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Primary Energy Demand Forecasting for Indonesia Railway using Software LEAP

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ABSTRACT

Development of Indonesia's Railway according to National Railway Vision 2030 (RIPNAS 2030), stipulated railway electrification expected to increase about 90% for the whole intercity railway network, however 89.2% railway network still use diesel train. This study would see the forecasting primary energy demand up to 2050 with two business-as-usual (BaU) scenarios, without any introducing the implementation of electrification plan, with latest data assumption year range 2019-2015. LEAP software was used to simulate or modelling Business as Usual in this study to forecast the primary energy demand of railways with coverage throughout Indonesia. The 1st BaU with Unit Grow scenario shows total energy demands of diesel, diesel-electric and electric trains of 0.268 million TOE in 2020, 0.602 million TOE by 2030 and 15.467 million TOE by 2050. Meanwhile The 2nd BaU Simulation results showed the total energy demand of diesel and electric trains amounted to 0.264 million TOE in 2020, then 0.411 million TOE in 2030 and continue growing to 1.201 million TOE by 2050. The result of energy demand shown high percentage for BaU with Unit GrowScenario because of assumption variable use with fast 12,1% growth of Electric Train Unit. Hence in 2050 with BaU with Unit Grow Scenario gives 95% of Indonesia Railway dominated by Electric Train in energy demand.

Key words: Primary Energy, Business as Usual Scenario, Indonesia Railway, Energy Forecasting, Software LEAP

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1. INTRODUCTION

Indonesia as a developing country requires infrastructure advancement massively, particularly in the transportation sector, purposely for boosting economic growth. Approximately 45,6 million TOE of energy demand in Indonesia is attributable to the transportation sector in 2018 and Indonesia has oil import ratio shown 35% in 2018 [1]. Railway in Indonesia contributed as one transportation sector which provides efficient and low emission modehowever,currently it has a track length about 8 thousand km and 10.8% each of it already electrified [2]. This total track length still lower compared with India and Japan with length 60 thousand km and 20 thousand kmas well as electrified track [3].

2. RATIONALE FOR STUDY

Development of Indonesia's Railway according to National Railway Plan2030 (RIPNAS 2030), stipulated railway electrification expected to increase about 90% for the whole intercity railway network [4]. As consequences, increasing electrification would decrease fossil energy demand and vice versa. In 2016 and 2018 Indonesia oil refinery capacity in total able to produce 338 Mil BOE and 283 Mil BOE, with projection oil production approximately 85 Mil BOE or 12,4 Mil TOE in 2050 [5, 6]. This decrease of fossil energy demand potentially reachable if the plan for electrification through National Railway plan 2030 successfully implemented. This study would see the forecasting primary energy demand up to 2050 with two business-as-usual scenarios only, without any introducing the implementation of electrification plan, with latest data assumption basis year 2019-2015 which may different to other study. Former studieshave shown energy demand forecast for railway Division I South Sumatra shows a 26% increase when running with business as usual (BAU) scenarios from 0.19 million TOE in 2019 to 0.244 million TOE in 2025 [7]. The forecast of energy demand for Operation Area IV (DAOP IV) Semarang, Central Java Province, Indonesiagives total energy demand 0,5 million TOE in 2030 with basis year 2014 [8].

3. METHODS

LEAP software developed by the Stockholm Environment Institute[9] was used to simulate or modellingBusiness as Usual in this study to forecast the primary energy demand of railways with coverage throughout Indonesia. The data used is the primary data of the number of Diesel train units, the number of Diesel-electric trains (DMU or KRDI), the number of Electric trains (EMU or KRL) obtained from Indonesia Railway Company (PT KAI) and Commuter Railway Indonesia (PT KCI) from 2015 to 2019.The basic year used is 2019 and ends in the simulation year 2050. The Annual Growth Rate of Mileage and Unit numberare calculated using the formula below [10].

$$a_g = \left(\frac{E_{T1}}{E_{T0}}\right)^{1/(T1-T0)} - 1$$

ag = Annual average growth rate over a period.

ET_1= Energy demand in period T_1

ET_0= Energy demand in period T_0

The scenarios and assumptions used for simulation are as follows:

Scenario Business as Usual with Unit Growth Variable or BaU with Unit Grow. This scenario will use all assumption of all Unit and Km Driven from 2015-2019. Some assumption gives negative annual growth percentage because of the fluctuation of itsactual data. All annual growth given as below in table 1.

Table -1 Assumption used for Scenario Business as Usual (BaU) with Unit Growth

Assumptions	Annual Growth
Diesel Locomotive Number	-0,1%
Ave Km Driven Diesel Locomotive p.a.	4,47%
Diesel Electric Train Number	-7,1%
Ave Km Driven Diesel Electric Train p.a.	-6,2%
Electric Train Number	12,1%
Ave Km Driven Electric Train p.a.	9%

Scenario Business as Usual or Business as Usual (BaU). This scenario only considers km driven for each type of locomotives without unit growth variable assumption used. All annual growthsgiven as below in table 2.

Table -2 Assumption used for Scenario Business as Usual (BaU)

Assumptions	Annual Growth
Total Km Driven Diesel Locomotive p.a.	4,35%
Total Km Driven Diesel Electric Train p.a.	-12,9%
Total Km Driven Electric Train p.a.	9%

4. RESULTS AND DISCUSSION

The simulation result of Business-as-Usual Scenario with Unit Grow (BaU with Unit Grow)is shown by Figure 1. The BaU with Unit Grow scenario shows total energy demands of diesel, diesel-electric and electric trains of 0.268 million TOE in 2020 than 0.602 million TOE by 2030 and 15.467 million TOE by 2050 as shown in Table 3.

Table -3 Total energy demands of diesel, diesel-electric and electric trains (in Mil TOE)

Type of Train	2019	2020	2030	2050
Diesel Electric	0.018	0.016	0.004	0.0003
Diesel Train	0.207	0.216	0.331	0.778
Electric Train	0.029	0.036	0.267	14.688
Total	0.255	0.268	0.602	15.467

When compared with simulation results for other countries, the simulation results of energy demand for Indonesia with BaU with Unit Growscenario in 2050 which is 15.467 million TOE, which are close to the estimated North American railway energy demandabout16 million TOE in 2050. However it is still under the energy demand for railways in China of 24.3 million TOE in 2050[11]. The simulation energy demand forecasting conducted by Agency for The Assessment and application of Technology (BPPT) gave the baseline for electric train around 0,07 mil TOE or 811 GWh projection in 2050 considered the Efficiency of train, regenerative braking etc in the assumption[5], meanwhile in this simulation resulted 170,882 GWh in 2050 with assumption the growth of Electric train very fast by 12,1% annual growth and without any efficiency initiative.

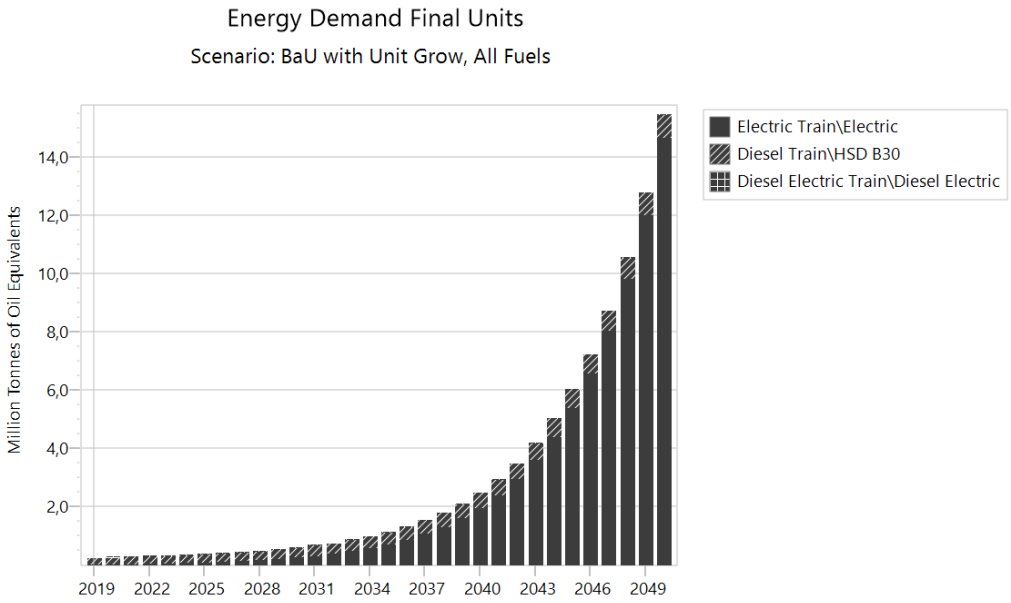

Fig. 1 Energy Demand up to 2050 for Scenario BaU with Unit Growth

The mix of energy demand in the basic year 2019 was 81.2% and 7.2% (in total 88.4%) was dominated by fossil energy, namely diesel fuels in basic year, while the electricity consumption for electric train demand was only 11.6%. This is different from the simulation results at the end of the simulation year in 2050, electricity energy demanddominates 95% of railwayenergy demand in Indonesia as shown in Fig 2.

The simulation results of the Business as Usual (BaU) Scenario are shown with Fig 3. This BaU (Business as Usual) scenario uses the assumption that the number of trains for each diesel and electric train remains same until 2050,however the assumption used is mileage annual growth of 4% for diesel trains and 9% for electric train. Simulation results showed the total energy demand of diesel and electric trains amounted to 0.264 million TOE in 2020, then 0.411 million TOE in 2030 and continue growing to 1.201 million TOE by 2050.

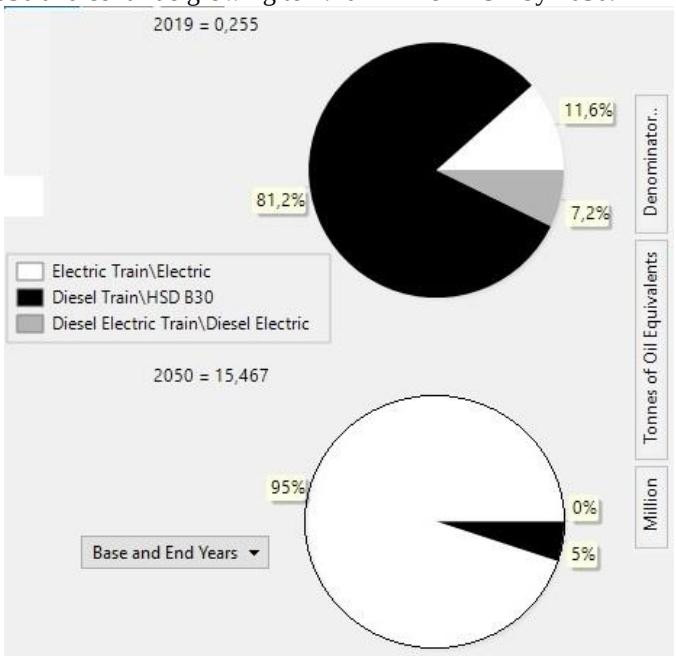

Fig. 2 Mix of Energy Demand up to 2050 for Scenario BaU with Unit Growth

Table -4 Total energy demands of diesel, diesel-electric and electric trains (in Mil TOE)

Type of Train	2019	2020	2030	2050
Diesel Electric Train	0.018	0.016	0.004	0.0003
Diesel Train	0.207	0.216	0.331	0.775
Electric Train	0.029	0.032	0.076	0.426
Total	0.255	0.264	0.411	1.201

When compared with simulation results for other countries. the results of the simulation of energy demand for Indonesia with BaU scenario in 2050 of 1.201 million TOEshown in Fig 3, shows half the energy demand of Japanese railways of 2.4 million TOE in 2050 and China will require 20 times energy of 24.3 million TOE than Indonesia's energy demand in 2050 [11].

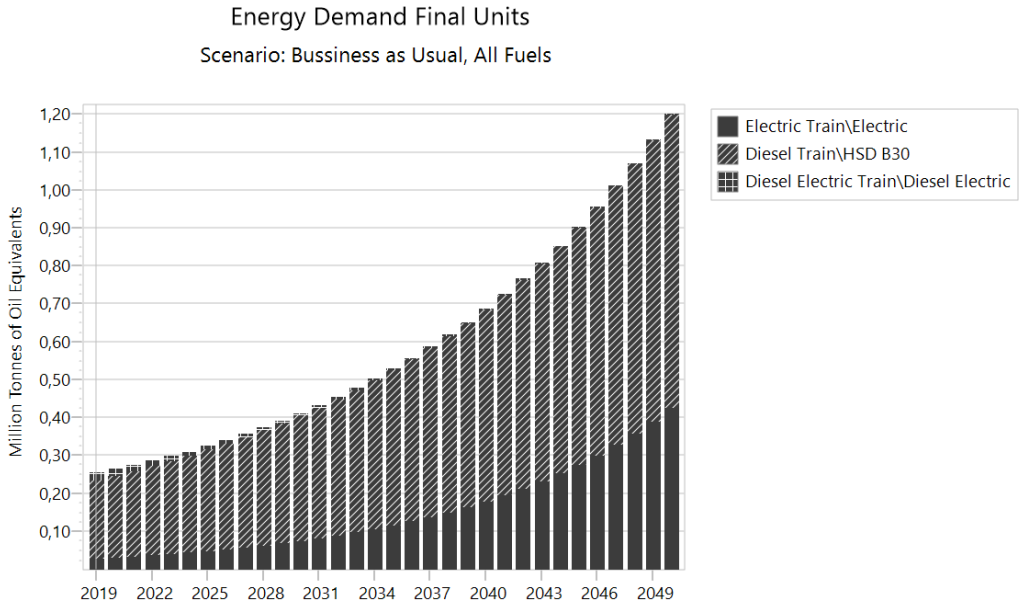

Fig. 3 Energy Demand up to 2050 for Scenario BaU

The mix of energy demand in the basic year 2019 was 81.2% and 7.2% (in total 88.4%) was dominated by fossil energy, namely diesel fuels, while the electricity consumption for electric railway demand was only 11.6%. This is different from the simulation results at the end of the simulation yearin 2050, electricity demand changed to 35.5% of the total railway energy demand in Indonesia. While the fossil energy needs of diesel fuel decreased by 16.7% to 64.5%.

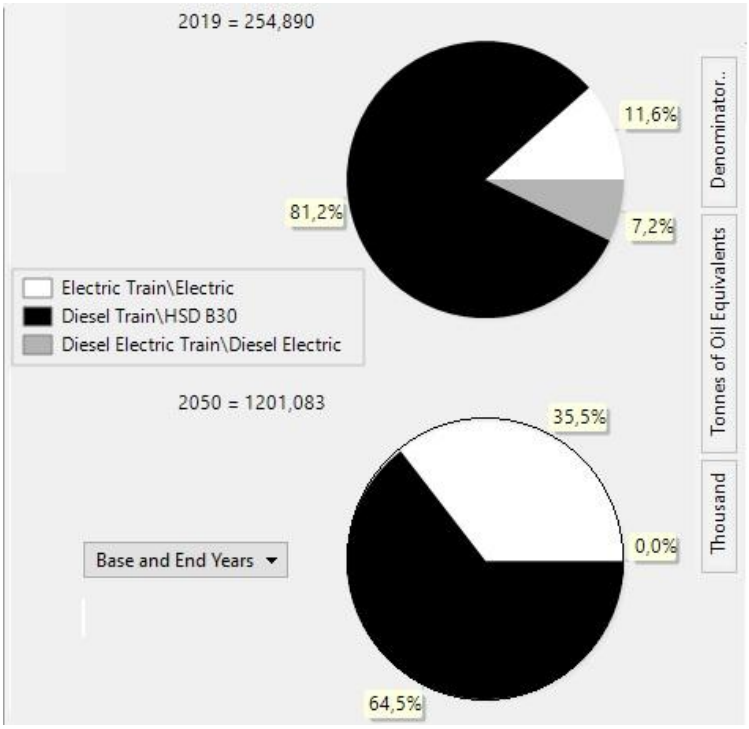

Fig. 4 Mix of Energy Demand up to 2050 for Scenario BaU

This study still has area to be covered for improvement with regard emission calculation and simulation with other possible scenarios with latest data available.

5. CONCLUSION

The Scenario BaU with Unit Growth gave the extremely high of 95% mostly for electric energy demand outlook for Indonesia railway up to 2050, in which circumstance and energy projection, Country must satisfy energy demand for both fossil fuel (diesel)and Electricity demand. The other scenario i.e. Business as Usual (BaU) resulted percentage of energy mix fossil fuel and electricity are 64,5% and 35,5% which Country still has effort to accommodate the demand by increase refinery capacity and reduce import ratio.

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