***Technoeconomic Analysis of Indonesia Generation Expansion to Achieve Energy and Economic Sustainability***

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## Overview

## Indonesia is the largest energy consumer in Southeast Asia, accounting for more than 36% of the region's energy demand and consuming 66% more energy than Thailand, the second-largest consumer (IEA, 2019). In response to continued economic and demographic drivers, electricity demand will grow steadily and power generating infrastructure in Indonesia will need substantial investment to support Indonesia's economic growth. Indonesia’s total power generating capacity currently stands at around 63.1 GW (PLN, 2020), but even the existing capacity still struggles to keep up with the demand and blackouts remain common across Sumatera, Kalimantan, Sulawesi and Eastern Indonesia. The Government of Indonesia since 2015 has implemented a 35,000 MW program to address the ever-increasing demand for electricity. However, based on the power plant construction status, the deployment of 35,000 MW of new generating capacity is delayed for several projects (PLN, 2019a). Furthermore, over the past year it has become apparent that power generating capacity is generally surplus for more than 30% reserve margin (DEN, 2020), with the largest grid being that of Java- Bali (PLN, 2019b). The electricity surplus is due to several large power plants successfully commissioned. Moreover, COVID-19 pandemic resulted in the reduced electricity demand from business and industry (Iqlima Fuqoha and Kresnawan, 2021). Currently, fossil energy power plants are the most widely built in the 35,000 MW program (Kurniawan et al., 2020). However, renewable energy research and development have made renewable energy investment cost cheaper than fossil energy so that renewable energy can be one of the options to achieve 35,000 MW power plant target (IRENA, 2020). The government aims to have at least 23% of total electricity from renewable energy by 2025 and 28% in 2038, align with the Indonesia’s Nationally Determined Contribution (NDC) for Paris Agreement on Climate Change (MEMR, 2016). The target is so ambitious that Indonesia will need accurate long-term energy planning to achieve the renewable energy target (IRENA, 2017). From an economic point of view, renewable energy generators' addition amid a surplus in generating capacity will be an inefficient investment (Schernikau, 2020). Especially, as renewable energy such as solar and wind power have intermittent characteristics, which requires in additional investment in the form of a generator or battery, causing a higher investment cost than other type of energy. Based on all the considerations above, this research aims to provide an insight for Indonesia long-term generation expansion planning for 2020 – 2050 period that is accurate and can meet renewable energy targets while remaining efficient in economic investment.

## Methods

This research use Low Emission Analysis Platform (LEAP) software, is a software tool for energy policy analysis and climate change mitigation assessment developed by Stockholm Environment Institute. LEAP used scenario-based modelling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. LEAP supports a wide range of different modelling methodologies: on the demand side these range from bottom-up, end-use accounting techniques to top-down macroeconomic modelling. On the supply side, LEAP provides a range of accounting, simulation and optimization methodologies that are powerful enough for modelling electric sector generation and capacity expansion planning, and which are also sufficiently flexible and transparent to allow LEAP to easily incorporate data and results from other more specialized models. The newest versions of LEAP also support optimization modelling: allowing for the construction of least cost models of electric system capacity expansion and dispatch, potentially under various constraints such as minimum renewable energy usage. The electricity demand and power generation data is based on the Indonesia’s National Electricity Plan (RUKN) 2019-2038 and PLN’s Electricity Supply Business Plan (RUPTL) 2019-2028, and other sources. The total cost of the power system is the total net present value of the system costs over the entire period of calculation. There are 2 scenario that will be simulated in this research; Reference scenario/BAU scenario (demand and power generation will be based on RUPTL 2019 – 2028, pre covid condition) and Post Covid-19 (demand will be adjust to post covid-19, while the power generation will be manually adjust to prioritize hydro and geothermal energy).

## Results

In the **Reference** scenario, the total projected electricity demand will increase from 261.5 TWh in 2020 to 360.9 TWh in 2025. In 2038 and 2050, the electricity demand will be 773.8 TWh and 1561.2 TWh, respectively. The total power generation capacity added during 2020 – 2050 is 54.2 GW. The total power generation capacity in 2025 will be 107.6 GW, with the energy mix consist of hydro (11.26%), geothermal (6.14%), biomass (0.16%), pv (0.06%), wind and other renewable energy (2.37%), natural gas (25.18%), coal (47.14%), and oil (7.68%). The total power generation in 2038 will be 115.4 GW, with the energy mix consist of hydro (12.34%), geothermal (5.94%), biomass (0.15%), pv (0.06%), wind and other renewable energy (2.27%), natural gas (24.5%), coal (47.59%), and oil (7.16%). The renewable energy percentage in 2025 and 2038 is 20% and 20.75%. The overcapacity of power generation in 2020 – 2028 causing the reserve margin growth up to 80% and so LEAP not added any capacity. The simulation show that beyond 2028 up to 2050, the total installed capacity is enough to supply the demand and keep a 35% reserve margin.

The total investment cost that will be need to fund the power generation expansion for 2020 – 2050 will be USD $ 509.9 Billion.

In the **Post Covid** scenario the total projected electricity demand decrease compare to reference (BAU) scenario, furthermore in this scenario, the LEAP simulation is set to maintain a 35% reserve margin since the first yeat of simulation. This scenario also purposely set to achieve the 2025 and 2038 renewable target.The demand in 2025 is 314.5 TWh while in 2038 will be 670.4 TWh. In 2050 the total demand will reach 1427.3 TWh. Based on the simulation, total power generation capacity in 2025 will be 66.4 GW, with the energy mix consist of hydro (10.22%), geothermal (5.56%), biomass (0.64%), pv (0.47%), wind and other renewable energy (0.57%), natural gas (29.28%), coal (51.52%), and oil (1.74%). The total power generation in 2038 will be 150.8 GW, with the energy mix consist of hydro (13.45%), geothermal (9.91%), biomass (1.77%), pv (1.7%), wind and other renewable energy (1.75%), natural gas (24.83%), coal (46.57%), and oil (0.02%). The renewable energy percentage in 2025 and 2038 is 17.46% and 28.58%. The total investment cost that will be need to fund the power generation expansion for 2020 – 2050 will be USD $ 482.4 Billion.

## Conclusions

Based on the simulation above we can see that Indonenesia current reserve margin is almost 80% as a result of reduced electricity demand and excess installed generating capacity. The 35000 MW program currently builds more coal plants, making it very difficult for Indonesia to achieve the renewable energy target of 21% by 2025. Meanwhile, for 2038, the renewable energy target of 28% is still very likely to be achieved. However, it is necessary to make massive efforts to replace diesel generators with renewable energy. Inappropriate planning in RUPTL, apart from causing the renewable energy target not to be achieved, also causes PLN to need more funds to invest in power plants. In the BAU scenario (which refers to RUPTL), a total cost of USD $ 509.9 billion is required until 2050 for the investment in power plants, whereas after proper planning the cost required is only USD $ 482.4 billion.

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