Planning and Fulfillment of North Kalimantan Province Energy Needs

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Abstract. Along with population and economic growth, increasing energy requirements require careful planning. Based on LEAP modeling, final energy requirements in North Kalimantan Province in 2025 are estimated to reach 975 thousand Ton Oil Equivalent (TOE), with the industrial sector as the largest user (39%), followed by other sectors (34%), transportation (14%), household contents (11%), and commercial (2%). In 2034, final energy requirements are expected to increase to 1,454 thousand TOE, dominated by the industrial sector (46%). The primary energy mix in 2030 consists of oil (29.4%), renewable energy (10.8%), coal (34.2%), and gas (20.9%). In 2034, it is recommended that renewable energy will increase to 25.4%. Electrical supply is estimated to reach 892 MW in 2030 and 2,242 MW in 2034, with increases in renewable energy levels.

1 Introduction

Energy is a crucial factor that plays a key role in the national economic development process. In addition to contributing to state revenue, exports, and the balance of payments, energy use also has a significant impact on other macroeconomic indicators. Inefficiency in energy utilization is reflected in high energy intensity figures. According to the Handbook of Energy & Economic Statistics of Indonesia (HEESI) published by the Ministry of Energy and Mineral Resources, in 2023 Indonesia's energy intensity was recorded at more than 1.5 BOE (Barrels of Oil Equivalent) per thousand US dollars, far higher than Japan's, which was below 1 BOE per thousand US dollars. On the other hand, national energy needs are still heavily dependent on imports-especially LPG and fuel-while global energy prices have soared due to the conflict between Russia and Ukraine.[1]

Indonesia actually possesses comprehensive resources to be a driving force behind the global energy transition. However, renewable energy utilization is currently far from optimal capacity. According to data from the Directorate General of New, Renewable, and Energy Conservation (EBTKE), the realization of renewable energy use in Indonesia has only reached around 0.3% of the total available potential [2]

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Table 1. EBT power plant potential and utilization in 2023.

Type of NRE	Total Potential (GW)	Utilization (GW)	% of Utilization
Ocean	63	-	-
Geothermal	23	2.4	10.3%
Bioenergy	57	3.1	5.4%
Wind	155	0.2	0.1%
Hydro	95	6.7	7.0%
Solar	3,294	0.3	0.01%
Total	**3,687**	**12.6**	**0.3%**

Source: Ministry of Energy and Mineral Resources.

The management of national energy resources has not yet been fully optimised to meet domestic consumption needs. A portion of the primary energy supply is still prioritised for export activities to obtain foreign exchange, which serves as revenue for the State Budget (APBN). Consequently, the availability of energy within the country-both for fuel consumption and as an essential input for industrial production-remains insufficient. This condition indicates that the mandate of Article 33 of the 1945 Constitution of the Republic of Indonesia, regarding the equitable utilisation of natural resources, has not been effectively realised [3].

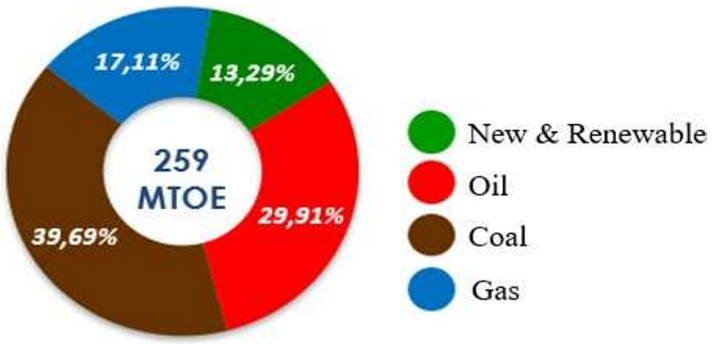


Fig. 1. Indonesia's energy fulfillment in 2023.
Source: Ministry of Energy and Mineral Resources.

The purpose of implementing Energy Management, as outlined in Government Regulation No. 79 of 2014, is to establish an energy governance system that is fair, sustainable, and environmentally friendly, while at the same time strengthening national energy independence and security on the foundation of energy sovereignty and just economic principles. Achieving a strong level of independence and resilience in the energy sector requires comprehensive and effective management practices [4].

In line with this vision, the Government of Indonesia through the Nawa Cita program has emphasized its commitment to a development pathway that is low in carbon emissions and resilient to climate challenges. Adaptation and mitigation of climate change have been positioned as cross-sectoral priorities. This stance later served as the cornerstone for the drafting of Indonesia's first Nationally Determined Contribution (NDC), which was officially presented to the UNFCCC in November 2016, marking an initial milestone toward realising a low-emission development trajectory [5].

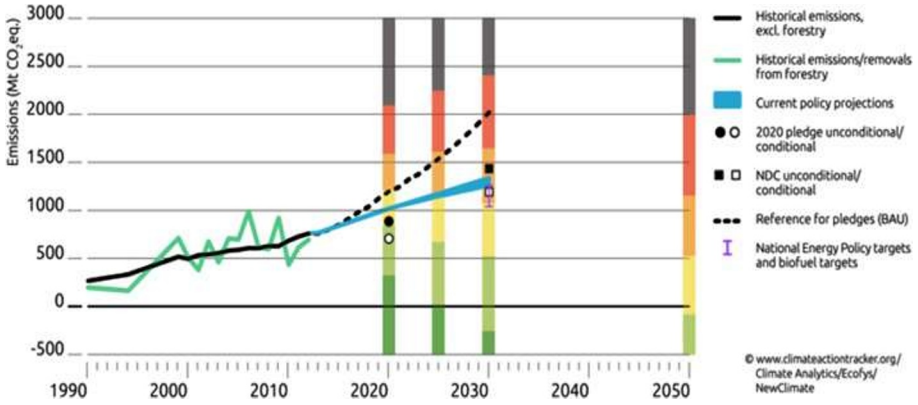


Fig. 2. Overview of Indonesia's NDC.
Source: Ministry of Energy and Mineral Resources.

In order for the emission reduction targets stated in the NDC document to be realistic and achievable, they must be supported not only by future energy management projections but also by the design of concrete strategies and detailed action plans. Within the energy sector, one of the widely adopted methods for planning is the use of modelling techniques, particularly optimisation models, which are frequently applied in both energy planning and management practices. The Indonesian government has consistently sought to ensure the adequacy of its domestic energy supply by introducing and implementing various policy instruments. Among these efforts is the policy on energy provision and utilization, which emphasizes the development of renewable energy programs. This policy direction is closely tied to the still limited energy condition in North Kalimantan. According to Ref. [6], the acceleration of renewable energy utilisation for electricity generation in the region could serve as a driver for sustainable and environmentally friendly economic growth.

The present research is designed to map out the regional energy system by employing input–output analysis combined with scenario-based approaches. By utilising regional macroeconomic data, the study provides projections of energy demand and proposes optimised energy supply models designed to meet the future needs of the North Kalimantan region.

2 Method

The analytical approach adopted in this study relies on econometric-based statistical techniques, which are further supported by the application of the LEAP (Long-range Energy Alternatives Planning) software. The data processing stages are carried out systematically and can be described as follows:

a. Preparation of the energy profile prior to the LEAP input process
- Estimating the overall energy supply expressed in SBM units;
- Determining the baseline year energy intensity values;
- Measuring the volume of energy consumption, also in SBM units;
- Identifying and quantifying energy user activities, such as the total number of vehicles, households, and other relevant indicators.

b. Assessment of the present energy condition
- Analyzing the current status of energy use in each sector of energy users;
- Mapping the energy situation according to the type of final energy utilized.

c. Development of assumptions and projections for future energy demand and supply
- Conducting forecasting to estimate upcoming energy needs and supply scenarios.

d. Formulation of regional policies and strategies

- Compiling comprehensive strategies and policy directions for regional energy management that align with long-term planning objectives.

2.1 Study Framework

This study was conducted through a series of systematic and carefully organised stages, ensuring that every process was executed in a focused manner and in accordance with the methodological framework outlined in Figure 3 of the research design.

a. Preliminary Data Collection

The first activity involved gathering initial data from diverse and publicly accessible references, including online databases, books, reports, and other supporting sources. This step provided a general overview of the energy supply and consumption conditions in the study area.

b. Verification and Updating with Official Sources

Afterward, the preliminary data was refined and verified by incorporating more accurate information obtained from authoritative institutions, such as the ESDM Office, the Ministry of Energy and Mineral Resources, and other relevant agencies. This stage was crucial to guarantee the reliability and relevance of the information used for analysis.

c. Processing and Classification of Data

Once the updated data was available, it was processed and grouped according to specific analytical needs. In cases where the dataset was incomplete or unsuitable for processing, additional collection efforts or data correction had to be performed before advancing to the next phase.

d. Analysis and Projection of Energy Consumption

1. Sectoral Classification of Energy Use: The data was categorised by sector, including industrial, transportation, household, and commercial energy users.
2. Estimation and Projection of Energy Demand-Forecasts of energy requirements were developed using historical consumption patterns, combined with economic growth indicators and demographic dynamics.
3. Scenario Simulation and Evaluation-Several possible energy management scenarios were modeled, allowing comparisons to identify the most feasible strategies to meet projected demand.

e. Energy Balance Assessment

Based on the classification, calculations, and scenario simulations, an energy balance evaluation was conducted. This assessment aimed to identify the equilibrium between available energy resources and projected consumption under the different scenarios tested.

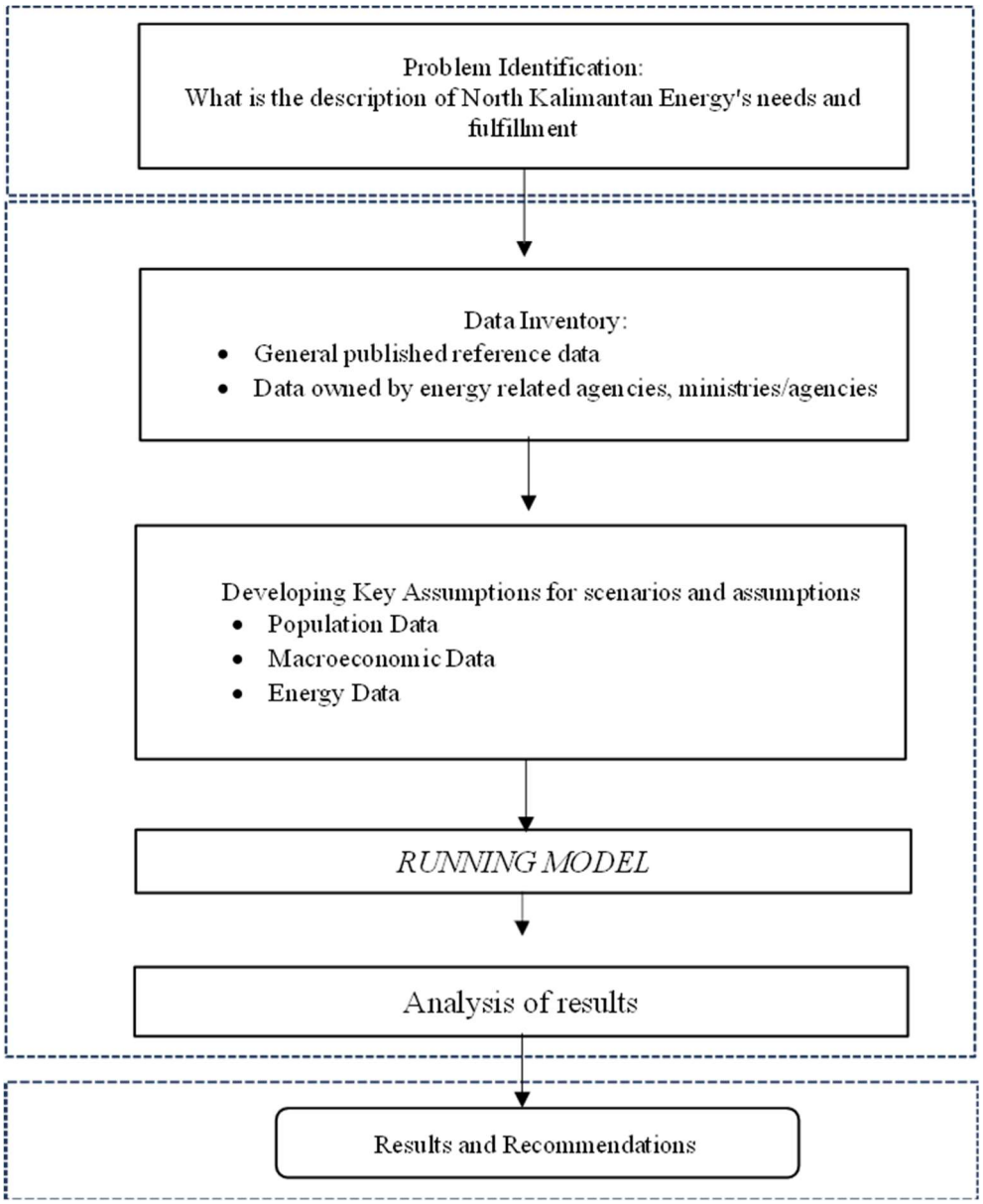


Fig. 3. Study framework.

2.2 Data Collection

Some data needed for this research are as follows:
a. The transportation sector data needs are shown in Table 2.

Table 2. Transportation sector data needs.

No	Data	Data Requirements	Data Source	Explanation
1	Activity Data	Data on the number of vehicles per vehicle type	BPS, RUEN	The data on the number of vehicles increased by province can be calculated using the provincial GRDP fraction approach to national GDP per type of transportation.
		Load Factor	RUEN	
		Cruising Distance	RUEN	
		Real sub-sector GDP	BPS / Provinsi dalam Angka	
2	Energy Intensity	Fuel sales in the transportation sector	Pertamina	Energy intensity for each transport is calculated by dividing fuel consumption by its activity level.
		BBG sales in the transportation sector	Pertamina	
		Electricity sales in the transportation sector	PLN	
3	Scenario	transportation sector activity projections	BPS, RUEN	Used to calculate the level of activity of the transportation sector (passenger-km, ton-km)
		Energy Intensity Decrease	RUEN	Indicators of energy use efficiency
		Transition of Transportation Mode	RUEN	

b. Household sector data needs are shown in Table 3

Table 3. Household sector data needs.

No	Data	Data Requirements	Data Source	Explanation
1	Activity Data	1. Population Size 2. number of households 3. electrification ratio 4. number of households using equipment/technology 5. quipment/technology penetration	• Provinsi dalam Angka • Statistics PLN • DJ Electricity, DJ OIL& GAS • -National Socioeconomic Survey	Available
2	Energy Intensity	1. electricity sales 2. Fuel Consumption (kerosene) 3. City gas 4. estimation of traditional biomass usage	• Provinsi dalam Angka • Statistics PLN • DJ Electricity, DJ OIL& GAS • Department of Energy and Mineral Resources	used to calculate energy intensity in households per type of equipment
3	Scenario	1. Population growth 2. Growth of urban households 3. increasing electrification ratio 4. household size change trend 5. Market Diffuion/penetration 6. Shifting Fuel	Central and regional government planning documents	Used to calculate energy requirement projections in the Baseline Scenario (BAU)

c. The need for industrial sector data is shown in Table 4.

Table 4. Industrial sector data needs.

No	Data	Data Requirements	Data Source	Explanation
1	Activity Data	Production Data per industry type	Department of Industry	Production Data for each type of industry is difficult to obtain and challenging to accumulate.
		Real subsector GDP	Prov. Dalam angka - BPS	Not all GDP data for the industrial sector is detailed in the Provinsi dalam Angka BPS
		Survei subsector GDP	Industry Survey - BPS	the last alternative if the sub-sector GRDP is not obtained, the industrial sub-sector GRDP figure is used from the results of the industrial survey
2	Energy Intensity	Fuel sales	Pertamina, Department of Energy and Mineral Resources	used to verify the results of the intensity survey
		BBG Sales	Pertamina, Department of Energy and Mineral Resources Pertamina, Department of Energy and Mineral Resources	used to verify the results of the intensity survey
		Coal Sales	MEMR, Department of Energy and Mineral Resources	used to verify the results of the intensity survey
		LPG Sales	Pertamina, Department of Energy and Mineral Resources	used to verify the results of the intensity survey
		natural gas sales	PGN, Department of Energy and Mineral Resources	used to verify the results of the intensity survey
		Electricity Sales	PLN	used to verify the results of the intensity survey
		Industry Survey	BPS	used to verify the results of the intensity survey
3	Scenario	GDP growth in the industrial sector	Prov. Dalam Angka	Used to calculate energy requirement projections in the Baseline Scenario (BAU)
		energy savings	Regional Medium Term Government Plan, Other sector strategic plans	Used as a Basis for Intensity Changes for Energy Sector Efficiency Scenarios

d. Commercial sector data needs are shown in Table 5.

Table 5. Commercial sector data needs.

No	Data	Data Requirements	Data Source	Explanation
1	Activity Data	Real Subsector GDP	Provinsi dalam Angka BPS	Trade, hotels and restaurants, finance, real estate, corporate services, communications and other services
		Average floor area of government buildings	Survey of several institutions	Floor area can describe the electricity consumption per type of use
2	Energy Intensity	Electricity sales	PLN & Private	Used to determine electricity consumption in the business sector, social government buildings and public street lighting.
		Fuel Sales	Pertamina, Directorate General of Oil and Gas, Department of Energy and Mineral Resources	Used to determine the intensity of energy use
		LPG and Gas sales	BPH Migas, Pertagas, PGN, Directorate General of Oil and Gas, Department of Energy and Mineral Resources	Used to determine the intensity of energy use
3	Scenario	GDP growth in commercial sector	Provinsi dalam Angka	Used to calculate energy requirement projections in the Baseline Scenario (BAU)
		energy savings	Regional Medium Term Government Plan, Other sector strategic plans	Used as a Basis for Intensity Changes for Energy Sector Efficiency Scenarios

e. Other sector data needs are shown in Table 6.

Table 6. Other sector data needs.

No	Data	Data Requirements	Data Source	Explanation
1	Activity Data	Real Subsector GDP	Provinsi dalam Angka PDRB menurut Lapangan Usaha BPS	Available
2	Energy Intensity	Other sectors Fuel Sales	Pertamina, Department of Energy and Mineral Resources	Used to calculate the percentage of fuel usage in other sectors
		Estimated share of fuel in other sectors	Department of Energy and Mineral Resources	Used if real data on fuel usage in other sectors is not available.
3	Scenario	GDP growth in other sctor	Provinsi dalam Angka	Used to calculate energy requirement projections in the Baseline Scenario (BAU)
		energy savings	Regional Medium Term Government Plan, Other sector strategic plans	Used as a Basis for Intensity Changes for Other Sector Efficiency Scenarios

3 Results and Discussion

3.1 Energy Modeling Results

3.1.1 Primary Energy Mix Projection

Tabel 7. Primary energy mix modeling results.

Types of Energy	2023	2030	2034
Coal	5.5%	34.2%	36.9%
Gas	31.8%	20.9%	11.9%
Oil	52.7%	29.4%	25.8%
New & Renewable	10.1%	10.8%	25.4%
Total	100%	100%	100%

At the initial stage of observation, the share of new and renewable energy (EBT) was documented at approximately 10.1%, and projections suggest a marginal increase to around 10.8% by 2030. A different trend is expected in 2034, when the contribution of EBT is anticipated to rise sharply, nearly doubling to reach 25.4%. In contrast, the utilisation of coal exhibits a substantial upward trajectory, starting at 5.5% in 2023, increasing significantly to 34.2% in 2030, and then further expanding to approximately 36.9% by 2034. This marked escalation is largely attributed to the establishment of large-capacity coal-fired power plants (PLTU) constructed in the industrial and economic development zones of North Kalimantan, aimed at satisfying the growing electricity demand [7,8]

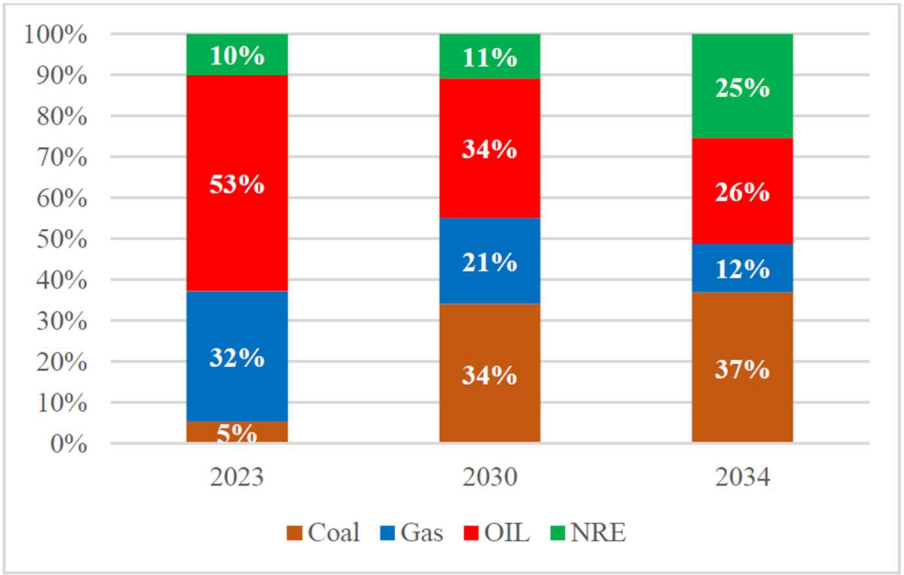


Fig. 4. Primary energy mix of North Kalimantan province in 2023, 2030, 2034.

3.2 Elasticity and Energy Intensity Projection

Table 8. Energy indicator projection 2023-2034.

Indicator	Year			
	2023	**2025**	**2030**	**2034**
Elasticity of Final Energy Consumption	1.2	1.1	1.0	0.95
Final Energy Consumption per GRDP	17.9	19.3	29	31.1
(TOE/Billion IDR)	0.7	1,0	1.2	1.3
Final Energy Consumption per capita (TOE/capita/year)	91.2	95	100	100

Table 8 presents the projected energy indicators for North Kalimantan, covering the period from 2023 to 2034. During this timeframe, the elasticity of final energy consumption is shown to decline from 1.2 to 0.95, which illustrates a gradual improvement in overall energy efficiency. At the same time, the ratio of energy use to GRDP rises notably, from 17.9 to 31.1 TOE per billion Rupiah. Likewise, per capita energy consumption also grows, increasing from 0.7 TOE per person per year to around 1.3 TOE per person per year, indicating that a higher energy demand accompanies economic expansion. In addition, the electrification ratio shows a steady increase and is projected to reach 100% by 2030, reflecting equal and universal access to electricity services across the North Kalimantan region [9]

3.3 Projection of Final Energy Needs and Energy Provision

3.3.1 Industrial sector

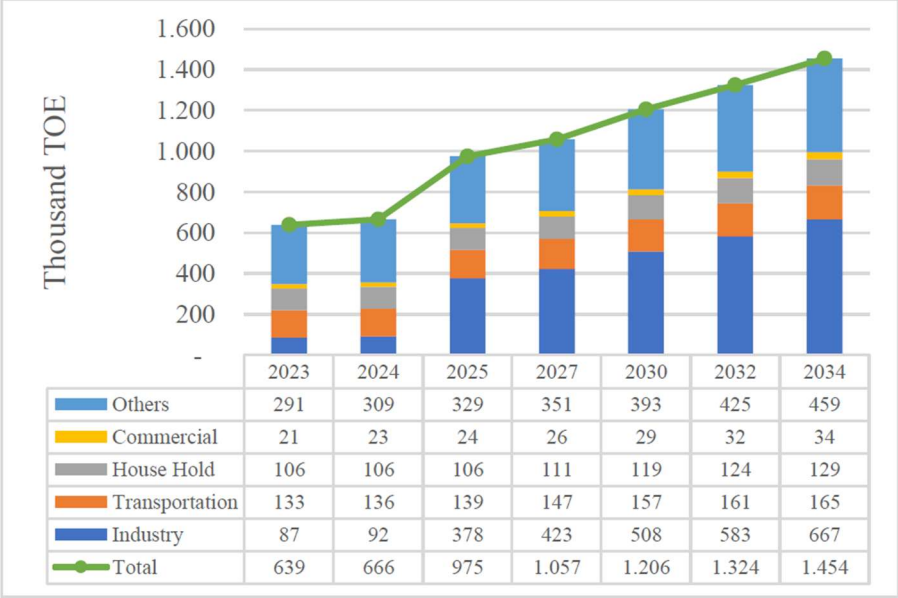
The Provincial Government of North Kalimantan has allocated approximately 25,000 hectares of land in Tanah Kuning, Bulungan Regency, to be developed as an aluminium-centred industrial zone, which includes smelter facilities as well as supporting industries such as coal processing. The establishment of this industrial area is expected to significantly enhance national aluminium production capacity, with a target to increase output from approximately 1 million tons per year to 2 million tons annually. PT Inalum is seen to have considerable potential to invest in this region, enabling the company to expand its operations while positioning production activities closer to the sources of raw materials. To attract both domestic and international investors, the government has also introduced various incentive schemes. Nevertheless, one of the critical obstacles remains the adequacy of energy supply, making the acceleration of hydroelectric power plant construction and the promotion of new and renewable energy (EBT) initiatives strategic priorities in order to strengthen investor confidence [10]

3.3.2 Transportation sector

Transportation activities within North Kalimantan Province encompass several modes, including land-based (road), river, sea, and air transportation. The road transportation system is divided into passenger transport-comprising motorcycles, private cars, and public transport services, and freight transport, which utilizes both small and large trucks. The scale of these road activities is generally assessed through the number of vehicles officially registered in the region. Meanwhile, the performance of river and sea transport is evaluated using the total operating hours recorded each year. For air transport, its contribution is not measured solely by the number of flights, but rather through the value-added share of airport operations to the

Gross Regional Domestic Product (GRDP), which reflects the sector's economic role in the province.

3.3.3 Final energy needs projection



	2023	2024	2025	2027	2030	2032	2034
Others	291	309	329	351	393	425	459
Commercial	21	23	24	26	29	32	34
House Hold	106	106	106	111	119	124	129
Transportation	133	136	139	147	157	161	165
Industry	87	92	378	423	508	583	667
Total	639	666	975	1.057	1.206	1.324	1.454

Fig. 5. Final energy demand by user sector

Figure 5 illustrates the forecast of final energy demand in North Kalimantan Province for the period 2023–2034. Throughout this time horizon, the demand for energy is projected to grow steadily, rising from approximately 639 thousand TOE in 2023 to about 1,454 thousand TOE by 2034. Among the various sectors, industry emerges as the dominant consumer of energy, while transportation ranks as the second-largest user, followed by contributions from other sectors. The most notable surge in demand is expected to take place starting in 2024, a trend that reflects the acceleration of regional economic growth and the expansion of industrial activities within North Kalimantan.

Table 9. Projected energy demand by type of final energy (thousand tons oil eqv).

Type of Energi	**2023**	**2024**	**2025**	**2028**	**2030**	**2034**
Electricity	68.43	74,20	108,64	147,89	181,81	269,64
Natural gas	7.83	8,89	19,88	26,37	31,63	45,50
Premium	154.84	164,36	159,88	170,26	175,69	175,43
Avtur	11.05	11,28	11,38	11,32	11,24	10,89
Kerosene	1.43	0.97	0.41	0.30	0.21	0.04
Diesel oil	99.28	99.73	92.80	98.12	101.43	106.92
LPG	19.36	19.99	20.58	19.88	19.33	18.07
Coal	32.87	33.34	206.75	217.51	223.96	236.62
Biogas	0.32	0.36	0.40	0.54	0.63	0.81
Biomass Tradisional	10.60	10.59	10.57	12.28	13.49	16.05
BioSolar	43.66	55.70	61.46	91.60	116.87	189.42
BioPremium	-	-	12.35	13.11	9.00	11.22
Commersial Biomass	0.70	0.75	0.79	0.90	0.99	1.21
Bioavtur	1.88	2.31	2.76	4.66	6.21	10.25

Dimethyl Ether	1.78	2.08	2.39	3.04	3.49	4.42
Total	**454.04**	**484.55**	**711,05**	**817,79**	**895,98**	**1,096.49**

3.3.4 Energy supply projection

Table 10. Primary energy supply (thousand TOE).

Types of Energy	2023	2024	2025	2027	2028	2030	2032	2034
Coal	48	47	49	50	50	734	874	1.045
Gas	279	294	325	380	390	451	346	336
Oil	463	471	530	543	552	732	699	729
New & Renewable	89	104	142	165	191	231	663	718
Total	879	915	1.046	1.137	1.184	2.148	2.582	2.827

Table 10 presents the forecast of primary energy supply in North Kalimantan for the period 2023–2034. Over this span of time, the supply is projected to grow consistently, from around 879 thousand TOE in 2023 to approximately 2,827 thousand TOE by 2034. Petroleum remains the dominant source of energy, while natural gas and new renewable energy sources (EBT) also exhibit a gradual upward trend in their contributions. A particularly sharp rise is recorded for coal starting in 2030, which is closely associated with the expansion of coal-fired power plant development within the province [11].

a. Electricity needs and provision

Table 15. Projection of electricity consumption per capita in North Kalimantan prov.

Year	Electricity Consumption
2023	1.377 kWh per Capita
2025	4.707 kWh per Capita
2030	5.599 kWh per Capita
2034	6.670 kWh per Capita

The projection for electricity consumption per capita in North Kalimantan indicates a sharp upward trend, rising from about 1,377 kWh in 2023 to reach around 6,670 kWh by 2034. This substantial growth is closely tied to the acceleration of regional economic development, the increasing demand for electricity within the industrial sector, and the ongoing improvement of the electrification ratio, which ensures wider access to electricity across the province.

Table 12. Projected generating capacity (MW).

Type of Generator	2023	2024	2025	2027	2030	2032	2034
Coal-Fired PP	15	15	15	15	350	700	1.000
Steam Gas PP	9	9	9	9	9	9	9
Gas PP	40	40	40	40	40	40	40
Gas Engine PP	137	137	137	177	217	217	217
Diesel PP	125	125	0	0	0	0	0
BioDiesel PP	-	-	125	125	125	125	125
Hydroelectric PP	-	-	-	-	-	400	500
Micro Hydro PP	1	1	1	1	1	1	1
Biomass PP	7	7	7	7	50	50	50
Solar PP	3	3	3	3	100	200	300
Total	337	337	337	377	892	1.742	2.242

Table 11 illustrates the forecast of electricity generation capacity in North Kalimantan over the period 2023–2034. During this period, capacity is expected to increase significantly, from approximately 337 MW in 2023 to around 2,242 MW by 2034. Coal-fired steam power plants are projected to play the most dominant role, with output estimated to reach 1,000 MW in 2034, in line with the rapid development of major industries such as PT Kalimantan Alumina Industries (KAI) and PT Phoenix Resources Indonesia (PT PRI). Although steam-based power generation remains the leading source, the government and industry are simultaneously pursuing decarbonization strategies, including the adoption of low-carbon technologies and carbon capture systems. At the same time, renewable energy capacity, particularly from solar and biomass power plants, is also projected to increase, thereby reinforcing efforts to realize a more sustainable and environmentally friendly energy transition in the province.

b. Distribution network in the future
The electricity infrastructure development plan in North Kalimantan Province includes generation, transmission, and distribution according to the projected power needs until 2034 which are estimated to reach 1,012 MW. Between 2023 and 2034, the transmission needs are projected to reach 950 km. The Medium Voltage Network (JTM) is approximately 237 km, the Low Voltage Network (JTR) is around 250 km, and an additional 76 MVA transformers and 31 substations with a capacity of 340 MVA are required.

4 Conclusion

Based on the results of the final energy demand modelling, the total requirement is projected to reach approximately 975 thousand TOE by 2025. Within this projection, the industrial sector emerges as the dominant consumer, accounting for about 39% of the total demand, followed by a group of other sectors at 34%. In addition, transportation is expected to contribute around 14% of energy use, households 11%, and the commercial sector making up the remaining 2%. Moving forward to 2034, the total final energy demand is anticipated to rise further, reaching roughly 1,454 thousand TOE. Similar to the trend in 2025, industry continues to dominate with a larger share of 46%, while other sectors contribute 32%. The transportation sector's share is estimated at 11%, household energy use at 9%, and the commercial sector remains stable at around 2%.

For the primary energy mix in North Kalimantan Province, the composition in 2030 is projected to consist of 29.4% oil, 10.8% new and renewable energy, 34.2% coal, and 20.9% natural gas. By 2034, the structure is expected to shift, with oil declining to about 25.8%, renewable energy expanding significantly to 25.34%, while the shares of coal and gas also adjust accordingly. Meanwhile, modelling of the regional energy supply system indicates that electricity generation capacity will reach approximately 892 MW by 2030 and increase sharply to around 2,242 MW by 2034. Notably, the proportion of renewable energy in supporting electricity generation capacity is projected to continue its upward trend, reinforcing the region's transition toward a cleaner and more sustainable energy system.

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