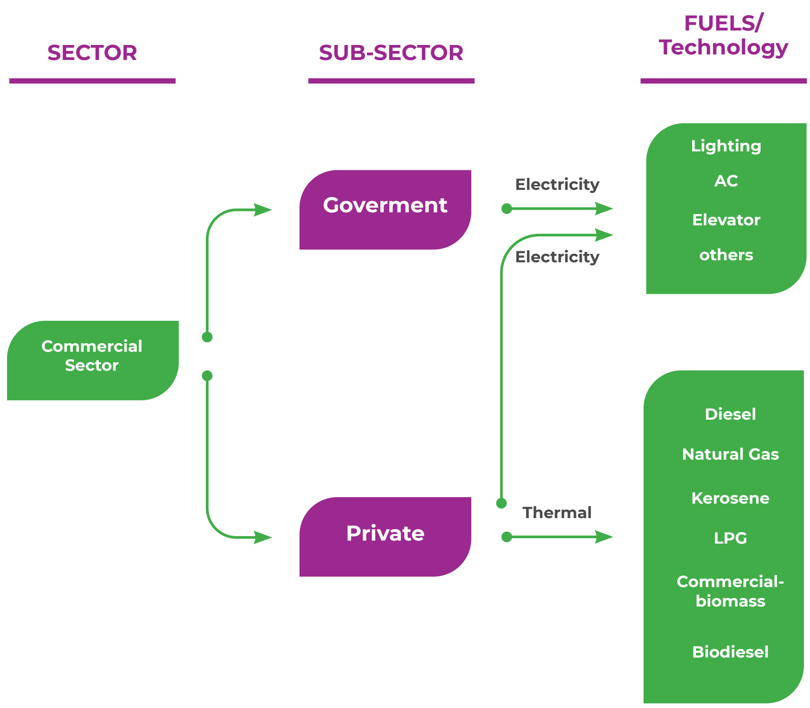


Figure 5 Model Structure of the Commercial Sector

Commercial sector growth is influenced by the annual floor area growth, which is acquired from elasticity and economic growth. Looking at the new figure from 2019–2050, the commercial sector growth in our model is smaller than that in the existing RUEN. In light of this condition, we projected that the new commercial demand from 2019–2050 will also be lower than the existing RUEN's projection. This newly updated projection can be seen in Table 7 below.

Table 7 Updated number of floor area growth, GDP's elasticity and total demand for commercial sector*

	Unit	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
"Commercial sector growth (Floor area growth)"	%	5.98	5.64	7.16	6.68	6.26	5.9	5.57	5.49	4.8	4.05
GDP's elasticity (Commercial sector)		1.1	1.16	1.16	1.17	1.17	1.18	1.18	1.15	1.09	1.03
Total commercial demand	MTOE	7.8	8.2	8.6	9.1	9.5	9.9	10.4	13.4	21.8	32.9

**Note: These area growth and elasticity are used for all modeled scenarios*
Source: adjustment of the existing RUEN data based on the realization number of floor area growth and commercial sector GDP's elasticity from 2015-2018

2.3. Transformation

Transformation is a process to transform primary energy into secondary/final energy or energy form that can be used by users.

In Indonesia, it means changing all energy sources, such as fossil fuels or renewables, using power plants to meet the energy needs of industries, transportations, households, and commercial sector.

Total power plants constructed from 2020–2050, both for fossil fuel and new renewable energy (NRE), is also updated and adjusted based on the new demand and is aligned with the power plants' mix in RUKN and RUPTL.

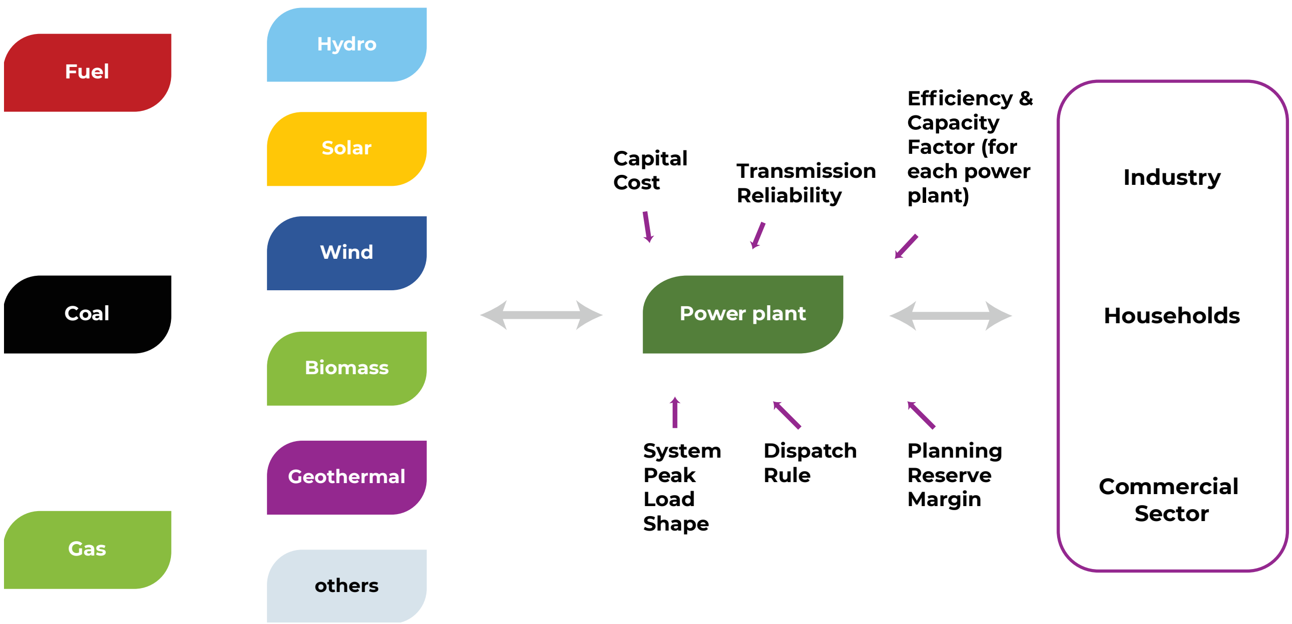


Figure 6 Model Structure of the Transformation

Table 8 Updated power plant's capacity in the new Indonesian energy model*

	Unit	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Fossil fuel power plants	GW	56	60	61	68	71	71	72	86	126	172
NRE power plants	GW	13	12	14	15	15	18	23	30	50	88
Total power plants	GW	69	72	75	83	86	89	95	116	176	260

**Note: This power plant capacity is the capacity from realization scenario*

2.4. Energy Supply Structure

Energy supply in Indonesia can be classified into the supply of petroleum, natural gas, coal, and new renewable energy (NRE).

2.4.1. Coal

The majority of Indonesian coal is still used as an export commodity, and the rest is used as fuel for coal-fired power plants, direct use in the industrial sector, and further processed into synthetic gas, Dimethyl Ether (DME), and briquette.

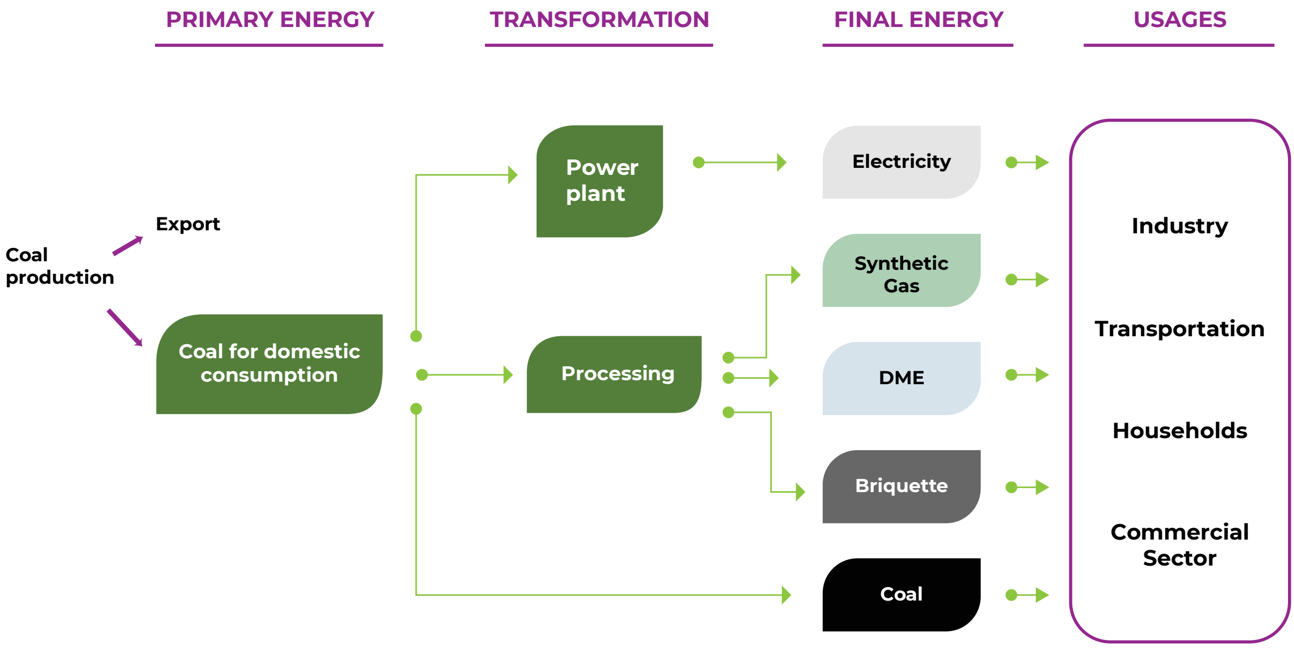


Figure 7 Model structure of the coal supply chain in Indonesia

Table 9 Updated number of Indonesian domestic coal consumption, export, and total production

	Unit	2020	2021	2022	2023	2024	2025	2030	2040	2050
Domestic consumption	Million Ton	101.0	102.0	104.0	110.0	113.0	115.0	149.0	203.0	313.0
Export	Million Ton	398.0	409.0	417.0	423.0	432.0	441.0	470.0	562.0	635.0
Total Production	Million Ton	499.0	511.0	521.0	533.0	545.0	556.0	619.0	765.0	948.0

**Note: This number is from the realization scenario*

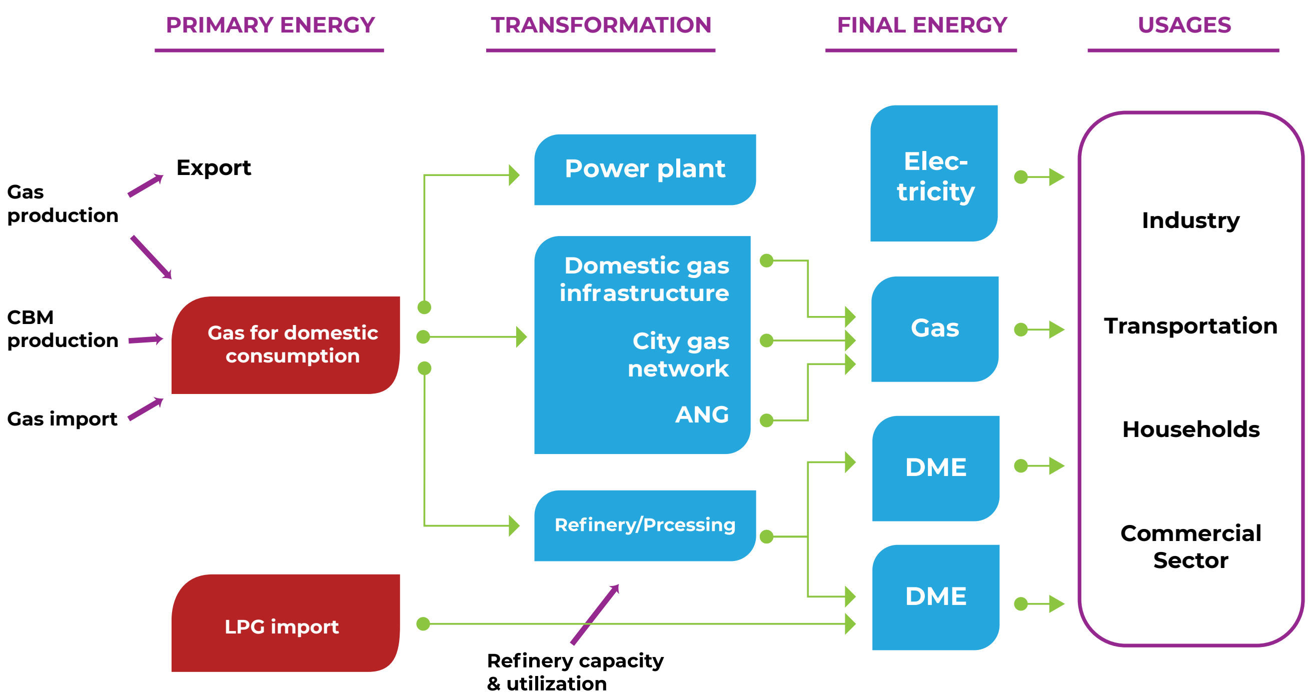


Figure 8 Model structure of the natural gas supply chain in Indonesia

2.4.2. Natural Gas

The primary energy supply to meet Indonesia's need for natural gas consists of domestic gas production and import, Coalbed methane (CBM) production, and Liquified Petroleum Gas (LPG) import. This natural gas and CBM will go through a transformation process in power plants and processing facilities/refineries to produce final energy: electricity, LPG, and Dimethyl Ether (DME), which will make up the total domestic supply. Additionally, this natural gas can also be utilized directly through the city gas network and Adsorbed Natural Gas (ANG). Indonesian local supply will be fulfilled by natural gas and CBM.

Table 10 Updated number of Indonesian domestic gas production (lifting) and consumption

	Unit	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Total production	mmscfd	4,352	6,739	7,135	7,248	7,276	7,389	7,652	7,696	6,628	5,709
Domestic Consumption	mmscfd	2,648	5,478	5,780	6,117	6,359	6,629	6,768	7,594	11,107	12,313

**Note: This number is from the realization scenario*

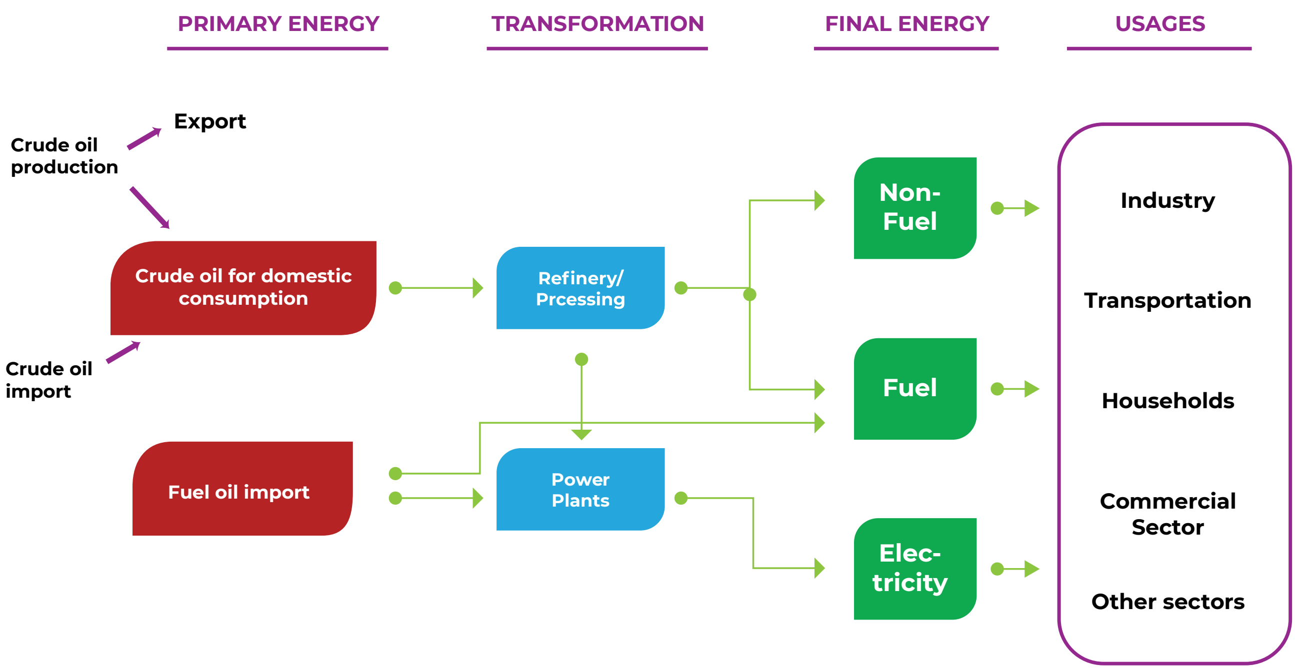


Figure 9 Model structure of the petroleum supply chain in Indonesia

2.4.3. Petroleum (Oil)

The primary energy supply to meet Indonesia's need for petroleum consists of crude oil production and import as well as fuel oil import. This crude oil for domestic consumption comes from domestic production and import. It will be processed in the local refineries to produce fuel and non-fuel products. Some of the refined fuel products will also be distributed to power plants for generating electricity. These non-fuel and fuel products as well as electricity will be utilized by industries, transportation, households, commercial sector, and other sectors. The new production amount for 2019 was taken from data published by SKK Migas in 2019. For 2020–2024, oil production data were taken from 2020–2024 RPJMN Technocratic, where domestic oil consumption is assumed to be 100% by 2024. It means oil total production will be absorbed 100% domestically. Further, looking at the trendline from 2016–2024, oil production will decrease at an average of 3.8% annually. This resulted in lower total oil production when compared to the existing RUEN.

Table 11 Updated number of oil production (domestic vs. export)*

	Unit	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Domestic consumption	MBOPD	677	655.6	639.5	626.0	592.1	550.1	529.2	435.9	295.8	200.8
Export	MBOPD	69	52.4	37.6	24	11.2	0	0	0	0	0
Total oil lifting	MBOPD	746	708	677.1	650.0	603.3	550.1	529.2	435.9	295.8	200.8

**Note: This number is from the realization scenario*

Table 12 Updated number of the oil refinery, crude oil demand, production, and import*

	Unit	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Refinery capacity	MBOPD	1,169.1	1,169.1	1,169.1	1,169.1	1,269.1	1,289.1	1,639.1	1,639.1	1,639.1	1,639.1
Refinery utilization	%	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
Share of crude oil in refinery	%	82.6	82.6	82.6	82.6	82.6	82.6	82.6	82.6	82.6	82.6
Crude oil demand	MBOE	322.7	322.7	322.7	322.7	350.3	355.9	452.5	452.5	452.5	452.5
Crude oil domestic production	MBOE	247.1	239.3	233.4	228.5	216.1	200.8	193.2	159.1	108.0	73.3
Crude oil import	MBOE	75.6	83.4	89.3	94.3	134.2	155.1	259.3	293.4	344.5	379.2

**Note: This number is from the realization scenario*

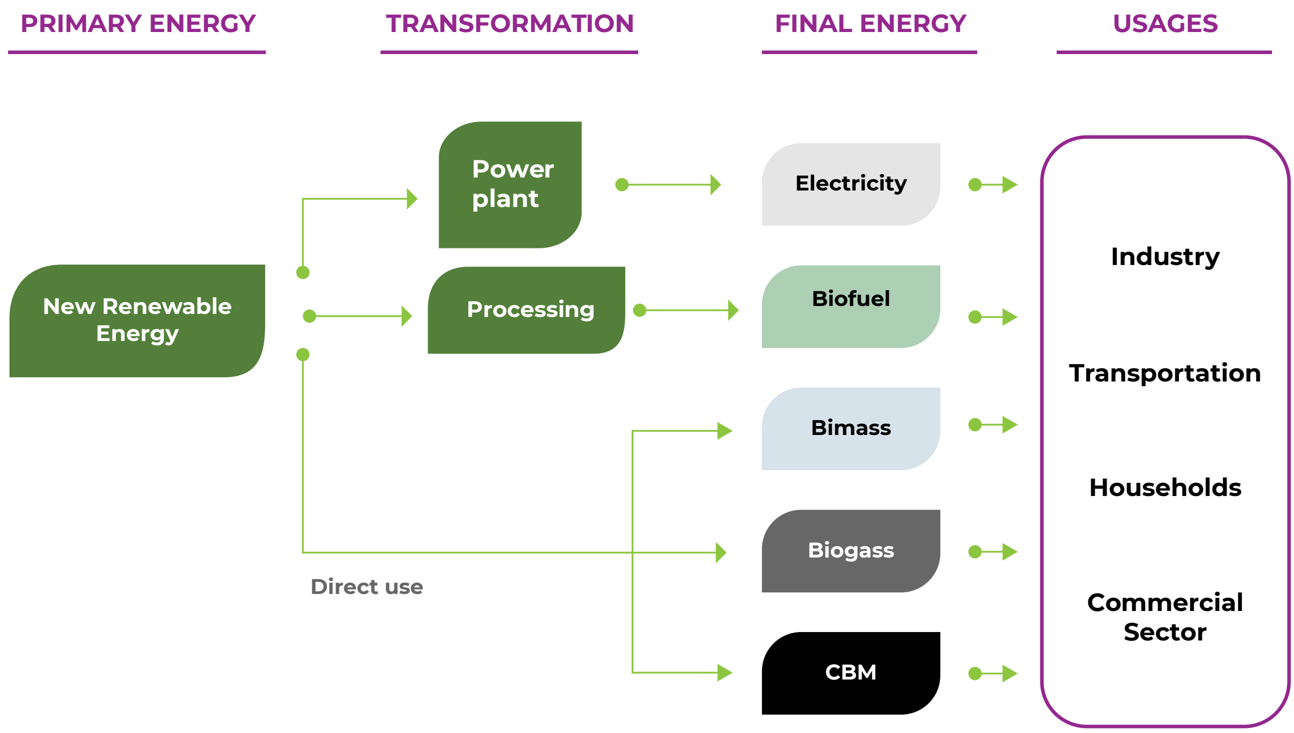


Figure 10 Model structure of the NRE supply chain in Indonesia

2.4.4. New and Renewable Energy (NRE)

There are two types of NRE utilization in Indonesia. First, NRE is used for power plants to generate electricity, for example for hydropower plants, geothermal power plants, and others.

Second, NRE is directly used by users in the form of biofuel, biomass, biogas, and CBM. From the said two applications, NRE is utilized more significantly by power plants.

STUDY REPORT

3 Modeling Scenarios

In this new Indonesian energy model, we aim at examining the impacts of changes in socio-economic indicators as well as energy production and demand, influence of new energy policies implementation, and consequences and importance of the increasing global concern over climate change. To assess impacts said above, we created several alternative scenarios that can be seen in Table 13.

Table 13 Alternative scenarios in the new Indonesian energy model

EXISTING RUEN	01 Realization Scenario	02 Current Policies Scenario	03 Energy Transition Scenario
RUEN as baseline scenario	**Updating :** 1. Economic growth 2. Demography 3. Growth of demands from industries and other sectors 4. Energy production data 5. Power plants data 6. Data from 2019-2028 RUPTL/RUKN	**Intensifying of :** A. City gas network B. Electric vehicles C. Biodiesel D. Combination of A + B + C	**Replacing fossil fuel with renewables :** A. Zero construction of new CFPPs from 2029 B. Cessation of new CFPPs construction from 2025 C. Combination of B and the implementation of latest government policies on the closing of old fossil-fired power plant

3.1. Existing RUEN

2015-2050 RUEN constitutes the current national energy planning. Released in 2017, said RUEN uses indicators acquired from real data collected up until 2015 that are now outdated.

Table 14 Socio-economic indicators in the existing RUEN

No	Indicators	Unit	2013	2014	2015
1	GDP*	Trillion Rupiah	9,524.7	10,542.7	11,540.8
2	Economic growth	%	5.6	5	4.8
3	GDP per capita*	Million Rupiah	38.3	41.8	45.2
4	GDP per capita growth*	%	9.1	9.1	8.1
5	Population	Million	248.8	252.2	255.5
6	Population growth	%	1.4	1.4	1.3
7	Urban population	%	51.9	52.6	53.3
8	Households number	Million	64.3	64.8	66.5

* GDP is based on the current market price

3.2. Latest-realization updates Scenario (Realization Scenario)

In this scenario, twenty input data essential for the modeling are updated. Said input data can be seen in Table 1. As a result of the input data update, energy and electricity demand projection and energy mix forecast will differ from those in the existing 2015–2050 RUEN. The updated values for economic growth, demography, primary energy supply (coal, natural gas, and petroleum), demand from all sectors, and transformation and supply can be seen in detail in Chapter 2.

3.3. Current Policies Scenario

This scenario is developed based on the realization scenario. The difference between this scenario and other scenarios is that there is intensification of construction of the city gas network, usage of electric vehicles, consumption of biodiesel , and the combination of these three which then reveal the impacts on Indonesian primary energy, based on the 2020–2024 RPJMN and 2020–2024 MEMR's Strategic Plan (Rencana Strategis/Renstra).

3.3.1. City gas-network intensification

Reducing Liquefied Petroleum Gas (LPG) import is one of the approaches that is implemented by the Indonesian government to reduce oil and gas trade balance deficit. City gas network intensification is a program to support LPG usage reduction. Recently, the government announced two targets concerning city gas network:

- By the end of 2024, city gas network is targeted to be installed in 2.5 million households (this figure is higher than that of the realization scenario's target which is 1.7 million households); and
- By the end of 2050, 50% of households in cities will be connected to the city gas network.

Compared to the realization scenario, household gas consumption in 2025 will increase from 0.09 MTOE to 0.18 MTOE and is projected to continuously grow until 2050. Conversely, in 2025, the household LPG consumption will decrease from 8.8 MTOE to 8.6 MTOE and is expected to decline until 2050 consistently.

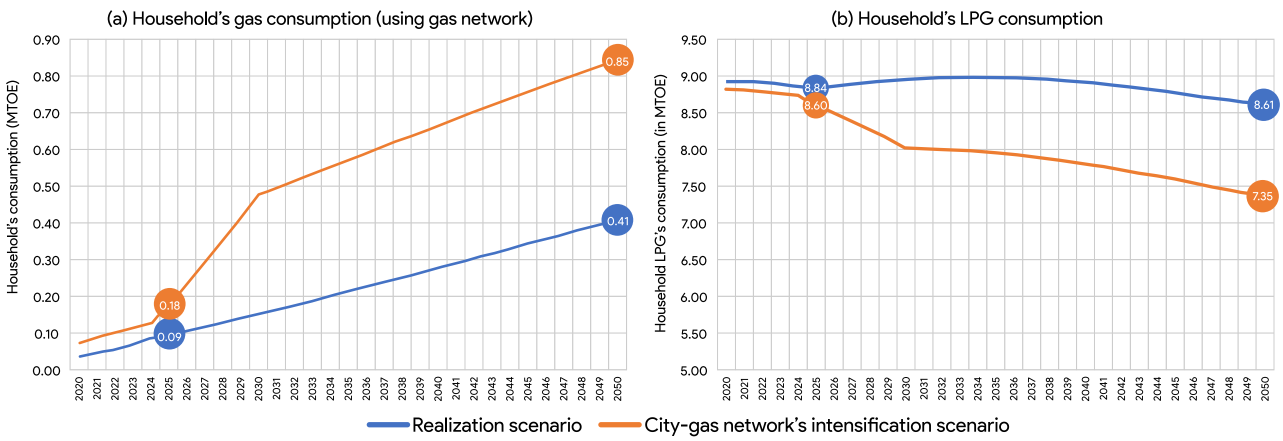


Figure 11 Projection of city-gas network intensification impact on (a) household's gas consumption and (b) household's LPG consumption

3.3.2. Increase the usage of electric vehicles

The Indonesian government also sees increasing the use of electric vehicles as an alternative to reduce oil import. This in turn will help minimizing oil and gas trade deficit. In light of that, the followings are two targets set by the government:

- In 2025, 20% of the total car sales in Indonesia is of electric cars (214 thousand units or around 2% of the total cars used in Indonesia); and
- From 2040 onwards, there will be zero conventional (Internal Combustion Engine/ICE) car sold. As a result, over 50% of cars used in 2050 will be electric cars.
- Based on these two targets, we projected that there will be 0.6 million electric cars and 19 million electric motorcycles in 2025. These numbers will continue to increase. In 2050, more than 50% of the total cars used (or 33.9 million units) constitutes electric vehicles. For motorcycles, our projection shows that all motorcycles will be converted to electric motorcycles and reach the total of 219 million units by 2050.

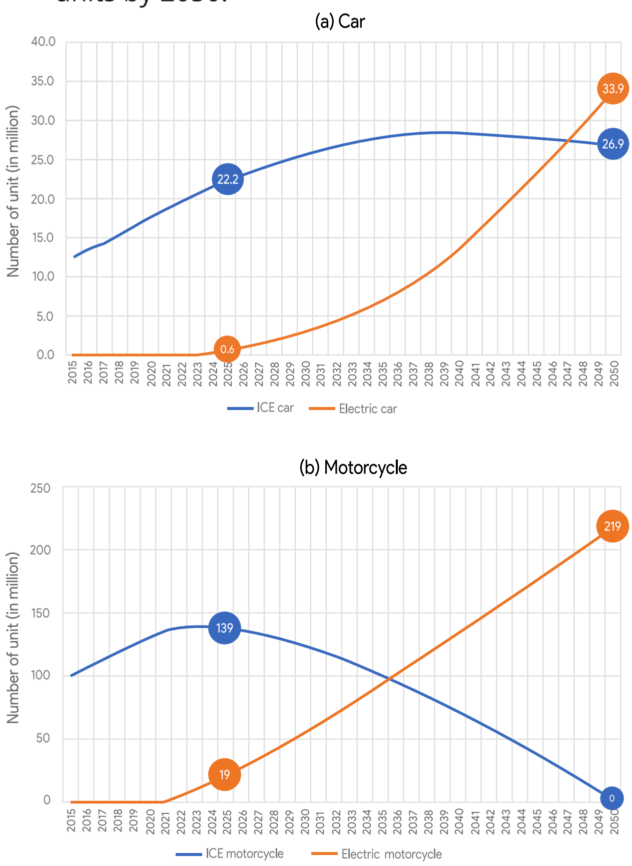


Figure 12 Projection number of car and motorcycle (both ICE and electric) until 2050

3.3.3. Increase usage of biofuel

The government of Indonesia has set up a plan to increase biofuel utilization: B30 starting from 2020; B50 from 2021; and B100 from 2030 onwards. The increased usage of biofuel aims at decreasing fuel import. This in turn will reduce the trade balance deficit. Under the biofuel intensification scenario, biofuel consumption will increase significantly in 2030, or during the implementation of policy concerning B100.

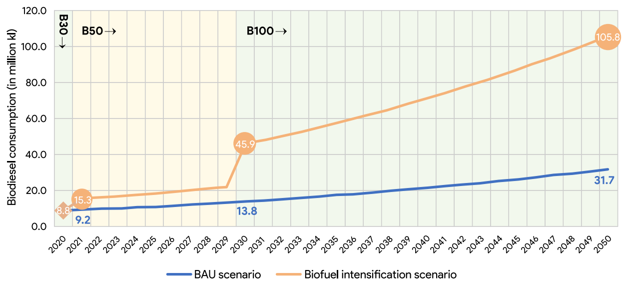


Figure 13 Projection of domestic biofuel consumption in two scenarios

3.3.4. Combination of the City-Gas Network, Electric Vehicles, and Biofuel Intensification

In this scenario, we combined city gas network intensification scenario with the increased usage of electric vehicles as well as biofuel to find out the impacts thereof on the primary energy and final energy mix.

3.4. Energy Transition Scenario

In energy transition scenario, we introduced a policy intervention to stop the construction of new CFPPs and replace them with renewables. Based on the target year during which the cessation of new CFPPs construction takes place, this scenario is further separated into two schemes:

3.4.1. No CFPPs Construction from 2029 onwards

This scenario corresponds directly to PLN's 2019–2028 RUPTL, which aims at building the proposed CFPPs from 2019-2028. As an intervention, we set the lifetime of all CFPPs to thirty years, and by 2029, there will be no new construction of CFPP. Therefore, renewables power plants will be selected to substitute the declining capacity of the decommissioned CFPPs.

3.4.2. No Construction of New CFPPs from 2025

This scenario also used 2019–2028 RUPTL as a basis. The difference lies on the construction cancelation of all CFPPs whose status is still planned (all aspects of said RUPTL are maintained except construction) from 2025-2028. Similar to the previous sub-scenario, the lifetime of all CFPPs is also limited to thirty years.

3.4.3. Combination of Cessation of CFPPs Construction from 2025 and Latest Government Policy to Phase Out Combined Cycle Power Plants Aging Older than 20 Years by 2024

This scenario employs the scenario 3.4.2. namely the 'no new CFPPs construction from 2025' as the basis. As an additional aspect, the latest announcement from the Ministry of Energy and Mineral Resources (MEMR) regarding the decommissioning of 13.34 GW old fossil-fueled power plants and their replacement with renewables will be incorporated herein (we assume that, by 2024, all power plants will be replaced by renewables). These old fossil-fueled power plants consist of 1.78 GW diesel power plants (>15 years old) and 5.91 GW gas-powered combined cycle power plants (>20 years).

Table 15 Power plants' capacity in the energy transition scenario

Scenario	Power plant's capacity									
	Unit	2020	2021	2022	2023	2024	2025	2030	2040	2050
No new CFPP's construction from 2029	GW	32.0	32.0	34.9	37.0	37.7	39.2	45.8	42.6	17.6
No new CFPP's construction from 2025	GW	32.0	32.0	34.9	37.0	37.7	39.2	35.4	32.1	7.3
No new CFPP's construction from 2025 + MEMR's initiative to phase-out old fossil-fueled power plants:										
Coal Fired Power Plants (PLTU) capacity	GW	32.0	32.0	34.9	37.0	37.7	39.2	35.4	32.1	7.3
Combined Cycle Power Plants (PLTGU) capacity	GW	11.8	13.0	15.4	14.6	13.8	13.8	15.1	34.6	26.5

4 Results and Discussion

4.1. Existing RUEN

In the existing RUEN, the final energy needed by 2025 reaches 248.4 MTOE, with industrial sector becomes the most energy-intensive sector with a share of 47.6% (including its raw material requirement) followed by transportation sector at 30.3%, household at 15%, commercial sector at 4.9%, and other sectors at 2.2%.

To supply this final energy demand, Indonesia will need 400 MTOE primary energy in 2025. This discrepancy between energy demand and supply is a result of energy transformation, where oil refineries have 73-80% efficiency, coal-fired power plants have 30-36% efficiency (ultra-supercritical efficiency is higher at 40-42% efficiency), diesel power plants have 33% efficiency, and geothermal power plants have 33% efficiency. On average, the efficiency used in RUEN to convert primary energy to final energy is at 62%. Further, by 2050, the country's final energy requirement is projected to reach 641.5 MTOE and the primary energy supply 1,012.2 MTOE.

Concerning electricity consumption, by 2025, it will be 772 TWh with consumption per capita at 2,500 kWh/capita. Meanwhile, in 2050, the consumption will increase to 2,373 TWh and consumption per capita will also increase to 7,000 kWh/capita.

Primary Energy

	MTOE	%
Crude oil	98.7	24.7
Natural gas	89.5	22.3
Coal	119.8	30
NRE	92.3	23
Total	**400.3**	**100**

Transformation

Power Plant 135.5 GW

NRE power plants	167.6	GW
Fossil fuels power plants	275.4	GW

Final Energy

	MTOE	%
Electricity	60.7	24.5
Gas	44.8	18
Fuel oil	86.9	35
Coal	32.2	13
Biofuels	12.2	4.9
Other renewables	11.6	4.6
Total	**248.4**	**100**

Energy Consumption

	MTOE	%
Transportation	75.2	30.3
Industry*	118.4	47.6
Households	37.2	15
Commercial	12.2	4.9
Other sectors	5.4	2.2
Total	**248.4**	**100**

Figure 14 Energy needs and supply modeling in 2025 in the existing RUEN

Primary Energy

	MTOE	%
Crude oil	197.7	19.5
Natural gas	242.9	24
Coal	255.9	25.3
NRE	315.7	31.2
Total	**1012.2**	**100**

Transformation

Power Plant 443.1 GW

NRE power plants	167.6	GW
Fossil fuels power plants	275.4	GW

Final Energy

	MTOE	%
Electricity	200	31.2
Gas	113.9	17.8
Fuel oil	184.2	28.7
Coal	67	10.4
Biofuels	45.5	7.1
Other renewables	30.9	4.8
Total	**641.5**	**100**

Energy Consumption

	MTOE	%
Transportation	169	26.3
Industry*	293.2	45.7
Households	91	14.2
Commercial	73	11.4
Other sectors	15.3	2.4
Total	**641.5**	**100**

Figure 15 Energy needs and supply modeling in 2050 in the existing RUEN

4.2. Realization Scenario

Under this scenario, Indonesia's primary energy demand up to 2050 is lower than in RUEN 2015–2050. Primary energy demand in 2025 will be 258 MTOE, lower than the existing RUEN projection at 400 MTOE. Correspondingly, in 2050, the new forecast for primary energy consumption will only be at 643 MTOE or about 50% smaller than the existing RUEN projection at 1,012 MTOE.

In terms of the energy mix, the renewable energy target in the existing RUEN for the primary energy mix by 2025 is 23%. However, in the realization scenario, the projected realization will not be that high. Our simulation shows that renewable energy will only increase to 15% maximum by 2025. Conversely, the 31% target by 2050 in the existing RUEN will also be missed by 8%, at only 23%. In terms of the power plant's installed capacity, RUEN's target sets are 135 GW in 2025 with renewables at 45.2 GW. However, our simulation demonstrates that only 95 GW of power plant's capacity is required to supply The electricity demand in 2025 with the share of renewables is only at 23 GW. Correspondently, 443 GW in RUEN's target for 2050 will also decrease to only 260 GW.

In the realization scenario, the share of renewables in the primary energy mix is projected to be 15% (or equal to 39 MTOE) in 2025, which mostly comes from the power plants (about 2/3 of the total share). The other share (about 1/3) includes biodiesel (accounting for about 10 MTOE or equal to 11 million kiloliters in volume). In 2050, the share of renewable for the power plant is still the majority, despite the increase of biodiesel to 29 MTOE or equivalent to 32 million kiloliters.

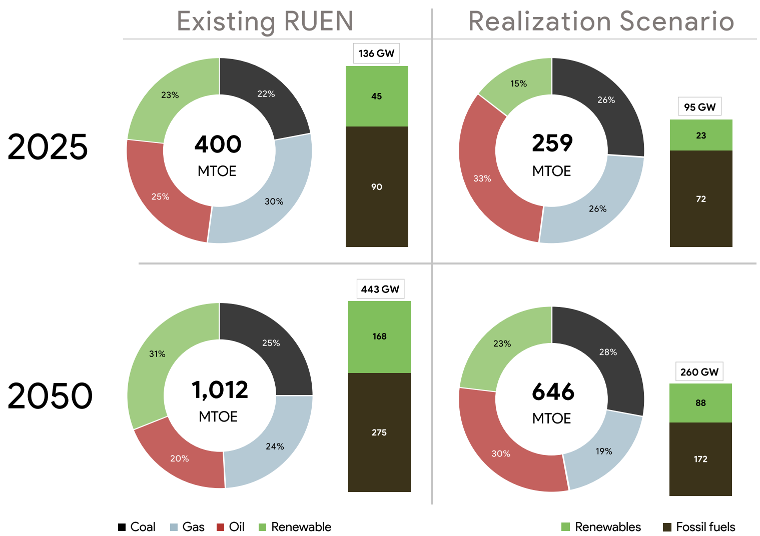


Figure 16 Primary energy comparison in the existing RUEN vs. realization scenario in 2025 and 2050

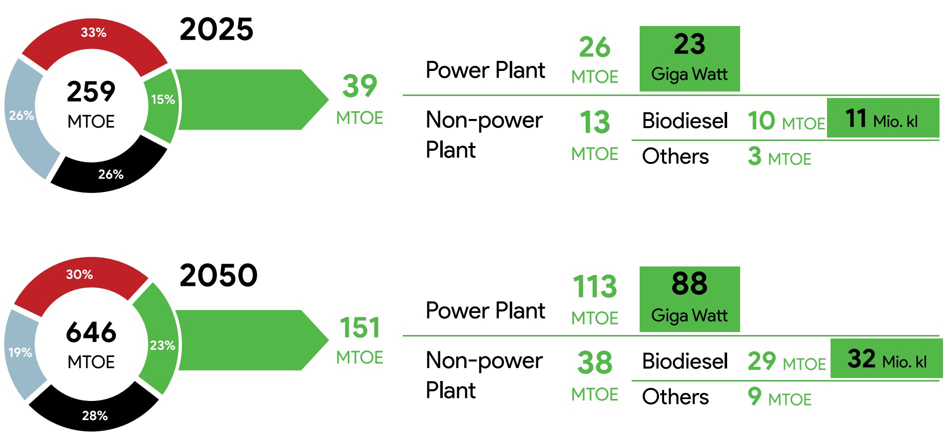


Figure 17 Composition of renewables in the primary energy mix (realization scenario)

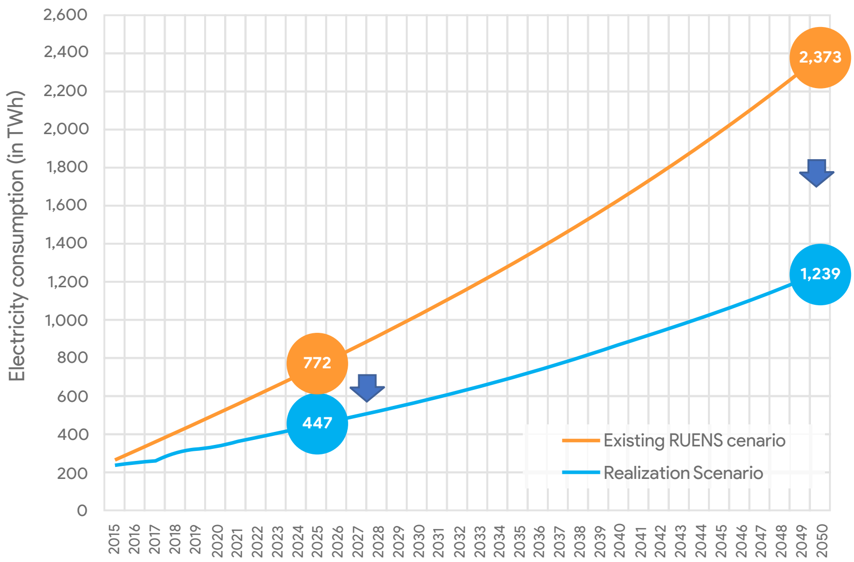


Figure 18 Electricity demand in the existing RUEN vs. realization scenario

Likewise, the electricity demand in this new scenario is also lower. In 2025, the electricity demand will decrease from 772 TWh in the existing RUEN to only 447 TWh. Then in 2050, the latest electricity demand will be at 1,239 TWh or more than 50% lower than the projection in the existing RUEN. As a result, with these new numbers, the electricity consumption per capita will also decrease. In 2025 the electricity consumption will be 1,581 kWh /capita, and in 2050 it will only reach to 3,806 kWh / capita. Our analysis indicates that lower socio-economic indicators, such as demography, and economic and industrial growth as well as the lower number of vehicles in the realization scenario compared to the existing RUEN are the main reasons why the total primary energy demand, electricity consumption, and power plant's capacity in this new scenario are lower than the existing RUEN.

Figure 19 Economic and industrial growth, demography, and number of vehicles in the existing RUEN vs. realization scenario

Table 16 New capacity for all power plants in the realization scenario

Power plant		2020	2021	2022	2023	2024	2025	2030	2040	2050
FOSSIL FUELS		60.99	62.53	68.92	71.63	72.08	72.79	86.32	125.88	171.67
	Stream (PLTU)	32.04	32.05	34.91	37.03	37.21	38.18	52.01	74.86	128.23
	Gas (PLTG)	27.23	28.99	32.66	33.30	33.62	33.41	33.42	50.55	43.44
	Diesel (PLTD)	1.72	1.50	1.35	1.30	1.26	1.20	0.88	0.48	0.00
RENEWABLES		12.17	14.04	14.62	15.26	17.65	22.62	29.91	50.31	88.43
	Geothermal (PLTP)	2.14	2.14	2.15	2.21	2.37	3.30	5.37	10.99	10.99
	Hydropower (PLTA)	5.65	6.41	6.41	6.54	8.79	12.48	17.90	20.90	62.29
	Mini & Microhydro (PLTM/MH)	0.51	1.61	1.63	1.67	1.67	1.67	1.67	1.67	1.67
	Bioenergy (PLTBio)	3.22	2.95	3.04	3.01	2.98	2.94	2.72	3.97	9.54
	Solar (PLTS)	0.50	0.76	1.02	1.19	1.19	1.43	1.45	2.86	2.98
	Wind (PLTB)	0.14	0.18	0.37	0.64	0.64	0.80	0.80	0.92	0.96
Total		73.16	76.57	83.54	86.89	89.73	95.41	116.22	176.19	260.10

Due to a lower number of total power plant's capacity in this new scenario, the share of each power plant will also be adjusted.

The new power plant capacity's projection of 2025–2050 in the realization scenario can be seen in Table 16. Moreover, the result of realization scenario shows that the existing renewables target with total renewables' installed capacity of 45.2 GW will not be achieved in 2050.

4.3. Current Policies Scenario

Gas-network construction is one of the RUEN mandates and a National Strategic Program (under Presidential Regulation Number 6/2019).

This city gas-network intensification for households and small businesses is aimed at reducing LPG consumption, hence minimizing its import. As a counterbalance, the household gas consumption through the city gas-network will increase. Our model shows a decrease of 4.7 percent in LPG import by 2025, from 6.3 MTOE to 6.0 MTOE, and 17.9 percent in 2050, from 6.7 MTOE to 5.5 MTOE.

This decline in LPG import is expected to help to lower the trade balance deficit by reducing the total import cost and government subsidies for LPG.

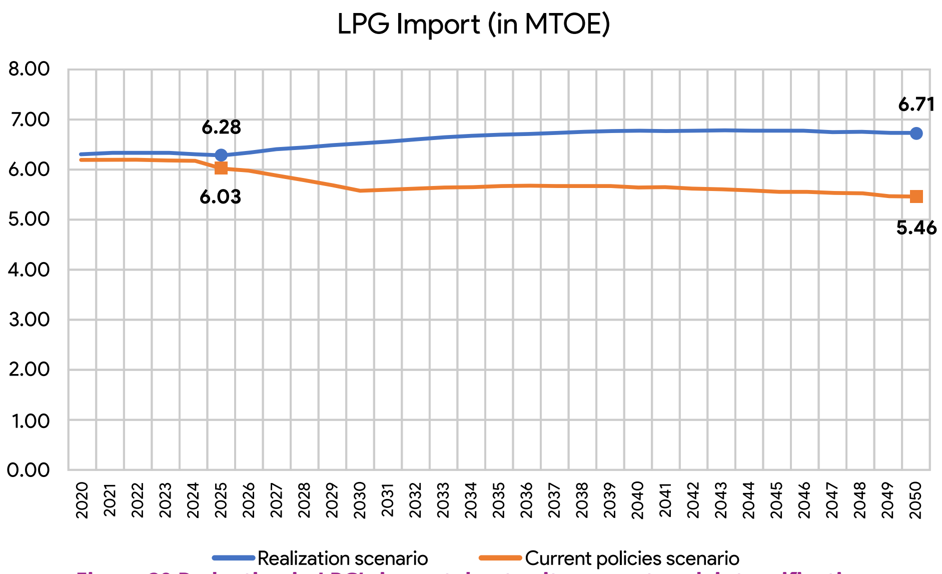


Figure 20 Reduction in LPG's import due to city gas-network intensification

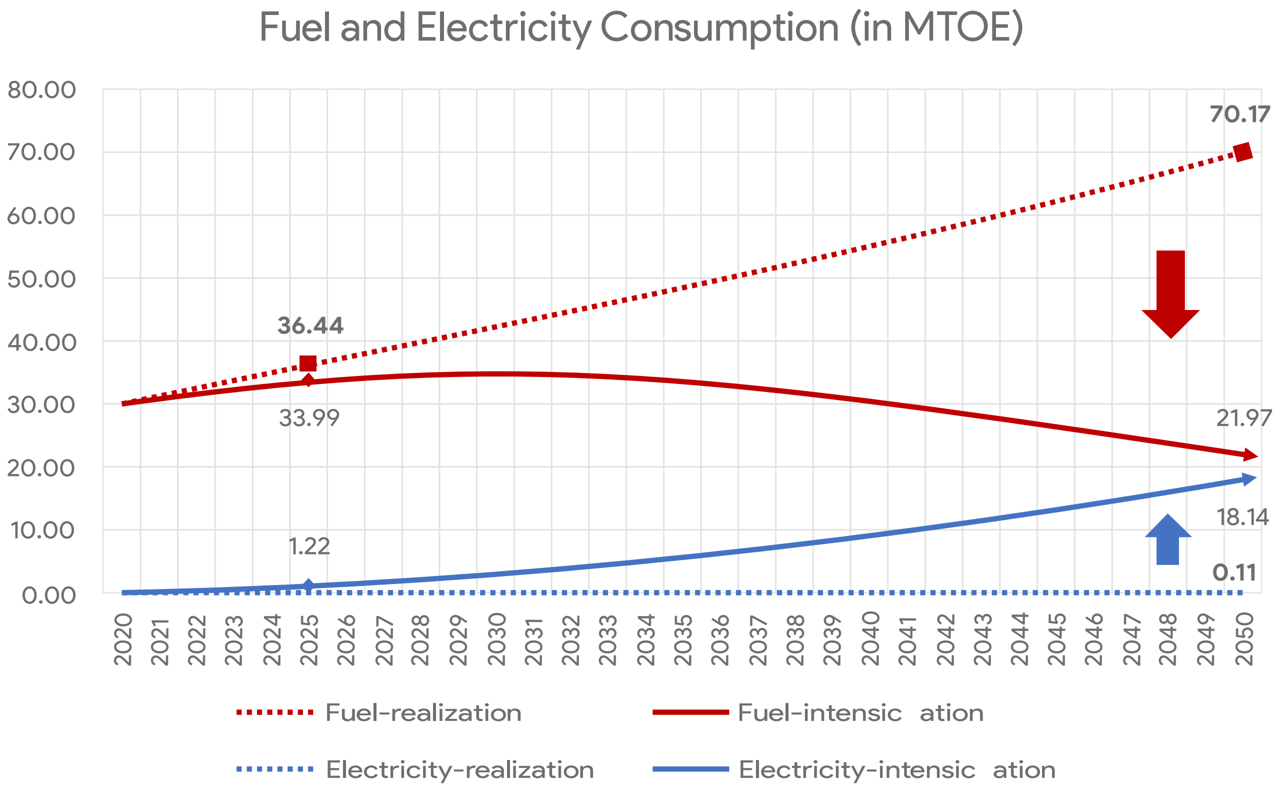


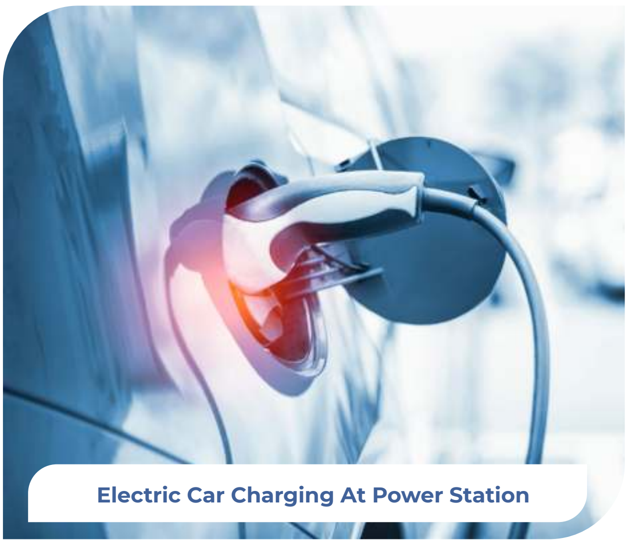
Figure 21 Changes in fuel and electric consumption due to electric vehicles intensification policy

Another recent policy that is also introduced by the government through Presidential Regulation Number 55/2019 is the utilization of electric vehicles. According to this policy, the electric vehicle intensification will shift the transportation consumption from fuel (mostly gasoline) to electricity.

Therefore, when the usage of electric cars and motorcycles increases, the fuel consumption in 2050 will decrease from 70.2 MTOE to 22 MTOE or less than the consumption in 2018. Conversely, the electrical consumption for transportation will increase from 0.11 MTOE to 18 MTOE.

Biodiesel intensification is another policy that has broad support from the government who is targeting the B50 program starting from 2021 and B100 in 2030 after implementing the B30 program in December 2019.

The implication of policy on biodiesel consumption is significant. In 2021 the biodiesel consumption will increase to 15.3 million kl (from 9.2 million kl in the existing RUEN), and in 2030 the consumption will triple to 45.9 million kl (from only 13.2 million kl in the existing RUEN).



Electric Car Charging At Power Station

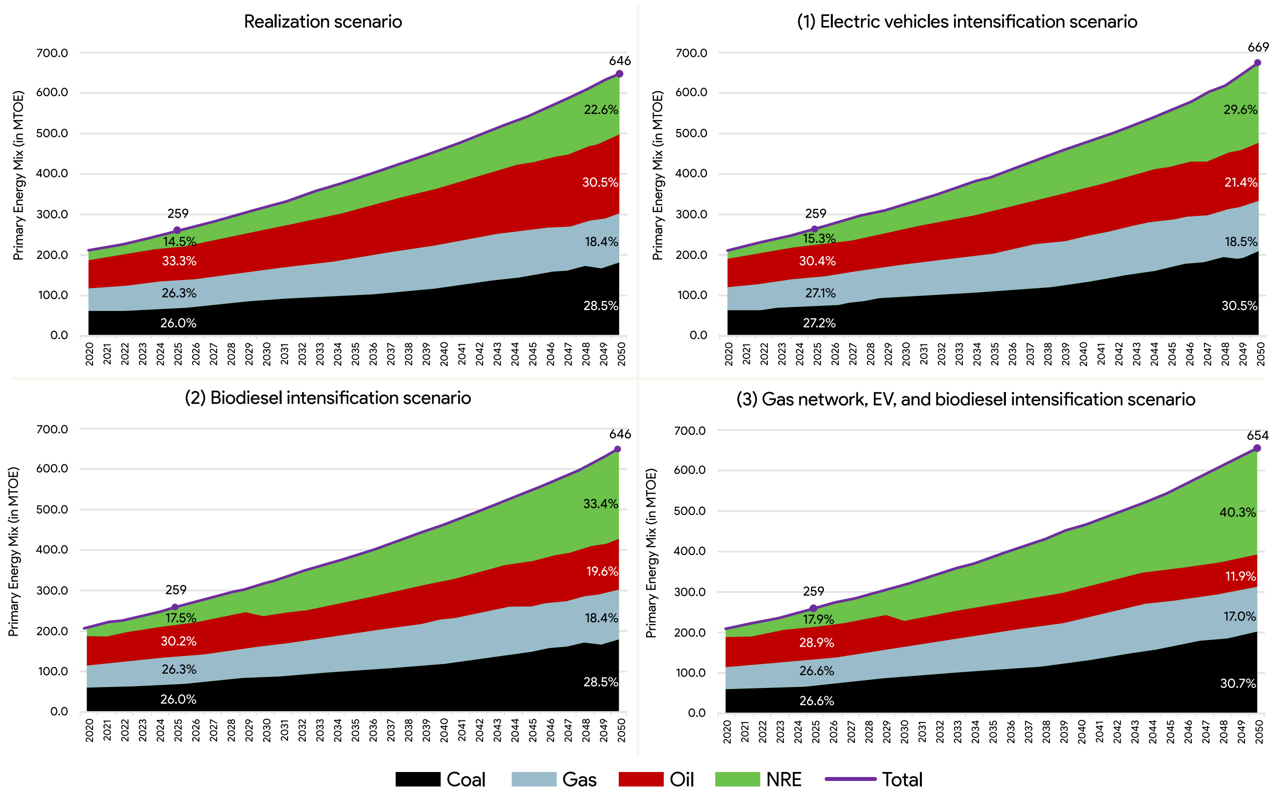


Figure 22 Primary energy mix in all current-policies scenarios

In terms of the primary energy mix, the city gas-network, electric vehicle, and biofuel intensification scenarios make a different contribution. The energy mix stays the same in the city gas-network intensification scenario. However, in the electric vehicle intensification scenario, we can see that the oil share will decrease from 33.3% to 30.4% in 2025 and from 30.5% to 21.4% in 2050, while the other primary energy share increase.

In the biodiesel intensification scenario, the renewables share will increase from 14.5% to 17.5% in 2025 and from 22.6% to 33.4% in 2050, while the oil share decreases proportionally (detail contribution of biodiesel to the power plant and non-power plant can be seen in Figure 24 below). When all the three intensification scenarios are combined, we see a more significant increase in the renewables share. It increases 3.4% in 2025 and 17.7% in 2050. Whereas for the other primary energies, they will decrease with varying sizes from 0 .7% to 18.5% in 2025 and 2050.

After comparing the realization scenario and current-policies scenario, i.e. the combination of all three initiatives including city gas-network, EV, and biodiesel intensification, the total primary energy in 2025 is similar at 259 MTOE, but not in terms of the energy mix. In this current-policies scenario, the share of renewable energy is slightly increased, while the percentage of oil decreases due to the B30 program in 2020 and B50 which starts in 2021. Then in 2050, the difference between these two scenarios becomes more obvious where the renewables reach 40% in the primary energy mix for the current policy ratio compared to 23% only in the realization scenario, while the oil share decreases from 30% to 12% .

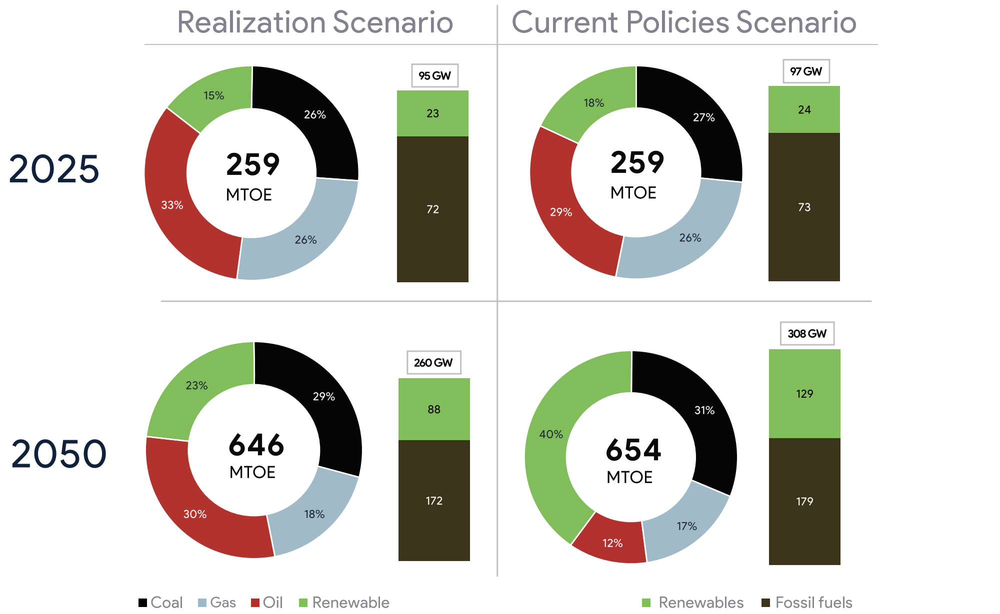


Figure 23 Primary energy comparison between realization scenario vs. current-policies scenario

One of the main reasons why the renewables share increases significantly in this current-policies scenario, particularly after 2025, is because this scenario includes the plan to increase the usage of biodiesel, from B50 starting in 2021 to B100 in 2030. This biodiesel share can be seen in Figure 24. The power plant's installed capacity in the intensification scenario also increases compared to the realization scenario from 95 to 97 GW in 2025 and from 260 to 308 GW in 2050.

The increase results from the electricity demand growth due to electric vehicles whose number expand significantly starting from 2025. Our model shows that the electricity demand in this scenario will increase compared to the realization scenario from 447 TWh to 462 TWh in 2025 and from 1,239 TWh to 1,475 TWh in 2050. Similarly, the consumption per capita will also slightly increase compared to the realization scenario. The latest consumption will be 1,635 kWh / capita in 2025 and 4,538 kWh / capita in 2050. The per capita consumption, particularly in 2025, is higher compared to the electricity consumption per capita in the Mid-Term National Development Plan (RPJMN) 2020– 2024, which sets the target at 1,400 kWh / capita in 2024.

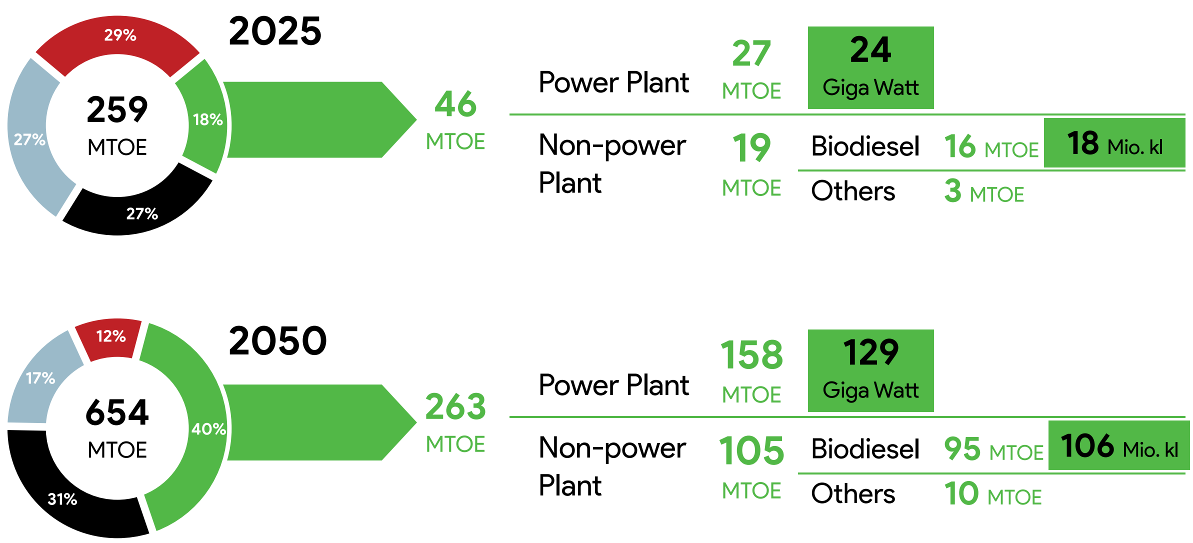


Figure 24 Composition of renewables in the primary energy mix (current-policies scenario)

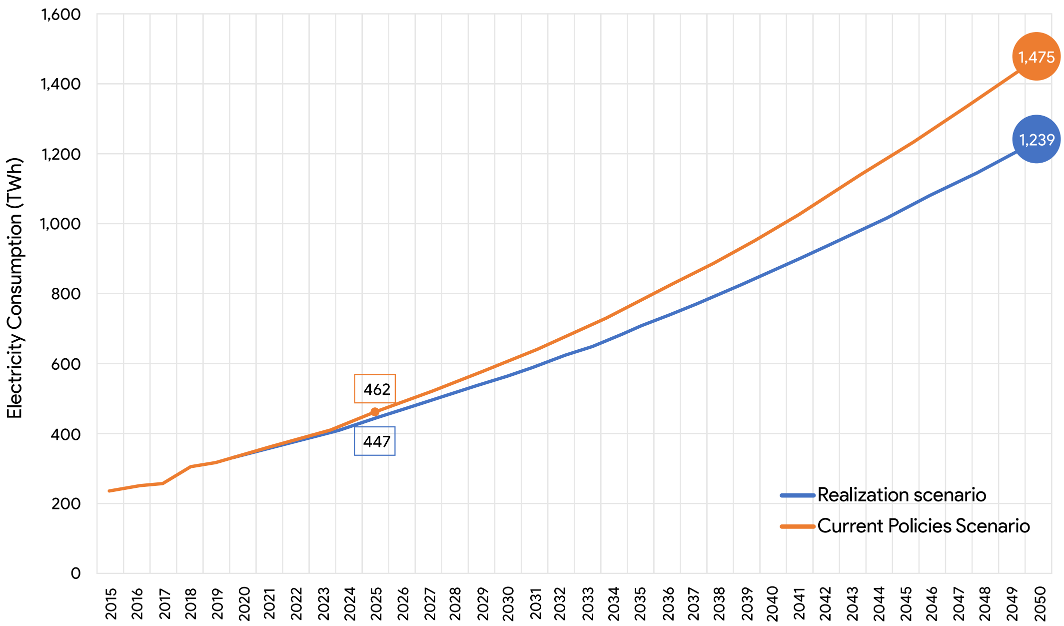


Figure 26 Electricity demand in the realization scenario vs. intensification scenario

Wh a larger total power plant's capacity in the current policies scenario, the share of each power plant is also adjusted.

The new power plant capacity's projection of 2025–2050 in this current policies scenario can be seen in Table 17 below.

Table 17 New capacity for all power plants in the current-policies scenario

Power plant		2020	2021	2022	2023	2024	2025	2030	2040	2050
FOSSIL FUELS		**59.80**	**61.49**	**67.98**	**70.73**	**71.71**	**72.96**	**88.52**	**133.95**	**178.83**
	Stream (PLTU)	32.04	32.05	34.91	37.03	37.71	39.18	54.83	83.26	145.43
	Gas (PLTG)	27.23	28.99	32.66	33.30	33.62	33.41	33.42	50.55	33.40
	Diesel (PLTD)	0.53	0.46	0.41	0.40	0.38	0.36	0.27	0.15	0.00
RENEWABLES		**12.18**	**14.07**	**14.68**	**15.37**	**18.63**	**23.74**	**36.32**	**69.29**	**128.81**
	Geothermal (PLTP)	2.14	2.14	2.15	2.21	2.37	3.30	5.37	10.99	16.00
	Hydropower (PLTA)	5.65	6.41	6.41	6.54	8.79	12.48	23.04	44.68	76.04
	Mini & Microhydro (PLTM/MH)	0.51	1.61	1.63	1.67	1.95	1.96	1.96	1.96	1.96
	Bioenergy (PLTBio)	3.22	2.95	3.04	3.01	3.33	3.30	3.08	5.89	21.81
	Solar (PLTS)	0.50	0.76	1.02	1.19	1.42	1.73	1.96	4.37	10.00
	Wind (PLTB)	0.16	0.21	0.43	0.74	0.77	0.97	0.97	1.40	3.00
Total		**71.98**	**75.56**	**82.66**	**86.09**	**90.34**	**96.70**	**124.84**	**203.24**	**307.64**

4.4. Energy Transition Scenario

The energy transition scenario in this report indicates a situation when the share of renewables surpasses the fossil fuel share in terms of the primary energy supply. Under this scenario, the fossil share by 2025 will still account for the largest portion. The share of renewables can only surpass the fossil share from 2040 to 2042 in the different intervention types.

In the first sub-scenario, involving the no new CFPP construction from 2029 onwards, the share of renewables will be 17.9% (or 46.3 MTOE) in 2025 and 66.3% (or 503.8 MTOE) in 2050. The share of renewables will exceed the fossil share in 2042, when it reaches 51% in the primary energy mix.

In the second sub-scenario, in which the cessation of new CFPP construction from 2025 onwards will be carried out, the share of renewables will be equal to the first sub-scenario at 17.9% (or 46.3 MTOE) in 2025. However, the share will increase to 68.1% (or 524.41 MTOE) in 2050. The share of renewables surpasses the fossil share one year earlier in this sub-scenario, in which 52% of the primary energy mix is already renewable in 2041. In the last sub-scenario, in which the cessation of new CFPP construction from 2025 onwards and the policy to phase out the combined cycle power plants (Pembangkit Listrik Tenaga Gas Uap/ PLTGU) older than 20 years old will be executed, the share of renewables is higher than the first two sub-scenarios. The renewables percentage is projected at 20.1% (or 52.56 MTOE). This is because renewables, especially solar PV, replace the capacity that comprises the combined-cycle power plants. In 2050, renewables' share will increase to 68.6% (or 530.5 MTOE), making this sub-scenario has the highest share of renewables compared to the previous two. In terms of overcoming fossils' share, this sub-scenario reaches it in the year of 2040, with renewables' share at 50.4%.

Power plant's installed capacity in 2025 for the first and second sub-scenario is similar to the current policies scenario, i.e. at 97 GW. However, in the third sub-scenario, the capacity in 2025 reaches 106 GW. This is due to the solar PV power plant, which has a lower capacity factor (CF), is used to replace the old combined cycle power plant that has a higher CF. In 2050, all the three sub-scenarios will have higher installed capacity, varying from 459 GW to 489 GW, compared to the current -policies scenario which is at 308 GW. Phasing out CFPPs and the combined cycle power plants as well as substituting it with renewables, e.g. solar and wind that have a lower CF, are the main reasons for this installed capacity incremental.

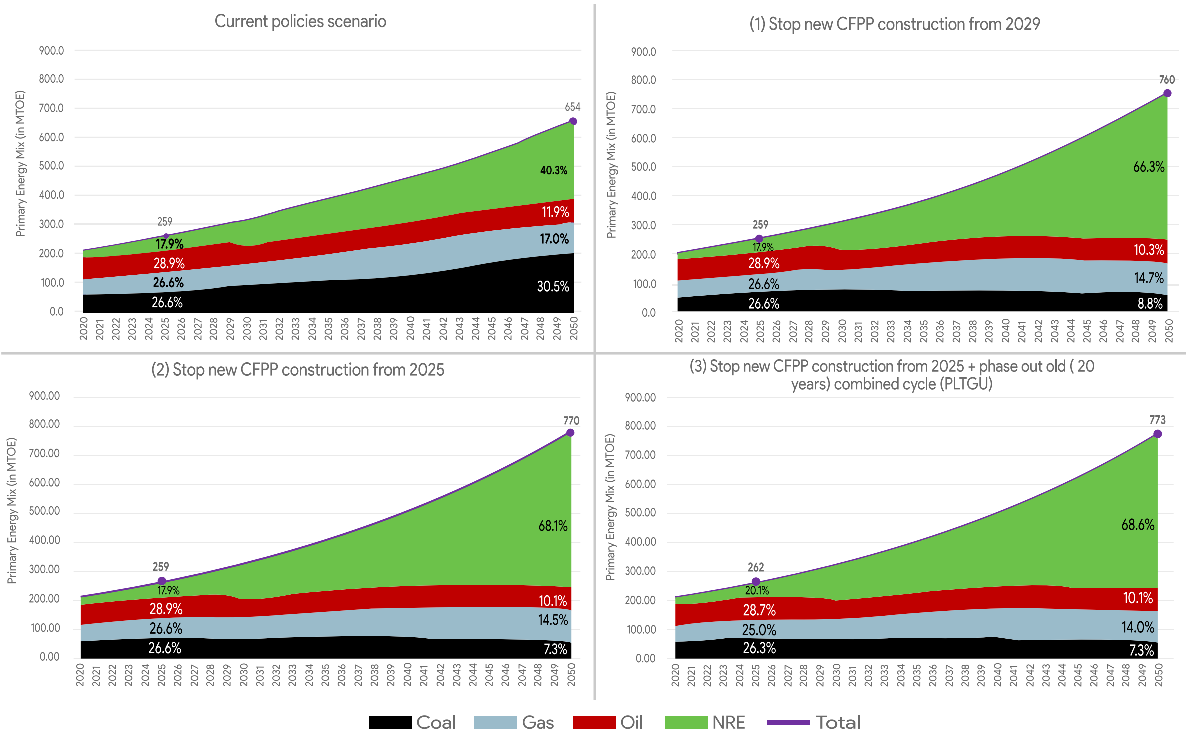


Figure 27 Primary energy mix in the energy transition scenario

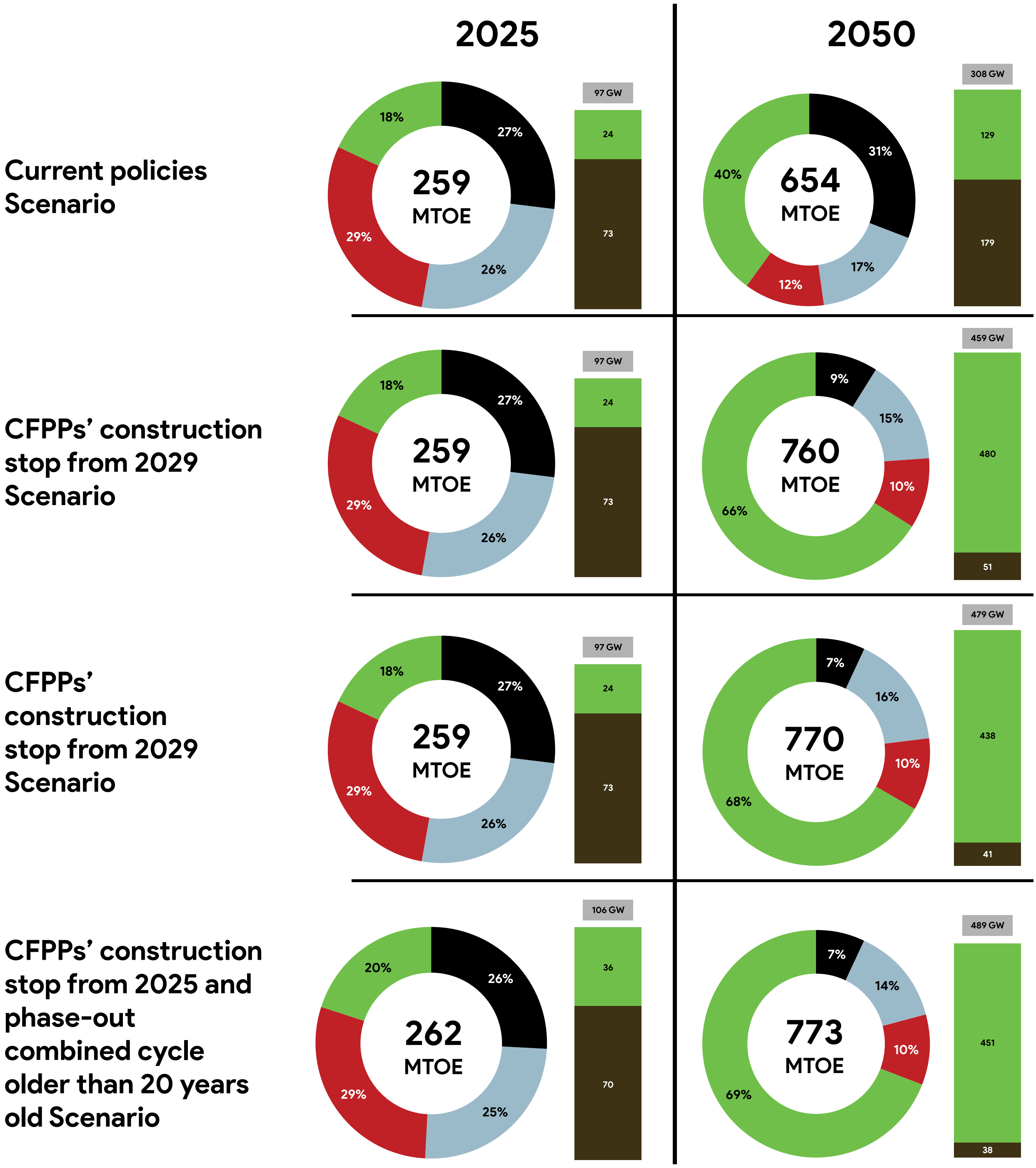


Figure 28 Primary energy comparison between current-policies scenario vs. energy transition scenario

In terms of electricity consumption, there is no difference between the energy transition scenario and the current-policies scenario, i.e. at 462 TWh in 2025 and 1,475 TWh in 2050. However, the contribution of electricity generation from renewables gradually increases from the first sub-scenario to the third sub-scenario, with renewables generation reaches 1,280 TWh (from the total of 1,475 TWh) in the third sub-scenario of the energy transition scenario.

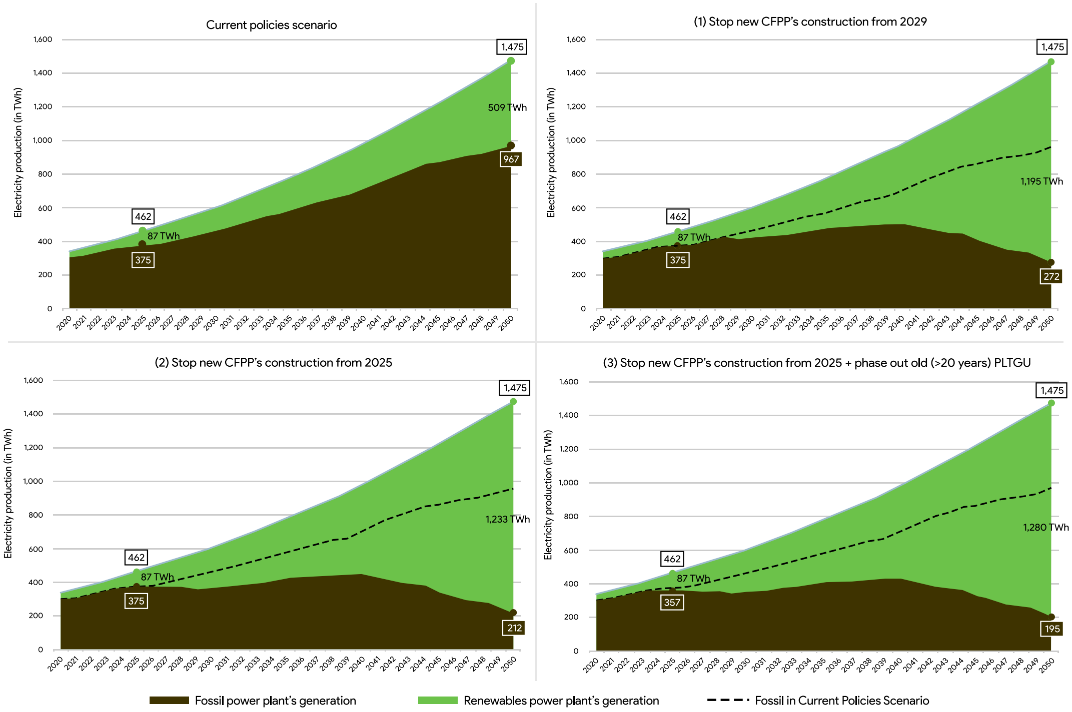


Figure 29 Shifting in fossil fuels' share in electricity production in the energy transition scenario

With higher total power plant's capacity in the energy transition scenario, the share of each power plant is also adjusted.

Latest projection of the power plant's capacity from 2025 to 2050 in the energy transition scenario which ceases the CFPP construction from 2029 onwards can be seen in Table 18 below. Meanwhile, Table 19 shows the capacity projection when the CFPP construction from 2025 onwards will not be carried out. In addition, Table 20 describes the capacity when the new CFPP construction from 2025 onwards will cease and the combined cycle power plants older than 20 years are phased out.

Halting the CFPP construction in 2025 will prevent 10 GW coal capacity by 2030 when compared to that of the scenario which ceases the CFPP construction from 2029 onwards. As a result, this 10 GW is replaced by 49 GW of renewables, with a 17-fold increase in the solar capacity from around 2 GW to 35 GW. Additionally, when the old combined cycles are also phased out, more solar capacity is needed - 47 GW by 2030, instead of 35 GW.

Table 18 New capacity for all power plants in the energy transition scenario (in GW) when there is no new CFPPs' construction from 2029

Power plant		2020	2021	2022	2023	2024	2025	2030	2040	2050
FOSSIL FUELS		59.80	61.49	67.98	70.73	71.71	72.96	79.53	93.26	51.05
	Stream (PLTU)	32.04	32.05	34.91	37.03	37.71	39.18	45.84	42.56	17.65
	Gas (PLTG)	27.23	28.99	32.66	33.30	33.62	33.41	33.42	50.55	33.40
	Diesel (PLTD)	0.53	0.46	0.41	0.40	0.38	0.36	0.27	0.15	0.00
RENEWABLES		12.18	14.07	14.68	15.37	18.63	23.74	48.94	143.18	407.89
	Geothermal (PLTP)	2.14	2.14	2.15	2.21	2.37	3.30	6.19	13.28	28.50
	Hydropower (PLTA)	5.65	6.41	6.41	6.54	8.79	12.48	31.57	57.91	76.04
	Mini & Microhydro (PLTM/MH)	0.51	1.61	1.63	1.67	1.95	1.96	3.05	7.69	19.39
	Bioenergy (PLTBio)	3.22	2.95	3.04	3.01	3.33	3.30	4.50	11.59	32.60
	Solar (PLTS)	0.50	0.76	1.02	1.19	1.42	1.73	1.99	41.57	172.87
	Wind (PLTB)	0.16	0.21	0.43	0.74	0.77	0.97	1.64	9.97	60.60
	Ocean (PLT Laut)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	17.90
Total		71.98	75.56	82.66	86.09	90.34	96.70	124.84	236.43	458.95

Table 19 New capacity for all power plants in the energy transition scenario (in GW) when there is no new CFPPs' construction from 2025

Power plant		2020	2021	2022	2023	2024	2025	2030	2040	2050
FOSSIL FUELS		59.80	61.49	67.98	70.71	72.96	72.96	69.11	82.84	40.
	Stream (PLTU)	32.04	32.05	34.91	37.03	37.71	39.18	35.42	32.14	7.33
	Gas (PLTG)	27.23	28.99	32.66	33.30	33.62	33.41	33.42	50.55	33.40
	Diesel (PLTD)	0.53	0.46	0.41	0.40	0.38	0.36	0.27	0.15	0.00
RENEWABLES		12.18	14.07	14.68	15.37	18.63	23.74	81.17	172.98	438.26
	Geothermal (PLTP)	2.14	2.14	2.15	2.21	2.37	3.30	5.88	12.94	28.50
	Hydropower (PLTA)	5.65	6.41	6.41	6.54	8.79	12.48	31.57	57.91	76.04
	Mini & Microhydro (PLTM/MH)	0.51	1.61	1.63	1.67	1.95	1.96	2.90	7.50	19.39
	Bioenergy (PLTBio)	3.22	2.95	3.04	3.01	3.33	3.30	4.31	11.30	32.60
	Solar (PLTS)	0.50	0.76	1.02	1.19	1.42	1.73	34.95	72.43	203.24
	Wind (PLTB)	0.16	0.21	0.43	0.74	0.77	0.97	1.56	9.72	60.60
	Ocean (PLT Laut)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	17.90
Total		71.98	75.56	82.66	86.09	90.34	96.70	150.28	255.81	479.00

Table 20 New capacity for all power plants in the energy transition scenario (in GW) when there is no new CFPPs' construction from 2025 plus phasing-out combined cycle power plant (PLTGU) older than 20 years

Power plant		2020	2021	2022	2023	2024	2025	2030	2040	2050
FOSSIL FUELS		59.80	60.69	66.38	68.51	68.51	69.76	65.91	79.64	37.53
	Stream (PLTU)	32.04	32.05	34.91	37.03	37.71	39.18	35.42	32.14	7.33
	Gas (PLTG)	27.23	28.99	31.06	30.90	30.42	30.21	30.22	47.35	30.20
	Diesel (PLTD)	0.53	0.46	0.41	0.40	0.38	0.36	0.27	0.15	0.00
RENEWABLES		12.18	16.93	20.78	24.41	31.00	36.04	89.47	185.28	450.56
	Geothermal (PLTP)	2.14	2.14	2.15	2.21	2.37	3.30	5.88	12.94	28.50
	Hydropower (PLTA)	5.65	6.41	6.41	6.54	8.79	12.48	27.57	57.91	76.04
	Mini & Microhydro (PLTM/MH)	0.51	1.61	1.63	1.67	1.95	1.96	2.90	7.50	19.39
	Bioenergy (PLTBio)	3.22	2.95	3.04	3.01	3.33	3.30	4.31	11.30	32.60
	Solar (PLTS)	0.50	3.62	7.12	10.24	13.79	14.03	47.25	84.73	215.54
	Wind (PLTB)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	17.90
Total		71.98	77.62	87.17	92.74	99.50	105.80	155.38	264.91	488.10

Power plant, field of photovoltaic panels and wind turbines

STUDY REPORT

5 Policy Consequences of the Energy Transition Scenario

The energy transition scenario is aimed at attransforming the energy sector, in particular the power sector, to be not heavily reliant on fossil fuels to utilize more renewables. To decarbonize the power sector, a policy mechanism need to be set up to help foster the replacement of fossil fuel sources by low / zero-carbon resources. In doing so, the policy will need to address the security of supply and the stable long-term financial incentives, as well as the market frameworks that provide a business case for timely fossils' divestment and retirement of old fossil power plants and the investment in adequate renewables (World Bank, 2017).

5.1. Legal Frameworks for Renewable Energy or Laws that Include Targets and Plans for Renewable Energy

Indonesia must have a clear and well-designed statutory framework/law to affirm the government's commitment to develop Indonesia's renewables sources. It is also important that the laws require the government to assume the responsibility to develop the renewables sector as well as to provide concrete and realistic plans that the government will take to achieve the renewables target.

The proposed New and Renewable Energy Bill, which is recently included in the national legislative program (Prolegnas), could provide the much-needed long-term stability in the Indonesian renewables market. The laws will establish some of the policy supports required by renewables to take off, such as the incentive schemes and/ or the priority of renewables in the energy mix (IESR, 2019).

5.2. Financial and Regulatory Incentives for Renewables

Financial and regulatory incentives for renewable energy have been widely implemented by the governments around the world to support deployment and scale-up of renewable energy installation. These financial and regulatory incentives can address various barriers to renewable energy. For example, they will improve financial returns of the renewables' projects as well as reduce the risk, improve access to capital, support the creation of new markets, and reduce the burden of high upfront cost. There are some schemes of financial and regulatory incentives that are widely used (e.g., feed-in tariff [FiT], reverse auction, and premium tariff). The Indonesian government is currently developing a presidential regulation on renewable energy, which will introduce a FiT policy to re-attract investment in the sector. The regulation is set to be issued in 2020. The level of FiT imposed on the regulation may be vital in determining the renewable investment climate in 2020 (IESR, 2019)

5.3. Grid Access and Dispatch Priority for Renewable Energy

Grid accessand dispatch for renewable energy refer to the admittance of electricity generation from renewables to the transmission and distribution systems. The policy will improve confidence to the potential investors that their renewables' projects can be connected to the grid and to sell the generated electricity.

European Union (EU) legislation, for example, mandates wind and solar priority feed-in, which means that whenever the wind plants and solar PV produce electricity, they are entitled to feed in the power into the grid.

6 Conclusion

This report describes the study that modeled different scenarios for the Indonesian energy planning by using the existing RUEN as its basis. The study incorporates all government policies on energy, such as city-gas network intensification, EV, and biodiesel programs.

The study considers the existing RUEN as the old baseline and compares this against an alternative scenario in which we updated the parameters and indicators used for a future projection. This alternative scenario develops into a new baseline utilized in the comparison against higher levels of renewables, which saw 40% by 2050 in the current-policies scenario and over 66% by 2050 in the energy transition scenario.

Modeling was performed with the Long-range Energy Alternative Planning (LEAP), which was used to model the existing RUEN. The study identifies the impact of updating twenty underlying assumptions and indicators that are used to do the LEAP modeling, incorporation of current government policies on energy, and assess the impact of replacing a significant amount of CFPPs and combined cycle power plants with renewables.

These proposed energy transition scenarios to the existing RUEN show that increasing the share of renewables more than fossil fuels are visible.

Key findings:

- Basic assumptions and indicators used to build the existing RUEN are already outdated. The existing RUEN was set in 2017, and the majority of the data used was from the real data up to 2015. From 2016 onwards, they were projected based on these existing data and tended to be overestimated, especially in the economic and industrial growth and in the demography. This causes the future projection in the existing RUEN is also disproportionate, for example, in the primary energy and electricity consumption, including in the power plant's capacity.
- Primary energy consumption in the realization scenario is lower than the existing RUEN with a yearly energy consumption growth rate at 4% (compared to 4.7%/year in the existing RUEN). Additionally, electricity consumption per capita will also lower in 2025, which is at 1,582 kWh/capita compared to 2,500 kWh/capita in the existing RUEN.
- Renewables target of 45.2 GW by 2025 in the existing RUEN will not be achieved. The realization scenario shows that renewables will only obtain 22.62 GW in 2025.
- Current policies scenario will increase renewables share in the primary energy mix due to the biodiesel program, from B50, starts from 2021, until B100, starts from 2030. Meanwhile, the policy to intensify electric vehicles will increase electricity demand compared to the realization scenario. This biodiesel program alone is not sufficient to increase renewables share in the primary energy mix to more than 50%. Moreover, the increasing electricity demand due to electric vehicles also highlighted the need to decarbonize the grid if EV's contribution to a reduction of Indonesian greenhouse gas (GHG) to be maximized.
- With the current policies scenario, the primary energy mix in 2025 will not reach 23% as mandated by the existing RUEN. However, by 2050, renewables' share in the primary energy mix will reach 40.3%, far above the existing RUEN and realization scenario target. In terms of the power plant installed capacity, the current policy scenario has more GW than the realization scenario.
- The energy transition scenario is modeled by replacing CFPPs older than 30 years old and combined-cycled PPs older than 20 years old with renewables, particularly solar PP. Additionally, in this scenario, new CFPPs' construction is also prohibited, either from 2029 or 2025. The sooner the CFPPs' ban is applied, the more significant shares of renewables in the primary energy mix is, and the earlier renewables' share surpasses fossil fuels.
- To be on-track with the energy transition scenario, renewables installed capacity by 2025 should be at least 23.74 GW (fossil fuels at 72.96 GW), and by 2050 should be a minimum 408 GW (fossil fuels at 51.1 GW).

References

IESR (2019). Indonesia Clean Energy Outlook: Tracking Progress and Review of Clean Energy Development in Indonesia. Jakarta: Institute for Essential Services Reform (IESR)

Ministry of Finance Republic of Indonesia (2019). Indonesia's Economic Growth in 2018 is Higher Than 2017. Retrieved from https://www.kemenkeu.go.id/en/publications/news/indonesias-economic-growth-in-2018-is-higher-than-2017/

Sakina Rakhma, & Diah Setiawan (October 2019). Masih ada 1724 Desa di Papua dan Papua Barat Belum Teraliri Listrik. Kompas. Retrieved from https://money.kompas.com/read/2019/10/03/202158226/masih-ada-1724-desa-di-papua-dan-papua-barat-belum-teraliri-listrik

Tim Pembinaan Penyusunan RUED-P (2017). Pedoman Teknis Permodelan Rencana Umum Energi Daerah (RUED) Provinsi.

World Bank. (2017). Regulatory Indicators for Sustainable Energy. A Global Scorecard for Policy Makers. Retrieved from http://documents.worldbank.org/curated/en/538181487106403375/pdf/112828-REVISED-PUBLIC-RISE-2016-Report.pdf