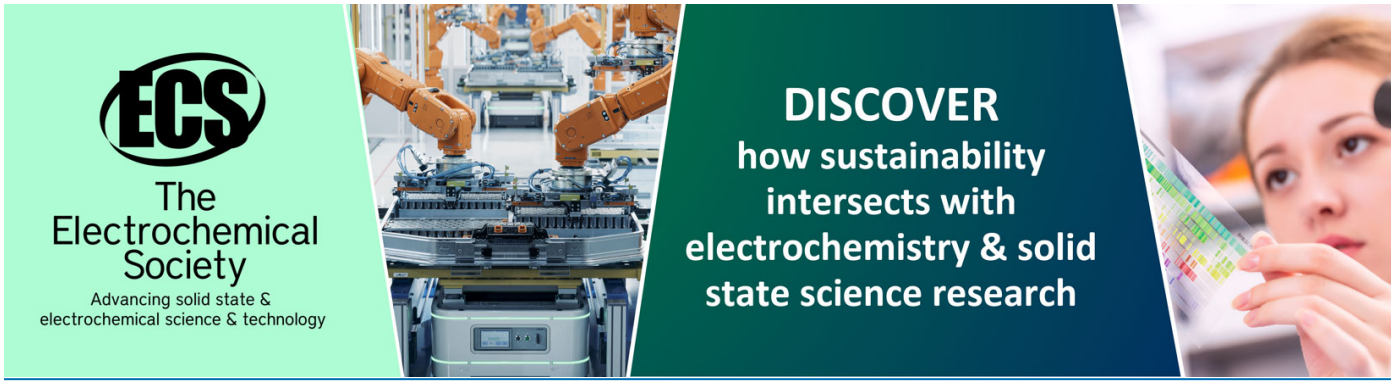
Demand and Electricity Energy Mix in Indonesia 2030 with Small Modular Reactor Nuclear Power Plant and Renewable Energy Scenario



Demand and Electricity Energy Mix in Indonesia 2030 with Small Modular Reactor Nuclear Power Plant and Renewable Energy Scenario

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Abstract. The interest in small modular reactors worldwide has been increasing due to flexibility in the power generation for more comprehensive users and applications. Small Modular Reactors or SMRs can be the primary choice for Indonesia provided with the geographical condition, which consists of many islands and is more flexible in construction compared to the conventional nuclear power plant. The main objective of this paper is to provide an overview projection of demand and energy mix of electrical in Indonesia 2030 with SMRs NPP in the energy mix referring to RUPTL or General Plan of Electricity Supply Indonesia. Using the end-use model, which is total electricity consumption for each electricity sector, it can be calculated how much electricity demand is from these sectors. The scenario uses RUPTL, roadmap from Energy and Mineral Resources Ministry references, and policy of no coal power plant added from 2020 onwards. The results show in 2030, Indonesia needs 577,016.2 GWh of electricity, where the household and industry sectors have the highest electricity needs, which is 44% for the household sector and 31% for the industry. The transformation projection in PLTGU or Combined Cycle Power Plants scenario also shows that without replacing the power plant, renewable along without SMRs only had ±7.49% of the total capacity mix, and the second scenario with SMRs shows that renewable energy share had 16.07%.

1. Introduction

The interest in small modular reactors worldwide has been increasing due to flexibility in the power generation sector for more comprehensive users and applications. Small Modular Reactors or SMRs can be the primary choice for Indonesia provided with the geographical condition, which consists of many islands and is more flexible in construction compared to the conventional nuclear power plant. SMRs can be built modularly, which are fabricated from the factory and transported as a module to the site location.

Energy has always been essential for development either in technology or human and economic growth. In Indonesia, energy consumption, especially electricity, continues to increase every year. Electricity demand projection has become a vital role in making critical decisions in energy policy and power plant construction plans in the future. The main aim of this paper is to provide an overview of the projected demand and energy mix of electrical energy in Indonesia in the year 2030 with small modular reactors nuclear power plant (SMRs NPP) and renewable energy referring to RUPTL or General Plan of Electricity Supply Indonesia 2019-2028 in order to meet the government target of 23% NRE mix by 2025 [1]. Data used for projection in secondary data gathered from PLN Statistic and BPS Indonesia [2].

2. Problem Statement

This paper objective is to simulate the projection of electricity demand and the energy mix of power plant used until 2030 referring to RUPTL 2019-2029 with the new power plant on the first scenario is PLTGU or Combined Cycle Power Plant based on government rules that no new coal power plant added from 2020. The second scenario use SMR NPPs added to the energy mix in 2028. Based on those conditions, the problem statement that wants to be solved in this paper is:

1. How is the projection of electricity demand in Indonesia from 2020 until 2030?
2. How is the energy mix after SMR NPPs added in the projection scenario?
3. Is the capacity mix of renewable energy based on RUPTL reach 23%, referring to Indonesia's goal for renewable energy mix based on the Paris Agreement?

3. Methodology

The methodology used to calculate the electrical energy demand is by using the end-use model. End-use energy is energy directly consumed by the user, which is electricity in this paper. The equation for end-use energy is written in the equation (1) [3].

$$Energy\ Demand = TA_{b,s,y}.EI_{b,s,y} \quad (1)$$

Whereas:

TA = Total activity for the sector (user)

EI = Electricity intensity of the sector (kWh/user)

The 'b' in the equation is the branch of each sector, 's' stand for the scenario if there are multiple scenarios in the simulation, while 'y' is year ranging from base year to end year of scenario. The energy intensity of each sector can be calculated by the equation (2).

$$EI\ [\frac{kWh}{user}] = \frac{Energy\ Consumption\ [kWh]}{Total\ Activity\ in\ the\ sector\ [user]} \quad (2)$$

The sector that will be calculated is based on PLN Statistic, which is household, business sector, industry sector, public sector, and social sector [4]. Variables that will be used for projection can be seen in Table 1 below.

Table 1. Variables used for projection

Variable	Unit	Sources
Population in Indonesia	People	BPS Statistic
Consumption of electricity per sector	kWh/year	PLN Statistic
Capacity of the power plant in every Province	Unit	PLN Statistic
Renewable energy potential in Indonesia	MW	RUPTL
Energy intensity per sector in Indonesia	Activity/kWh	PLN Statistic
Annual growth of energy intensity	%	PLN Statistic
Load factor in Indonesia	%	PLN Statistic

For transformation projection in this paper utilize exogenous and endogenous methods from LEAP software. The exogenous method is a method that manually adds all power plant construction plans from RUPTL 2019-2028, while the endogenous method will be added automatically based on demand forecast if the reserve margin from projection is below the parameter adjusted by the user, which is 30% for Indonesia then LEAP will add the power plant that user already defined before which is SMRs 60 MW and the PLTGU (Combined Cycle Power Plant) 100 MW until the reserve margin reaches 30%.

4. Result and Discussion

Figure 1 shows the results for electricity demand projection in Indonesia until 2030. In 2030, Indonesia needs a total of 577,016.2 GWh of electricity. In Figure 2, the demand projection from RUPTL until 2028 shows that Indonesia needs a total of 432,715 GWh of electricity. The differences between the simulation and RUPTL demand projection caused by the growth of electricity based on RUPTL is constantly 6.3% average each year, while in the simulation, each sector has individual growth based on historical data provided by PLN statistic and Statistical Year Book Indonesia BPS.

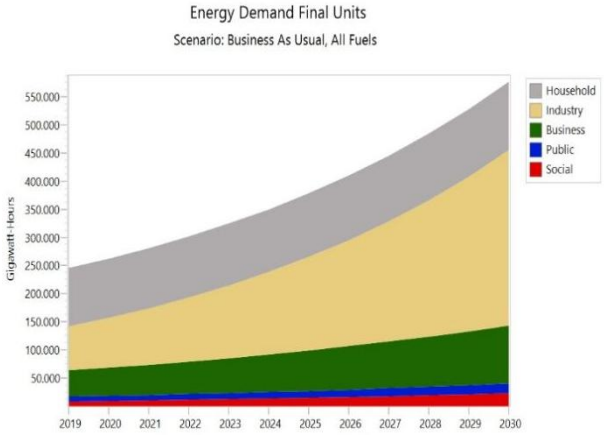

Figure 2. Result of energy demand from simulation until 2030

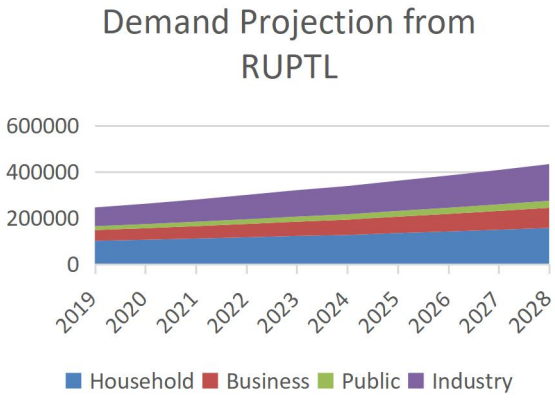

Figure 1. Energy demand in Indonesia based on RUPTL

It is calculating demand in simulation-based on the methodology provided before need total activity and electricity intensity data which is why there are two growths used for simulation. Growth of user activity from each sector and growth of electricity intensity used in the simulation can be seen in Table 2 and Table 3 below. The industry sector has the highest annual user growth per year in Indonesia based on historical data, which is around 13.54% per year average. For the household user, it is calculated by using population growth per year and divided by four based on BPS statistics of each household average consist of four people.

Table 2. The average growth rate of activity in Indonesia

Sector	Growth Rate
Household	1.49%
Industry	13.54%
Business	7.36%
Public	7.16%
Social	9.3%

Electricity intensity growth is negative per year, which means the use of energy electricity becomes efficient each year. The reason why some of the sectors have negative growth for energy intensity is

that less energy used to do some activity or create product will reduce the energy intensity of those sectors. The social sector in Indonesia had annual positive growth per year in energy intensity used, which is 0.024% per year.

Table 3. The average growth rate of electricity intensity in Indonesia

Sector	Growth Rate
Household	-0.013%
Industry	-0.082%
Business	-0.011%
Public	-0.05%
Social	0.024%

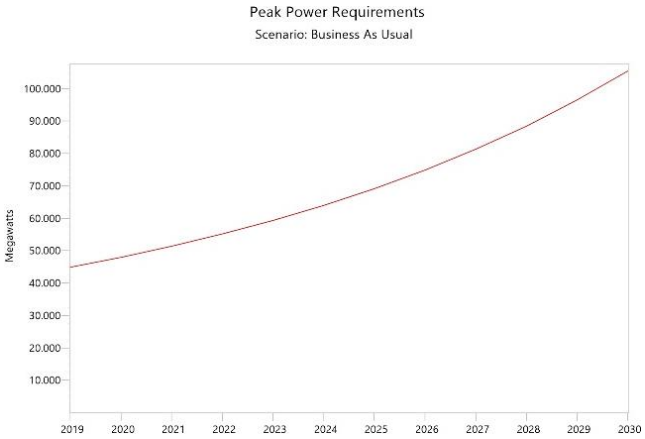

Figure 3. Power requirements in Indonesia until 2030

In 2030, Indonesia needs around 105,449.9 MW of electricity based on demand projection converted to peak power requirements which can be seen in Figure 3. Figure 4 and Figure 5 is the result from simulation. The power requirement in simulation compared to RUKN (National Electricity General Plan) 2019-2038 is lower. In 2028 the result of capacity projection from the simulation is 88 GW, while in RUKN projection is 105 GW [5].

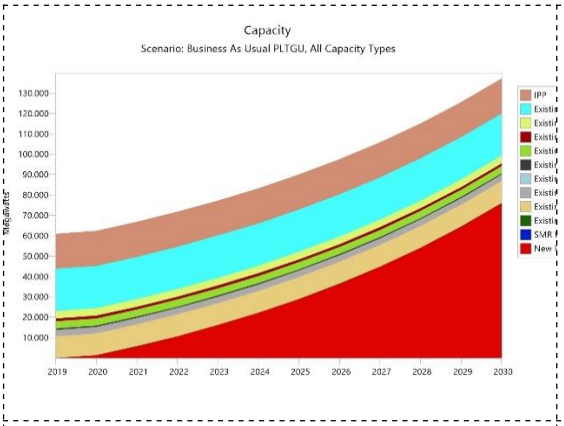

Figure 4. Capacity in PLTGU Scenario

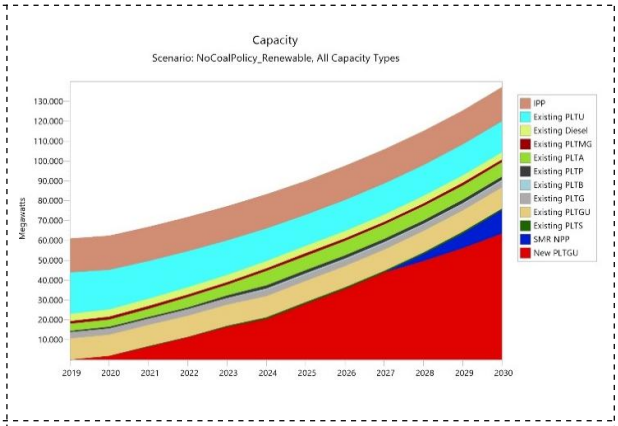

Figure 5. Capacity in NoCoalPolicy Renewable Scenario

Capacity projection in simulation in Figure 4 and Figure 5 shows that PLTGU (Combined Cycle Power Plant) has the biggest share in the energy capacity mix. IPP is the second largest. IPP is an individual power producer like PT. Indonesia Power which consists of mixed power plant like Gas and Coal power plant. Based on the results, the energy capacity mix will be divided based on the fuel needed to power up the power plant, which is gas, oil, coal, and renewables. The energy capacity mix from the PLTGU scenario is 23.84% coal, 65% gas, 3.67% oil, and 7.49% renewable. The energy capacity mix for SMR along with PLTGU is 23,84% coal, 56.43% gas, 3.67% oil, and 16.07% renewable.

In both scenarios, the total renewable energy mix consists of 819.55 MW of PLTS (Solar Power Plant), 1,606.5 MW of PLTP (Geothermal Power Plant), 7,290.28 MW of PLTA (Hydro Power Plant), and 560.47 MW of PLTB (Wind Power Plant). This addition of renewable energy power plant is based on the construction plan to be added in RUPTL and the roadmap of ESDM [6]. A list of power plants along with capacity in 2030 based on simulation for the renewable scenario can be seen in Table 4 below:

Table 4. List of capacity installed in renewable scenario

Power plant (fuel)	Capacity Installed (MW)
PLTU (Coal)	15,562.9
PLTD (Oil)	3,692.4
PLTMG (Gas/Oil)	1,336.9
PLTA (Hydro)	7,290.3
PLTP (Geothermal)	1,606.5
PLTB (Wind)	560.5
PLTG (Gas)	3,188.9
PLTGU (Gas/Oil)	74,208.8
PLTS (Solar)	819.6
SMR (Uranium)	11,760

In Table 4, SMRs have 11,760 MW capacity installed in 2030, which is planned to be added from 2028 onwards in the simulation. In 2028, the capacity of SMR only has 3,480 MW capacity installed. The reason why 2028 was chosen as a first-year simulation is that the factory-built nuclear power plant based on Indonesia regulation and construction time of SMR will need around 6-10 years on average [7]. If the government plan to add nuclear power plant in the energy mix between 2022 until 2024, then 2028 is the optimal choice to add SMRs in the projection.

5. Conclusions

The electricity demand projection for Indonesia in 2030 is 577,016.2 GWh which is increased by 331,497.8 GWh from 2019. The projection also shows most electricity consumed by household and industry sector which is 75.19% electricity used for both sectors in 2030.

The power plant capacity mix in Indonesia in 2019 is still dominated by coal and diesel power plant. The projection shows that in 2030, the capacity mix will be dominated by a combined cycle power plant or PLTGU. The energy mix based on the fuel itself from the PLTGU scenario is 23.84% coal, 65% gas, 3.67% oil, and 7.49% renewable, while energy capacity mix for SMRs and renewable scenario is 23,84% coal, 56.43% gas, 3.67% oil and 16.07% renewable. Based on RUPTL (General Plan of Electricity Supply) and roadmap from ESDM, the renewable energy power plant to be added is still small compared to energy demand in Indonesia to reaching 23% shares of energy mix based on the Paris Agreement. Indonesia should adjust the energy policy to add nuclear power plant as the backbone for renewable energy along with other renewable energy such as hydropower plant and geothermal power plant which is the biggest sources of renewable energy installed in 2019.

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