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Research Article

New and Renewable Energy Optimization to Meet North Sumatera Province's Energy Share and Emission Road Map Period Year of 2022-2025 by Using LEAP

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A B S T R A C T

The objective of this work is to evaluate the long-term energy demand and supply in North Sumatera Province. The Road Map for both NRE energy shares and GHG Emissions in North Sumatera is in Regional Regulation No. 4 Year 2022. The growth of electricity demand, type of power generation determination and transmission/distribution losses will be defined into two main scenarios: Business As Usual (BAU) and Policy (KEB), and eight sub scenarios to assess possibilities to reach the Road Map during period of 2022-2050. Four scenarios under BAU Scenario show that the percentage of NRE energy shares and GHG Emissions are achievable during period of 2022-2025. The range of NRE shares is 45.1% up to 96.2%, and GHG Emissions production range is 3% - 30% from the Road Map. Meanwhile, Four scenarios under KEB Scenario show that the percentage of NRE energy shares and GHG Emissions are achievable during period of 2022-2025. The range of NRE shares is 44% up to 93.4%, and GHG Emissions production range is 4% - 30% from the Road Map. Some scenarios under BAU gives slightly higher NRE shares and GHG Emissions production saving since the higher growth of demand in BAU Scenarios is possible for more NRE power generation capacity in operation.

1. INTRODUCTION

The power generation sector to meet electricity needs in Indonesia is currently dominated by fossil fuel sources as per 55.390 MW or 87% of the total power generation in 2020 [1]. This fossil fuel based power generation will still dominate the share about 75% up to 81% in 2050 [2]. Meanwhile, the shares of NRE for electricity generation as per 11.28% or 162.39 MOE in 2020 [3]. The New and Renewable Energy (NRE) power generation shares will grow with 5.7% annual average growth for Business As Usual (BAU) scheme and 7.0% annual average growth for NRE scheme and reach 18% or about 854 MOE for AU scheme and 25.4% or about 1.271 MOE for NRE scheme in 2050 [2]. In 2050, NRE additional capacity will be dominated by Hydropower and Geothermal by 10% for BAU scheme and 14% for NRE scheme, Solar Photovoltaic and Wind Energy by 7% for BAU scheme and 17% for NRE [2].

The current global demand to lowering Green-House-Gas (GHG) emissions is taken as the National target as represented by the Government commitment through regulation of Law No. 16 year

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2016 subject to Approval of Paris Agreement To The United Nations Framework Convention On Climate Change. The Paris Agreement ratification defined that Indonesia spotted a target to reduce GHG emissions by 29% unconditional (with own effort) and 41% conditional (with adequate International support) in 2030. As one of the long-term strategy 2050, one of the common target to lowering GHG emissions within National Determined Contribution (NDC) framework is the energy sector by NRE resources utilization for power generation capacity expansion plan [4].

North Sumatera Province has been well-known with its abundant potential NRE resources for hydropower, geothermal, biomass, solar and other bio energy resources. The resources are expected to be optimum-utilized for electricity power generation [1]. The clean NRE resources is also expected to lower the GHG emissions rate.

Optimizing the NRE resources for boosting the NRE shares in North Sumatera Province, in which currently achieve 40.02% of the total installed power generation capacity 3,770 MW in October 2022, may give several concerns to be answered. The concern whether this optimization would reach both National (NRE shares 23% in 2025 and 31% in 2030) and Regional (NRE shares 23.98% in 2025, 30.91% in 2030 and 49.91% in 2050) target. The another concern is whether the NRE resources would decrease GHG emissions in several development schemes.

Based on the above said concerns, the assessment will be carrying out to the electricity planning in North Sumatera Province to meet the following purposes: Analyzing the energy shares through energy planning scenario up to 2050 by defining said scenario Business As Usual (BAU) and Policy (KEB), and analyzing the GHG emissions produced for each scenario.

This research is expected to give a sight for performance efficiency of power generation in North Sumatera Province so that may give some opportunities this Province to meet both National and Regional NRE energy shares and reducing GHG emissions as per stated in the Long-term planning document.

2. LITERATURE STUDY

2.1. *NRE Power Generation Road Map*

2.2.1. National NRE Power Generation Road Map

The New and Renewable energy power generation national road map has been set up in the general planning of national energy as per stated in the Presidential Degree No. 22 year 2017 subject to General Planning of National Energy. The National Energy Demand (KEN) modelling result in 2025 shows the NRE shares has achieved the National target of minimum 23% NRE shares or about 135.5 GW installed capacity. Meanwhile, the modelling result in 2050 shows the NRE shares will reach minimum rate of 31,2% with total installed capacity 443.1 GW [5].

The Long-term Electricity General Planning 2021-2030 (RUPTL) document prepared by PT PLN (Persero), which is a reflection of efforts to reach the NRE energy shares as compliance to KEN and RUEN, gives a more description regarding the additional capacity of NRE power generation sources. Additional capacity of 40.6 GW within period 2021-2030 where NRE shares will reach 52% or about 20.9 GW nationally. This additional capacity will increase the NRE capacity to 28.9 GW of the total installed capacity 99 GW or shares 24.8% of NRE in 2030 [1].

2.2.2. North Sumatera Regional NRE Power Generation Road Map

The New and Renewable energy power generation North Sumatera Regional road map has been set up in the document of Regional General Energy Planning of North Sumatera as stated in the Regional Regulation No. 4 Year 2022 subject to Regional General Energy Planning of North Sumatera 2022-2050. The composition of power generation derived from NRE shares compared to total capacity is as shown in the Fig. 1 below [6]:

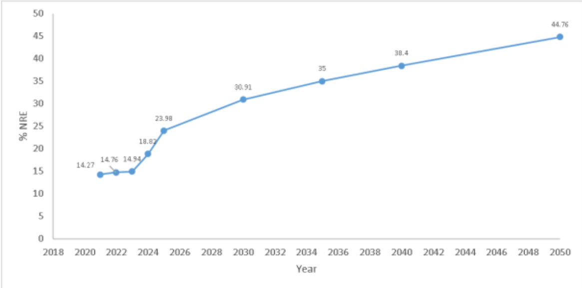

Figure 1. NRE Energy Shares in North Sumatera Province Period 2021-2050

Power generation additional capacity from NRE sources will reach 2,826.7 MW from the total capacity 3,151.7 MW, or shares 89.7% compliance to The Long-term Electricity General Planning 2021-2030 document prepared by PT PLN (Persero). The NRE power generation will be dominated by hydropower (45.50%), Pumped Storage (15.86%), Mini-hydro (9.44%), Geothermal (7.46%), others (4.76%), Wind (3.49%), Solar (2.61%) and Biomass (0.31%) [1]. The detail additional power plant is as show in the Table 1 below:

Table 1. Detail Planned Power Generation in North Sumatera Province

No.	Generation Type	Developer	Power Generation	Fuel	Capacity (kW)	COD Target
1	Hydropower	PLN	Asahan III	Hydro	174,000	2023 2024
2	Hydropower	PLN	Simonggo	Hydro	90,000	2029
3	Hydropower	PLN	Pumped Storage	Hydo	500,000	2029 2030
4	Others	PLN	EBT Peaker	Others	150,000	2030
5	Wind	PLN	Pembangkit Bayu	Wind	110,000	2024 2025
6	Gas Engine	PLN	Nias 2	Gas	20,000	2024
7	Gas Engine	PLN	Nias 3	Gas	5,000	2027
8	Solar PV	PLN	EBT Lisdes	Solar	2,600	2022
9	Solar PV	PLN	Surya Nias	Solar	6,000	2025
10	Solar PV	PLN	Surya Nias	Solar	20,000	2028 2029

(Source: PLN, 2020)

(a)

No.	Generation Type	Developer	Power Generation	Fuel	Capacity (kW)	COD Target
1	Hydropower		Hydropower	Hydro	1,480,000	2030-2050
2	Minihydro		Minihydro	Hydro	222,000	2030-2050
3	Wind		Wind	Wind	163,000	2030-2050
4	Biogas		Biogas	Biogas	300,000	2030-2050
5	Biomass		Biomass	Biomassa	400,000	2030-2050
6	Geothermal		Geothermal	Geothermal	670,000	2030-2050
7	Solar PV		Solar PV	Solar	1,900,000	2030-2050

(Source: RUED, 2022)

(b)

No.	Generation Type	Developer	Power Generation	Fuel	Capacity (kW)	COD Target
1	Geothermal	IPP	Sorik Marapi (FTP2)	Geothermal	100,000	2023 2024
2	Geothermal	IPP	Sumatera (kuota) tersebar	Geothermal	40,000	2024 2025
3	Hydropower	IPP	Batang Toru (Tapsel)	Hydro	510,000	2025
4	Hydropower	IPP	Hidro Sumatera (tersebar)	Hydro	300,000	2022 2025 2028 2030
5	Minihydro	IPP	Aek Sisira Simandame	Hydro	4,600	2023
6	Minihydro	IPP	Anggoci	Hydro	9,000	2023
7	Minihydro	IPP	Sei Wampu I	Hydro	9,000	2023
8	Bio Energy	IPP	(kuota) Sumatera	Bio Energy	2,000	2022
9	Solar PV	IPP	Dedieselisasi	Solar	3,600	2025
10	Minihydro	IPP	Aek Sigeaon	Hydro	3,200	2023
11	Minihydro	IPP	Batang Toru 3	Hydro	10,000	2023
12	Biomass	IPP	Deli Serdang	Biomass	9,900	2023
13	Minihydro	IPP	Kandibata 2	Hydro	10,000	2023
14	Minihydro	IPP	Kineppen	Hydro	10,000	2023
15	Minihydro	IPP	Lae Ordi	Hydro	10,000	2023
16	Minihydro	IPP	Rahu 2	Hydro	6,400	2023
17	Minihydro	IPP	Sidikalang 2	Hydro	7,400	2023
18	Minihydro	IPP	Simbelin-1	Hydro	6,000	2023
19	Minihydro	IPP	Aek Pungga	Hydro	2,000	2024
20	Minihydro	IPP	Aek Sibundong	Hydro	8,000	2024
21	Minihydro	IPP	Aek Situmandi	Hydro	7,500	2024
22	Minihydro	IPP	Aek Tomuan-1	Hydro	8,000	2024
23	Minihydro	IPP	Batang Toru-1	Hydro	7,500	2024
24	Minihydro	IPP	Batang Toru-4	Hydro	10,000	2024
25	Minihydro	IPP	Batang Toru-5	Hydro	7,500	2024
26	Minihydro	IPP	Hutapadang	Hydro	10,000	2024
27	Minihydro	IPP	Ordi Hulu	Hydro	10,000	2024
28	Bio Energy	IPP	(kuota) Kepulauan	Bio Energy	3,000	2024
29	Minihydro	IPP	Sidikalang 1	Hydro	8,600	2024
30	Minihydro	IPP	Raisan Hutadolok	Hydro	7,000	2024
31	Minihydro	IPP	Raisan Nagatimbul	Hydro	7,000	2024
32	Minihydro	IPP	Simonggo	Hydro	8,000	2024
33	Minihydro	IPP	Sisira	Hydro	9,800	2024
34	Minihydro	IPP	(kuota) Tersebar	Hydro	40,300	2023 2024 2025
35	Solar PV	IPP	Surya Sumatera (kuota) Tersebar	Solar	50,100	2025
36	Bio Energy	IPP	Sumatera (kuota) Tersebar	Bio	3,000	2025

(Source: PLN, 2020)

(c)

2.2. *GHG Emissions Reduction Road Map*

2.3.1. *National GHG Emissions Reduction Road Map*

The GHG emissions produced by power generation sector is projected as the most emissions producer. GHG emissions projection in 2025 is as per 893 Million Ton CO_2Eq and in 2050 is as per 1,950 Million Ton CO_2Eq. The KEN target simulation shows a significant GHG emission reduction. The reduction in 2025 is 34.8% and in 2050 is 58.3% as shown in the Fig. 2 below [5]:

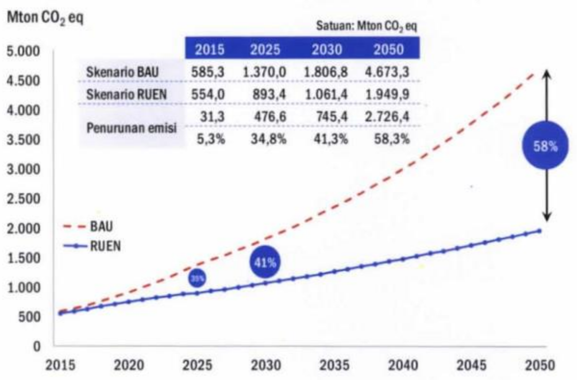

Figure 2. GHG Emissions Reduction Period 2015-2050

Energy diversification efforts by increasing NRE shares portion and reducing fossil fuel sources will effect to GHG emissions reduction.

2.3.2. North Sumatera Province GHG Emissions Reduction Road Map

The CO_2 emissions data in North Sumatera Province in 2020 is 16.953 Million Ton CO_2 from industry sector, household, transportation, commercial, power generation and other sector [6].

Annual energy increasing in North Sumatera leads to GHG emissions growth. GHG Emissions projection in North Sumatera within period of 2020-2050 is as shown in Table 2 below:

Table 2. GHG Emissions Projection in North Sumatera Period 2020-2050

Emissions (1000 TCO2)	2020	2021	2022	2023	2024	2025	2026	2027
Carbon Dioxide	16,935.35	17,829.66	18,652.66	19,777.16	19,789.56	19,564.73	20,059.74	20,623.13
Methane	14.26	15.51	16.45	16.96	16.82	16.18	16.37	16.57
Nitrous Oxide	47.93	51.78	54.37	58.75	57.32	54.37	55.45	56.77
Total	**16,997.54**	**17,896.95**	**18,723.48**	**19,852.87**	**19,863.70**	**19,635.28**	**20,131.56**	**20,696.47**

(Source: RUED, 2020)

(a)

Emissions (1000 TCO2)	2028	2029	2030	2035	2040	2045	2050
Carbon Dioxide	20,750.26	21,063.93	20,759.07	22,673.19	24,769.99	25,751.51	26,977.86
Methane	16.60	16.69	16.54	17.10	17.63	17.60	17.63
Nitrous Oxide	56.63	55.16	53.68	56.56	59.58	58.81	58.31
Total	**20,823.49**	**21,135.78**	**20,829.29**	**22,746.85**	**24,847.20**	**25,827.92**	**27,053.80**

(Source: RUED, 2020)

(b)

2.4. LEAP in Energy System Modelling

2.4.1. LEAP Structure

Long-range Energy Alternative Planning Sistem (LEAP) is an integrated modelling tool to track the energy consumption, production and resources extraction in all economic sector, which developed by Stockholm Environment Institute [7]. Not only simulating the supply and demand energy regulation, LEAP is also used for analyzing the impact from energy regulation implementation. Hence, the accounting framework will be used for analyzing implication of several scenario demand and supply application to reach the defined targets. Besides that, LEAP with its accounting framework also be used to explore primary energy resources, environmental impact, and social cost might be produced from several alternative scenario [8].

2.4.2. Methods in LEAP

Energy demand analysis in LEAP has a purpose to determine energy demand and costs that may direct related to energy consumption in a energy system model. Energy demand is being hierarchy flexible structure modeled. Energy demand can be categorized based on the user sector, energy user sub-sector, and also energy user technology type [8].

On the electricity supply side, LEAP simulates by two conditions, power generation expansion and power generation dispatch rules. Power generation expansion has a purpose to determine additional power generation capacity and power generation type as well as the said additional time to fulfill electricity energy demand. Meanwhile, the dispatch has a purpose to determine on how the power generation operated after completed [8].

The determination power generation capacity expansion could be defined by 2 (two) ways: exogenous and endogenous. Capacity expansion exogenously is manually defined by determining capacity and time for capacity additional and retirement. Meanwhile, power generation expansion endogenously is determined automatically by LEAP. LEAP will determine the capacity size and additional time in compliance with previously defined type of power generation. In determining capacity endogenously, the capacity produced by LEAP has a purpose to maintain defined reserve margin [8].

LEAP provides two power generation dispatch system methods: historical and power generation dispatch rules. Dispatch rule method in LEAP is available from most simple way by using the percentage from energy power generation, up to energy order and cost management method. LEAP is also simulating various power generation system with different dispatch method. For example, power generation from NRE resources uses dispatch based on power generation percentage, meanwhile other power generation uses merit order dispatch method [8].

2.4.3. Green House Gas (GHG) Emissions

Calculating GHG emissions from power generation activities could use emission factor available in LEAP software. One of the reference is emissions default factor IPCC Tier 1 [8].
Contributing gases to climate change has been identified in the IPCC assessment reports. IPCC Guidelines 2006 covers the gases cause longer GHG with value of Global Warming Potentials (GWPs) those have been identified di the Third IPCC Assessment Report (IPAA 2001a; IPCC 2001b) as follows [9]:

Table 3. IPCC Guideline 2006 Green House Gas

Name	Symbol(s)	In IPCC 1996 Guidelines	GWP available in TAR
Carbon Dioxide	CO_2	Yes	Yes
Methane	CH_4	Yes	Yes
Nitrous Oxide	N_2O	Yes	Yes
hydrofluorocarbons	HFCs (e.g., HFC-23 (CHF_3), HFC-134a (CH_2FCF_3), HFC-152a (CH_3CHF_2))	Yes	Yes
Perfluorocarbons	PFCs (CF_4, C_2F_6, C_3F_8, C_4F_{10}, c-C_4F_8, C_5F_{12}, C_6F_{14})	Yes	Yes
Sulphur Hexafluoride	SF_6	Yes	Yes
Nitrogen Trifluoride	NF_3		Yes
Trifluoromethyl Sulphur Pentafluoride	SF_5CF_3		Yes
Halogenated Ethers	e.g., $C_4F_9OC_2H_5$, $CHF_2OCF_2OC_2F_4OCHF_2$, $CHF_2OCF_2OCHF_2$		Yes
Other halocarbons	e.g., CF_3I, CH_2Br_2, $CHCl_3$, CH_3Cl, CH_2Cl_2 $C_3F_7C(O)C_2F_5$, C_7F_{16}, C_4F_6, C_5F_8, c-C_4F_8O		Yes

3. METHODOLOGY

The objective of this research is to projecting the electricity energy needs in North Sumatera Province from 2022 to 2050 and analyzing the share of NRE and the GHG emissions level produced. The above data will be analyzed by using Microsoft Excel and LEAP software.

Next step is to arrange scenario. The scenario model is used to projection model simulation from 2022 to 2050. The scenario will provided into two: Demand Scenario and Supply Scenario. The demand scenario is used to project the demand meanwhile the supply scenario is used to project power generation in North Sumatera Province.

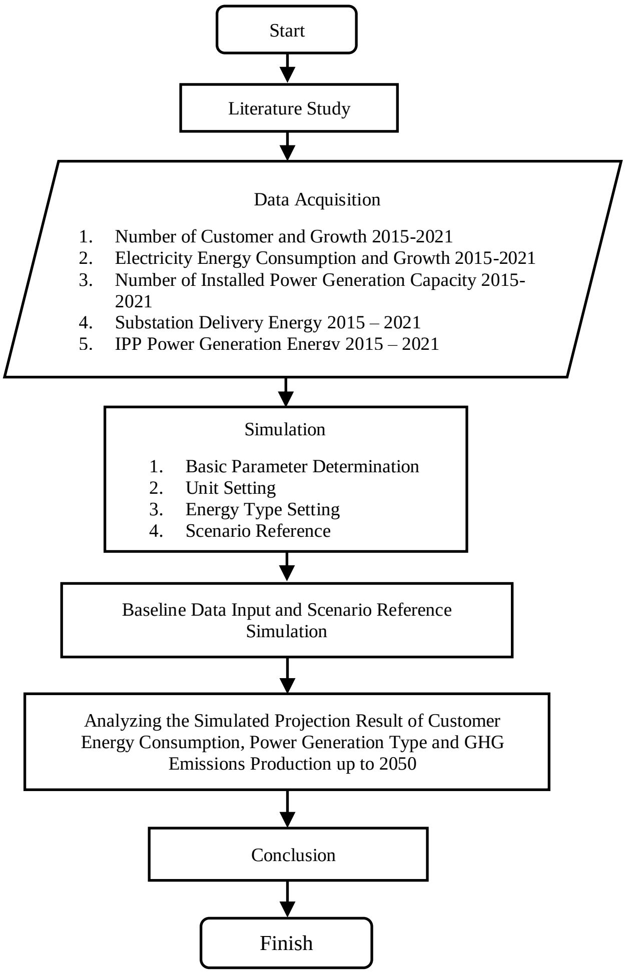

Figure 3. Framework Analysis of NRE Optimization in North Sumatera

Figure 4 shows the demand scenario divided into two: Business as Usual (BAU) and Policy (KEB) scenario. The BAU defines electricity energy demand using historic (following trend based on previous year data). On the other hand, KEB defines policy intervention such as people and economic growth as shown in the Table 4.

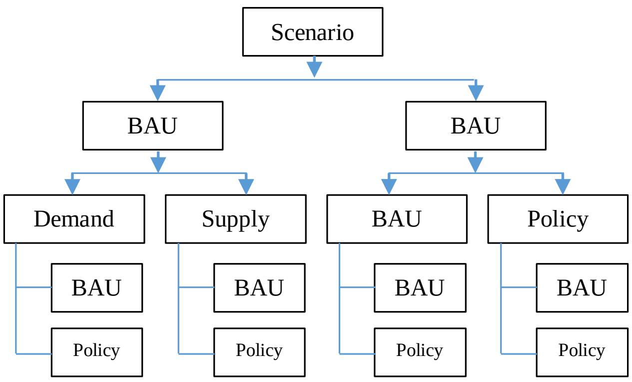

Figure 4. NRE Optimization Scenario Analysis

Table 4. Scenario Definition for BAU and KEB

No.	Parameter	Business As Usual (BAU)	Policy (KEB)
1	People Growth	Average Growth Period 2015-2021	RUPTL Projection 2021-2030
2	Economic Growth	Average Growth Period 2015-2021	RPJM Projection 2020-2024 and Target BPPT 2020-2025
3	Electrification Ratio	Achieve 100% as per target KEN	
4	Intensity	Average Intensity Period 2015-2021	- RUPTL Projection 2021-2030 - RUED Projection 2030-2050

The supply scenario is divided into two: Business as Usual (BAU) and Policy (KEB) scenario. The BAU defines additional capacity will follow reference additional capacity year (2015-2021) or the average reference energy shares of the power generation energy shares. Endogenously Power generation additional capacity process will take the energy shares amount from reference year type and capacity adjusted to electricity energy demand, where the simulation will be carried out by LEAP (Long-range Energy Alternative Planning System) program. Meanwhile, the Policy scenario defines exsogenously additional power generation capacity will calculate the size and type of power generation and also the operational date and retirement determined by RUPTL, and endogenously additional power generation capacity during period of 2031 to 2050 determined by RUED as shown in Table below:

Table 5. Supply Scenario Definition

Parameter	Business As Usual (BAU)	Policy (KEB)
Power Generation Capacity	Following tred of period 2015-2021 - Average Percentage of Power Generation Energy Shares 2015-2021 - Endogenous Power Generation Addition	Target: - Exsogenous Additional Capacity as per RUPTL period of 2021-2030 - Endogenous Additional Capacity as per RUED period of 2030-2050

Next step is simulating the demand and supply side by creating eight sub-scenarios representing results from three parameters: demand, supply, and losses. The calculation to losses is based on the 20 kV distribution line in 2021 and the target of losses reduction in 2050. The scenario is as shown in Table below:

Table 6. Scenario Simulating Demand, Supply and Losses

Scenario	Demand	Supply	Losses
BAU_MOA	BAU	BAU	7%
BAU_LOA	BAU	BAU	5% in 2050
BAU_KMOA	BAU	Policy	7%
BAU_KLOA	BAU	Policy	5% in 2050
RUPTL_MOA	Policy	BAU	7%
RUPTL_LOA	Policy	BAU	5% in 2050
RUPTL_KMOA	Policy	Policy	7%
RUPTL_KLOA	Policy	Policy	5% in 2050

The projection result from eight scenario above will be further analyzed to obtain both energy shares and GHG emissions. The calculation to GHG emissions will be carried out by LEAP through GHG Emissions Library IPCC Tier 1 existing in LEAP program. The result of analysis will represent the balance of both supply and supply of electricity energy, power generation, primary energy shares as well as GHG emissions data. Further explanation to each scenario energy shares to GHG emissions production will be provided.

Data analysis method to analyze research data is carried out by using software Microsoft Excel LEAP (Long-range Energy Alternative Planning System). The Policy (KEB) scenario, where NRE optimization is carried out from supply side, is expected to give more NRE shares and least GHG emission production.

4. RESULTS AND DISCUSSION

4.1. Energy Shares Results

The calculation of energy shares on BAU Scenario is as shown by four sub-scenario as follows:

4.1.1. Business As Usual (BAU) Scenario

A. BAU_MOA Scenario

In this scenario, both demand and supply pattern are determined and complied with BAU pattern and losses 7% per-year will remain unchanged during period of 2022-2050 as per Table 6. Power plant operation parameter will comply with the pattern where the existing Diesel, some Gas Engine and other designed peak power plant will be operated as peak load service. Meanwhile the other power plant will serve baseload. The result of NRE energy shares in this scenario compared to RUED is shown as follows:

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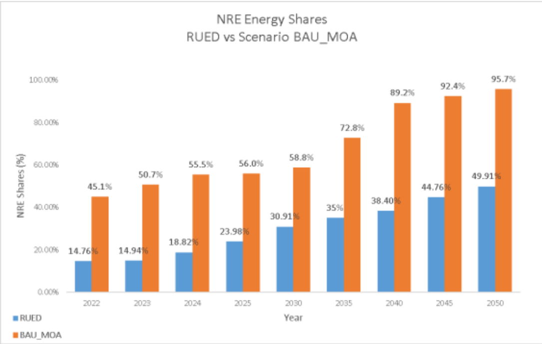
Table 7. NRE Energy Shares Comparison Between BAU_MOA and RUED

NRE Energy Shares	Year								
	2022	2023	2024	2025	2030	2035	2040	2045	2050
RUED	14.76%	14.94%	18.82%	23.98%	30.91%	35%	38.40%	44.76%	49.91%
BAU_MOA	45.1%	50.7%	55.5%	56.0%	58.8%	72.8%	89.2%	92.4%	95.7%

(a)



(b)

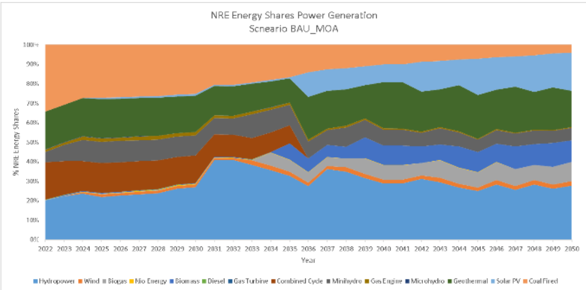


Figure 5. NRE Energy Shares Power Generation Scenario BAU_MOA

It could be observed that in this BAU_MOA scenario, the power generation operating in compliance to Merit Order to fulfill energy demand growth, followed by losses 7% to achieve NRE energy shares more than to RUED target annually. This scenario has a big potential opportunity to reach NRE energy shares even more than RUED target.

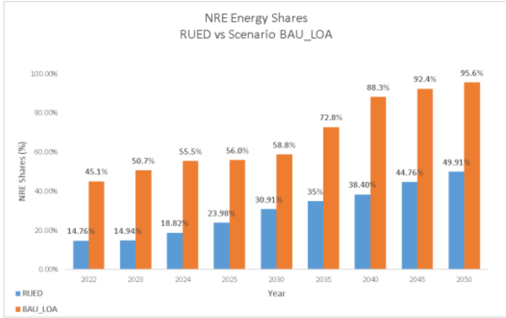
B. BAU_LOA Scenario

In this scenario, both demand and supply pattern are determined and complied with BAU pattern and losses 7% in 2022 will be reduced linier to 5% in 2050 as per Table 6. Power plant operation parameter will comply with the pattern where the existing Diesel, some Gas Engine and other designed peak power plant will be operated as peak load service. Meanwhile the other power plant will serve baseload. The result of NRE energy shares in this scenario compared to RUED is shown as follows:

Table 8. NRE Energy Shares Comparison Between BAU_LOA and RUED

NRE Energy Shares	Year								
	2022	2023	2024	2025	2030	2035	2040	2045	2050
RUED	14.76%	14.94%	18.82%	23.98%	30.91%	35%	38.40%	44.76%	49.91%
BAU_LOA	45.1%	50.7%	55.5%	56.0%	58.8%	72.8%	88.3%	92.4%	95.6%

(a)



(b)

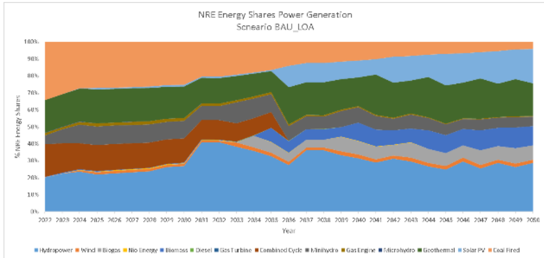


Figure 6. NRE Energy Shares Power Generation Scenario BAU_LOA

It could be observed that in this BAU_LOA scenario, the power generation operating in compliance to MeritOrder to fulfill energy demand growth, followed by decreasing losses 7% to 5% in order to achieve NRE energy shares more than to RUED target annually. This scenario has a big potential opportunity to reach NRE energy shares even more than RUED target.

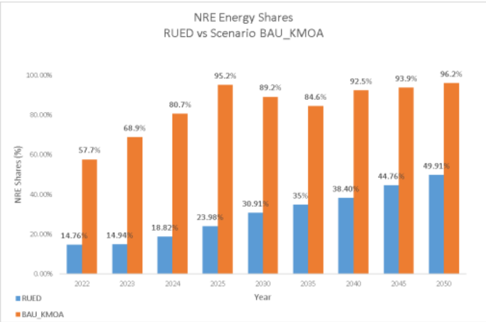
C. BAU_KMOA Scenario

In this scenario, demand pattern is determined complying with BAU pattern. Meanwhile the supply pattern is determined complying with KEB pattern and losses 7% per-year will remain unchanged during period of 2022-2050 as per Table 6. Power plant operation parameter will comply with the pattern where the existing Diesel, some Gas Engine and other designed peak power plant will be operated as peak load service. In addition, NRE Power plant will operation in Full Capacity. The result of NRE energy shares in this scenario compared to RUED is shown as follows:

Table 9. NRE Energy Shares Comparison Between BAU_KMOA and RUED

Share EBT	Tahun								
	2022	2023	2024	2025	2030	2035	2040	2045	2050
RUED	14.76%	14.94%	18.82%	23.98%	30.91%	35%	38.4%	44.76%	49.91%
BAU_KMOA	57,7%	68,9%	80,7%	95,2%	89,2%	84,6%	92,5%	93,9%	96,2%

(a)



(b)

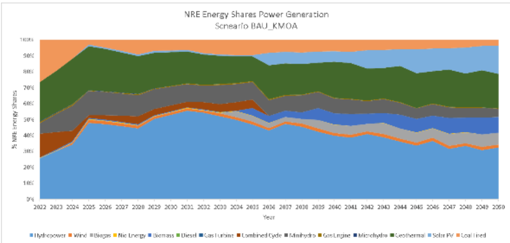


Figure 7. NRE Energy Shares Power Generation Scenario BAU_KMOA

It could be observed that in this BAU_KMOA scenario, the NRE power generation operating in Full Capacity to fulfill energy demand growth, followed by losses 7% in order to achieve NRE energy shares more than to RUED target annually. This scenario has a big potential opportunity to reach NRE energy shares even more than RUED target.

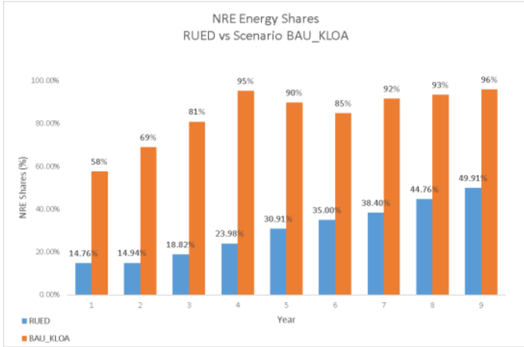
D. BAU_KLOA Scenario

In this scenario, demand pattern is determined complying with BAU pattern. Meanwhile the supply pattern is determined complying with KEB pattern and losses 7% in 2022 will be reduced linier to 5% in 2050 as per Table 6. Power plant operation parameter will comply with the pattern where the existing Diesel, some Gas Engine and other designed peak power plant will be operated as peak load service. In addition, NRE Power plant will operation in Full Capacity. The result of NRE energy shares in this scenario compared to RUED is shown as follows:

Table 10. NRE Energy Shares Comparison Between BAU_KLOA and RUED

NRE Energy Shares	Year								
	2022	2023	2024	2025	2030	2035	2040	2045	2050
RUED	14.76%	14.94%	18.82%	23.98%	30.91%	35.00%	38.40%	44.76%	49.91%
BAU_KLOA	58%	69%	81%	95%	90%	85%	92%	93%	96%

(a)



(b)

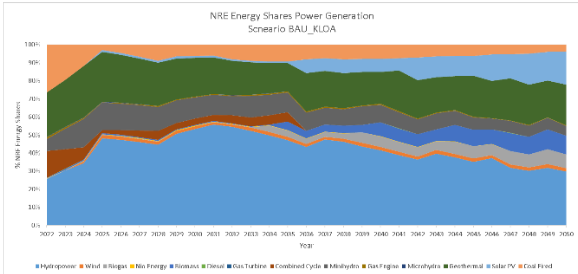


Figure 8. NRE Energy Shares Power Generation Scenario BAU_KLOA

It could be observed that in this BAU_KLOA scenario, the NRE power generation operating in Full Capacity to fulfill energy demand growth, followed by decreasing losses 7% to 5% in order to achieve NRE energy shares more than to RUED target annually. This scenario has a big potential opportunity to reach NRE energy shares even more than RUED target.

4.1.2. Policy Scenario (KEB)

The calculation of energy shares on KEB Scenario is as shown by four sub-scenario as follows:

A. RUPTL_MOA Scenario

In this scenario, demand pattern is determined complying with KEB pattern. Meanwhile the supply pattern is determined complying with BAU pattern and losses 7% per-year will remain unchanged during period of 2022-2050 as per Table 6. Power plant operation parameter will comply with the pattern where the existing Diesel, some Gas Engine and other designed peak power plant will be operated as peak load service. Meanwhile the other

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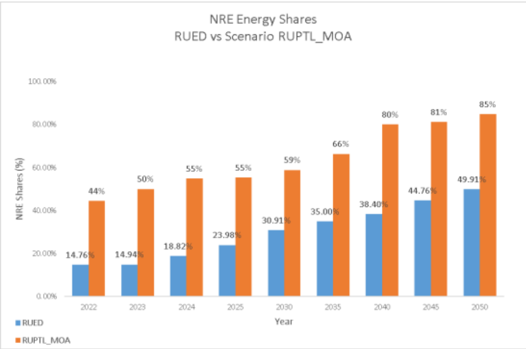
power plant will serve baseload. The result of NRE energy shares in this scenario compared to RUED is shown as follows:

Table 11. NRE Energy Shares Comparison Between RUPTL_MOA and RUED

NRE Energy Shares	Year								
	2022	2023	2024	2025	2030	2035	2040	2045	2050
RUED	14.76%	14.94%	18.82%	23.98%	30.91%	35.00%	38.40%	44.76%	49.91%
RUPTL_MOA	44%	50%	55%	55%	59%	66%	80%	81%	85%

(a)



(b)

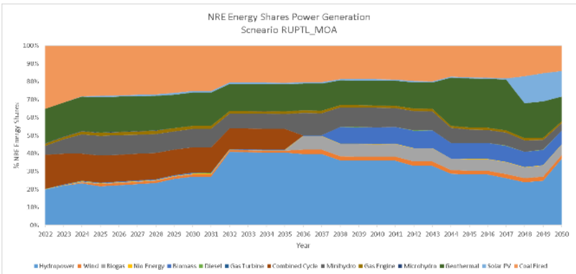


Figure 9. NRE Energy Shares Power Generation Scenario RUPTL_MOA

It could be observed that in this RUPTL_MOA scenario, the power generation operating in compliance to Merit Order to fulfill energy demand growth, followed by losses 7% in order to achieve NRE energy shares more than to RUED target annually. This scenario has a big potential opportunity to reach NRE energy shares even more than RUED target.

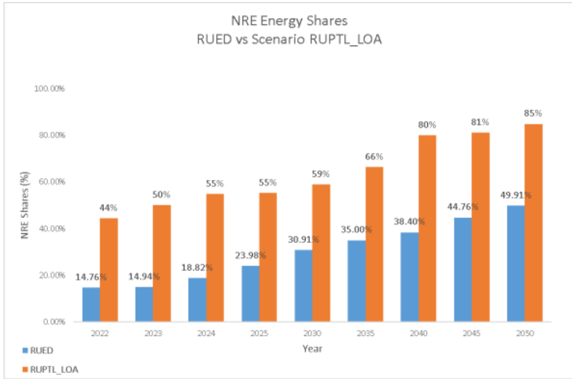
B. RUPTL_LOA Scenario

In this scenario, demand pattern is determined complying with KEB pattern. Meanwhile the supply pattern is determined complying with BAU pattern and losses 7% in 2022 will be reduced linier to 5% in 2050 as per Table 6. Power plant operation parameter will comply with the pattern where the existing Diesel, some Gas Engine and other designed peak power plant will be operated as peak load service. Meanwhile the other power plant will serve baseload. The result of NRE energy shares in this scenario compared to RUED is shown as follows:

Table 12. NRE Energy Shares Comparison Between RUPTL_LOA and RUED

NRE Energy Shares	Year								
	2022	2023	2024	2025	2030	2035	2040	2045	2050
RUED	14.76%	14.94%	18.82%	23.98%	30.91%	35.00%	38.40%	44.76%	49.91%
RUPTL_LOA	44%	50%	55%	55%	59%	66%	80%	81%	85%

(a)



(b)

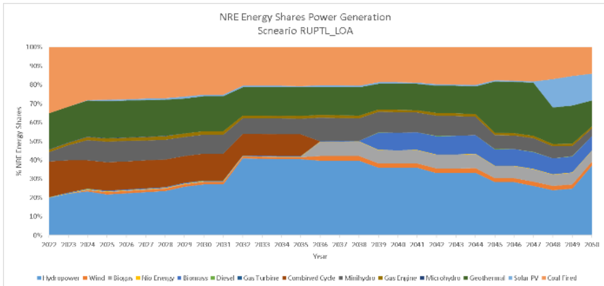


Figure 10. NRE Energy Shares Power Generation Scenario RUPTL_LOA

It could be observed that in this RUPTL_LOA scenario, the power generation operating in compliance to Merit Order to fulfill energy demand growth, followed by decreasing losses 7% to 5% in order to achieve NRE energy shares more than to RUED target annually. This scenario has a big potential opportunity to reach NRE energy shares even more than RUED target.

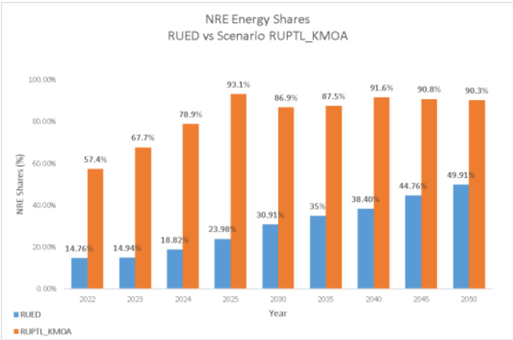
C. RUPTL_KMOA Scenario

In this scenario, both demand and supply pattern are determined complying with KEB pattern and losses 7% per-year will remain unchanged during period of 2022-2050 as per Table 6. Power plant operation parameter will comply with the pattern where the existing Diesel, some Gas Engine and other designed peak power plant will be operated as peak load service. In addition, NRE Power plant will operation in Full Capacity. The result of NRE energy shares in this scenario compared to RUED is shown as follows:

Table 13. NRE Energy Shares Comparison Between RUPTL_KMOA and RUED

NRE Energy Shares	Year								
	2022	2023	2024	2025	2030	2035	2040	2045	2050
RUED	14.76%	14.94%	18.82%	23.98%	30.91%	35%	38.40%	44.76%	49.91%
RUPTL_KMOA	57.4%	67.7%	78.9%	93.1%	86.9%	87.5%	91.6%	90.8%	90.3%

(a)



(b)

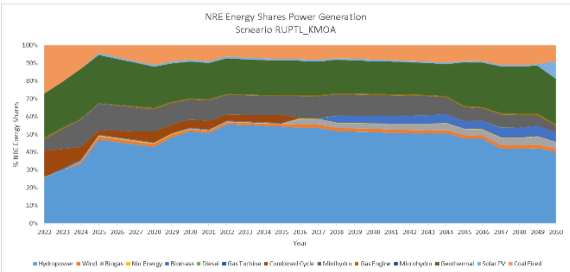


Figure 11. NRE Energy Shares Power Generation Scenario RUPTL_KMOA

It could be observed that in this RUPTL_KMOA scenario, the NRE power generation operating in Full Capacity to fulfill energy demand growth, followed by losses 7% in order to achieve NRE energy shares more than to RUED target annually. This scenario has a big potential opportunity to reach NRE energy shares even more than RUED target.

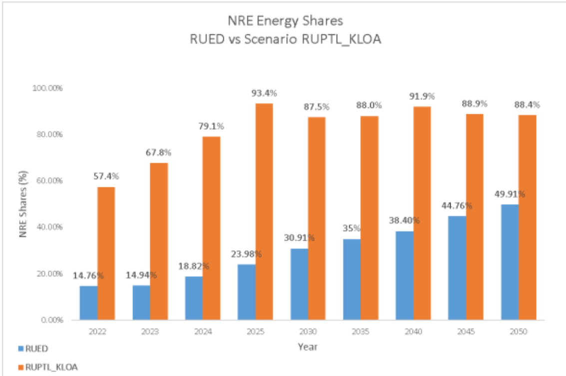
D. RUPTL_KLOA Scenario

In this scenario, both demand and supply pattern are determined complying with KEB pattern and losses 7% in 2022 will be reduced linier to 5% in 2050 as per Table 6. Power plant operation parameter will comply with the pattern where the existing Diesel, some Gas Engine and other designed peak power plant will be operated as peak load service. In addition, NRE Power plant will operation in Full Capacity. The result of NRE energy shares in this scenario compared to RUED is shown as follows:

Table 14. NRE Energy Shares Comparison Between RUPTL_KLOA and RUED

NRE Energy Shares	Year								
	2022	2023	2024	2025	2030	2035	2040	2045	2050
RUED	14.76%	14.94%	18.82%	23.98%	30.91%	35%	38.40%	44.76%	49.91%
RUPTL_KLOA	57.4%	67.8%	79.1%	93.4%	87.5%	88.0%	91.9%	88.9%	88.4%

(a)



(b)

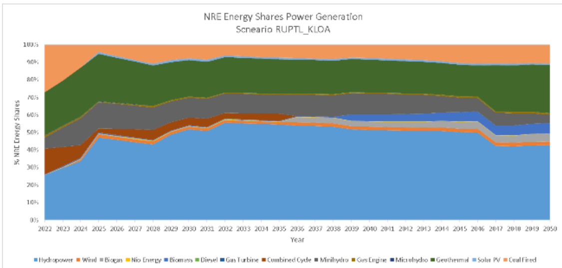


Figure 12. NRE Energy Shares Power Generation Scenario RUPTL_KLOA

It could be observed that in this RUPTL_KLOA scenario, the NRE power generation operating in Full Capacity to fulfill energy demand growth, followed by decreasing losses 7% to 5% in order to achieve NRE energy shares more than to RUED target annually. This scenario has a big potential opportunity to reach NRE energy shares even more than RUED target.

4.2. GHG Emissions Results

The calculation of GHG Emissions on BAU Scenario is as shown by four sub-scenario as follows:

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A. BAU_MOA Scenario

In this scenario, the highest GHG emissions production is in 2030 with 6.167 Million Ton CO_2 or 30% of RUED projected Emissions, and the lowest is in 2050 with 3.235 Million Ton CO_2 or 12% from RUED projected emissions. The GHG Emissions simulation result compared to RUED projection is as shown below:

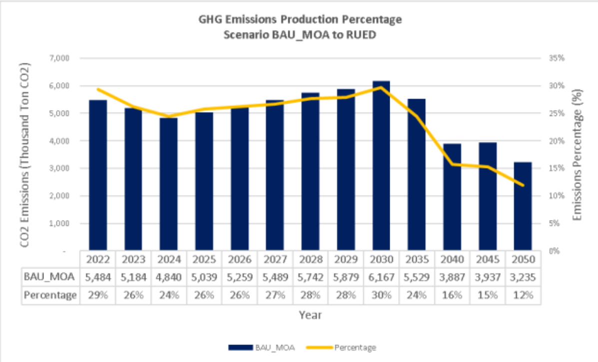

Figure 13. GHG Emissions Production Percentage Scenario BAU_MOA to RUED

The increasing portion NRE in power generation shares affects to declining rate of CO_2 emissions. In this BAU_MOA scenario, the average GHG emissions production during period of 2022-2050 is 24% from RUED emissions projection. This emissions rate is still far below RUED emissions projection.

B. BAU_LOA Scenario

In this scenario, the highest GHG emissions production is in 2030 with 6.13 Million Ton CO_2 or 30% of RUED projected Emissions, and the lowest is in 2050 with 3.26 Million Ton CO_2 or 12% from RUED projected emissions. The GHG Emissions simulation result compared to RUED projection is as shown below:

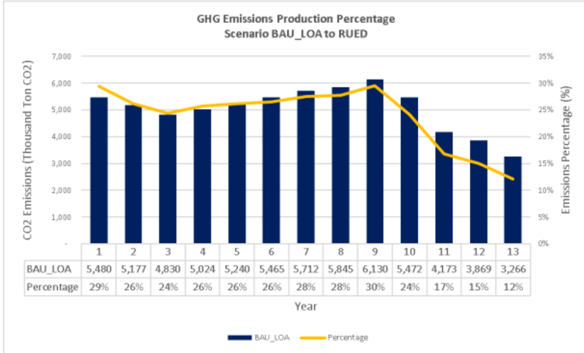

Figure 14. GHG Emissions Production Percentage Scenario BAU_LOA to RUED

The increasing portion NRE in power generation shares affects to declining rate of CO_2 emissions. In this BAU_LOA scenario, the average GHG emissions production during period of 2022-2050 is 24% from RUED emissions projection. This emissions rate is still far below RUED emissions projection.

C. BAU_KMOA Scenario

In this scenario, the highest GHG emissions production is in 2022 with 4.95 Million Ton CO_2 or 22% of RUED projected Emissions, and the lowest is in 2025 with 0.558 Million Ton CO2 or 3% from RUED projected emissions. The GHG Emissions simulation result compared to RUED projection is as shown below:

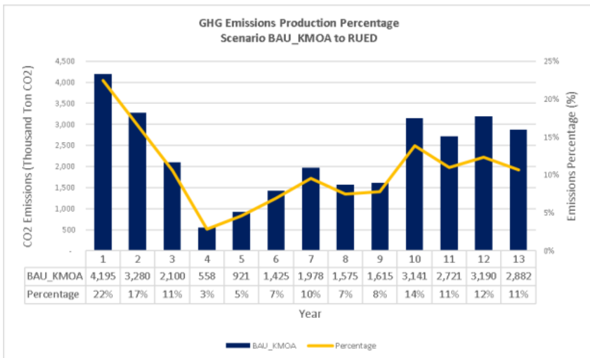

Figure 15. GHG Emissions Production Percentage Scenario BAU_KMOA to RUED

The increasing portion NRE in power generation shares affects to declining rate of CO_2 emissions. In this BAU_KMOA scenario, the average GHG emissions production during period of 2022-2050 is 11% from RUED emissions projection. This emissions rate is still far below RUED emissions projection.

D. BAU_KLOA Scenario

In this scenario, the highest GHG emissions production is in 2022 with 4.23 Million Ton CO_2 or 23% of RUED projected Emissions, and the lowest is in 2025 with 0.535 Million Ton CO2 or 3% from RUED projected emissions. The GHG Emissions simulation result compared to RUED projection is as shown below:

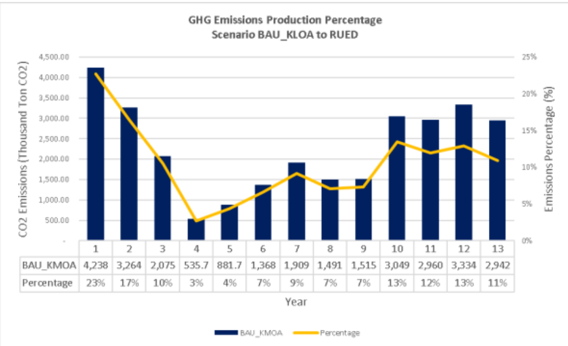

Figure 16. GHG Emissions Production Percentage Scenario BAU_KLOA to RUED

The increasing portion NRE in power generation shares affects to declining rate of CO_2 emissions. In this BAU_KLOA scenario, the average GHG emissions production during period of 2022-2050 is 10% from RUED emissions projection. This emissions rate is still far below RUED emissions projection.

4.6.1 Policy Scenario (KEB)

The calculation of GHG Emissions on KEB Scenario is as shown by four sub-scenario as follows:

A. RUPTL_MOA Scenario

In this scenario, the highest GHG emissions production is in 2030 with 6.31 Million Ton CO_2 or 30% of RUED projected Emissions, and the lowest is in 2050 with 3.55 Million Ton CO2 or 13% from RUED projected emissions. The GHG Emissions simulation result compared to RUED projection is as shown below:

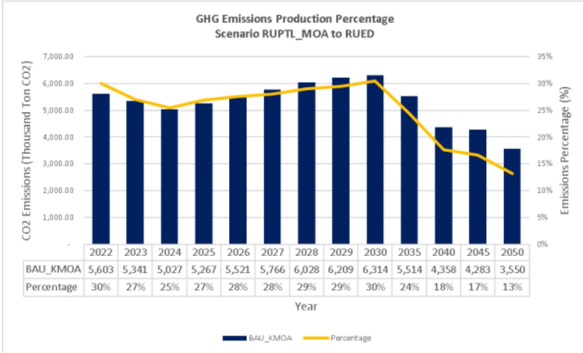

Figure 17. GHG Emissions Production Percentage Scenario RUPTL_MOA to RUED

The increasing portion NRE in power generation shares affects to declining rate of CO_2 emissions. In this RUPTL_MOA scenario, the average GHG emissions production during period of 2022-2050 is 25% from RUED emissions projection. This emissions rate is still far below RUED emissions projection.

B. RUPTL_LOA Scenario

In this scenario, the result is almost typical with scenario RUPTL_LOA, whereas the highest GHG emissions production is in 2030 with 6.27 Million Ton CO_2 or 30% of RUED projected Emissions, and the lowest is in 2050 with 3.47 Million Ton CO_2 or 13% from RUED projected emissions. The GHG Emissions simulation result compared to RUED projection is as shown below:

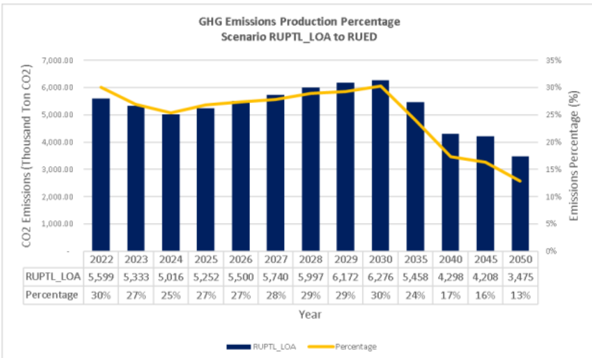

Figure 18. GHG Emissions Production Percentage Scenario RUPTL_LOA to RUED

The increasing portion NRE in power generation shares affects to declining rate of CO_2 emissions. In this RUPTL_LOA scenario, the average GHG emissions production during period of 2022-2050 is 25% from RUED emissions projection. This emissions rate is still far below RUED emissions projection.

C. RUPTL_KMOA Scenario

In this scenario, the highest GHG emissions production is in 2022 with 4.25 Million Ton CO_2 or 23% of RUED projected Emissions, and the lowest is in 2025 with 0.809 Million Ton CO_2 or 4% from RUED projected emissions. The GHG Emissions simulation result compared to RUED projection is as shown below:

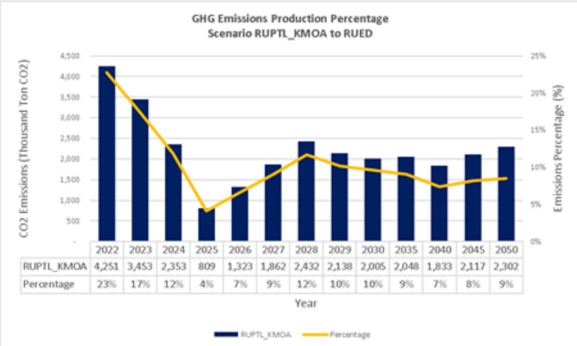

Figure 19. GHG Emissions Production Percentage Scenario RUPTL_KMOA to RUED

The increasing portion NRE in power generation shares affects to declining rate of CO_2 emissions. In this RUPTL_KMOA scenario, the average GHG emissions production during period of 2022-2050 is 11% from RUED emissions projection. This emissions rate is still far below RUED emissions projection.

D. RUPTL_KLOA Scenario

In this scenario, the highest GHG emissions production is in 2022 with 4.24 Million Ton CO_2 or 23% of RUED projected Emissions, and the lowest is in 2025 with 0.778 Million Ton CO_2 or 4% from RUED projected emissions. The GHG Emissions simulation result compared to RUED projection is as shown below:

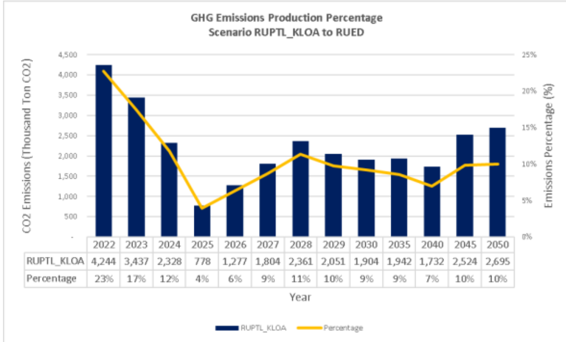

Figure 20. GHG Emissions Production Percentage Scenario RUPTL_KLOA to RUED

The increasing portion NRE in power generation shares affects to declining rate of CO_2 emissions. In this RUPTL_KLOA scenario, the average GHG emissions production during period of 2022-2050 is 11% from RUED emissions projection. This emissions rate is still far below RUED emissions projection.

5. CONCLUSION

The NRE energy shares in power generation in four scenarios: Business As Usual (BAU) and Policy (KEB) during period of 2022-2050 shows energy shares higher than the minimum projection in RUED.

Four scenarios under BAU Scenario show that the percentage of NRE energy shares and GHG Emissions are achievable during period of 2022-2025. The range of NRE shares is 45.1% up to 96.2%, and GHG Emissions production range is 3% - 30% from the Road Map.

Meanwhile, four scenarios under KEB Scenario show that the percentage of NRE energy shares and GHG Emissions are achievable during period of 2022-2025. The range of NRE shares is 44% up to 93.4%, and GHG Emissions production range is 4% - 30% from the Road Map. Some scenarios under BAU gives slightly higher NRE shares and GHG Emissions production saving since the higher growth of demand in BAU Scenarios is possible for more NRE power generation capacity in operation.

Future research might consider in calculating the financial and economic point of view from the operation of NRE power operation and also saving cost from GHG Emissions reduction.

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