Chapter 27
Sizing and Costs Implications of Long-Term Electricity Planning: A Case of Kupang City, Indonesia

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Abstract This paper presents long-term electricity supply-demand scenarios for Kupang City, Indonesia. The objective of the analysis is to reveal the alternatives sizing of power plants along with the power generation costs that is potentially incurred during the study period. The study is conducted using bottom-up energy model. Electricity energy in terms of supply-demand variation is taking into account both fossil fueled and renewable energy potential in the supply side, and the scheme of high as well as average electricity growth rate in the demand side. Four variations of supply-demand conditions is presented as the study result. The results has shown total energy supplied which is required in order to satisfy the usual demand growth and the total saving potential under the demand scheme. The variation in terms of costs also shown depending upon the renewable energy penetration. The study is expected to contribute towards the utilization of more renewable energy potential, particularly the possible implementation of Photovoltaic plants and the campaign of energy efficiency and conservation within the observed area.

Keywords Kupang City · Renewable energy · Sizing · Generation costs

27.1 Introduction

Energy system model, particularly in the area of electricity supply-demand can be constructed using several approaches. As part of the energy system model, the long-term electricity planning is dealing with some scenarios of supply and demand which reflect potential utilization of supply as well as demand management in a certain economy boundary, such as in a nation wide or within smaller boundary. Commonly, two approaches are used to deal with the problem of constructing appropriate model, i.e. the top-down method and the bottom-up method. The first

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method uses aggregated economic data and suffers many drawbacks when applied in the area of energy planning. In addition, it is not well suited for examining technology-specific policies. Types of top-down approaches include macroeconomic assessment, input-output method, and general equilibrium method [1]. The second approach comprises three broad methods to matching with the study objectives. The accounting frameworks based model is a type of method used in the bottom-up energy model. One advantage of the bottom-up model over the previous one is the ability to capture interactions among projects and policies, as the analysis is assessing costs, resources allocation, and benefits of the projects. One example of accounting framework based model is the long-term forecast of Taiwan's energy supply and demand [2]. Another bottom-up approach is the utilization of either linear programming model or goal programming model for solving decentralized energy planning [2].

This paper uses the accounting framework based model similar in [2], to construct long-term electricity supply-demand model for Kupang City, Indonesia. However, the analysis is focusing in the sizing and essential generation costs implications from the potential electric power mix and aggregated long-term electricity demand of the city. The methodology is described in the next section followed by the simulation results and discussion.

27.2 Methodology

Kupang City is the capital of East Nusa Tenggara. Geographically located between 10° 39' South Latitude and 123° 37' East Longitude, the city has 180.27 km^2 land area. Kupang City often been called the rock city due to its dry area and crisis of fresh water that is happened in the dry season. The condition in fact offering other benefit in terms of solar energy potential. The monthly percentage of sunshine in Kupang City is quite good. During April to November, the percentage of sunshine can achieve roughly 79–100 % [3].

Up to now, Kupang City is the only city or regency in East Nusa Tenggara which has 100 % electrification rate. It is reflected from the data of the percentage of fuel used for lighting. Kupang City uses 100 % electricity for household lighting. In 2013, the population of Kupang City was 378,425 people. Aggregately, total number of PLN (state electricity company) customer along with the number of consumption in 2009–2013 is shown in Table 27.1.

Table 27.1 Number of PLN customer and electricity consumption in Kupang City during 2009–2013 [3]

Year	Number of customer	Electricity consumption (MWh)
2009	55,480	134,594
2010	59,311	156,097
2011	74,040	172,070
2012	79,354	203,471
2013	89,564	253,940

Table 27.2 Current installed and available capacity of power plant in Kupang Area [4]

Power Plant	Type	Installed (kW)	Available (kW)
Kuanino	Diesel	5,000	2,300
Tenau	Diesel	46,122	11,550
Rental	Diesel	23,000	18,930
Bolok	Coal	33,000	33,000
Gudang	Diesel	1,220	372

The current power generation has been relied on diesel power plants as well as the relatively new coal fired power plant. The installed power capacity as well as the available capacity of both types of plant is presented in Table 27.2, including the rental based plant.

The simulation is conducted using LEAP (Long range Energy Alternatives Planning System), a tool developed by Stockholm Environment Institute (SEI) [5]. The tool is classified as bottom-up method and worked based on the accounting framework. The tool itself has been utilized in many studies, reports, and journal papers [6]. Focusing in the end-use driven scenario-based analysis, the advantages of the tool include flexibility in processing the amount of available data. Despite the data limitation, the tool can be used to evaluate impacts that is potentially occurred due to scenarios selection. The tool is equipped with several modules to enable analysis of energy flow from the supply side into demand side. In the context of the study, data of electricity consumption of Kupang City is aggregated from all customer sectors.

The objective of the study is to match the long-term demand of the city through appropriate generation mix up to 2025 by possibly reducing the role of diesel power plant and increasing the penetration of renewable energy, particularly solar energy, in parallel with the contribution of coal fired power plant as the backbone of the system. By conducting the simulation under several scenarios, the energy mix and the associated costs will be revealed. In this study, two scenarios are taken into account. The first scenario deals with fully non-renewable power plants whereas the second scenario includes Photovoltaic plants. Please be noted, the contribution of diesel power plants in terms of its capacity will be reduced in both scenarios. Meanwhile, the demand side considers high growth rate and average growth rate of electricity consumption over the simulation period. Some important key parameters imposed into the simulation are as follows: the high and average growth rate of electricity consumption are taken 20 and 15 %, respectively, the high and average growth rate of users are taken 15 and 10 %, respectively, the capital cost of coal fired power plant, Photovoltaic, and diesel power plant per MW are USD 1.26 million, USD 2 million, and USD 200 thousand, respectively, the variable operation and maintenance costs per MWh include the fuel cost are USD 8, USD 20, and USD 20, respectively, the plant efficiency are taken 35, 15 and 30 % for coal, Photovoltaic, and diesel, respectively, the starting year of operation is 2013 for coal and diesel plant, and in 2018 onwards for Photovoltaic, the transmission and distribution losses is set 8.6 % in 2013 and interpolated to 6 % in 2025, and the discount rate is taken 5 %.

27.3 Results and Discussion

The electricity demand projection up to 2025 is shown in Table 27.3. The projection is based on the high and average growth as indicated in earlier section.

As seen in Table 27.3, the anticipated electricity consumption growth would be in the range of 5–8 times higher compared to 2013. According to the LEAP simulation, existing available power plant capacity would only meet the demand within the Kupang City system up to 2018 and 2019, for the case of average growth and high growth, respectively. Additional supply would be needed up to 865.9 MWh in 2025 for the average growth scenario, and around 1,829 MWh in the same year for the high growth scenario.

To meet both demand scenarios, more capacity of coal fired power plants is required, considering no more additional capacity of diesel power plant. Figure 27.1 shows the graph of required energy supply in the case of high growth demand as well as average growth demand.

Initially in 2013, both power plant types' share were roughly equal. Nevertheless, in 2025, the share of coal fired power plant would be around 88 % for scenario-1, and around 80.3 % for scenario-2. In this case, the required demand would potentially be meet by increasing the coal fired power plant capacity up to 120,000 MW in 2018 and 245,000 MW in 2025, for the case of high growth. Meanwhile, the capacity should be increased up to 70,000 Mw in 2018 and 135,000 MW in 2022, for the case of average growth.

Additional capacity of coal fired power plants that is required to meet both demand scenarios would slightly lower compared to scenario-1. Table 27.4 shows the required capacity in the case of high growth demand as well as average growth demand, under scenario-2, so that energy import from outside Kupang City system would be unnecessary.

Table 27.3 Electricity consumption of Kupang City up to 2025 (in MWh)

Scenario	2017	2019	2021	2023	2025
High growth	526.5	758.3	1,091.9	1,572.3	2,264.2
Average growth	444.1	587.4	776.8	1,027.3	1,358.6

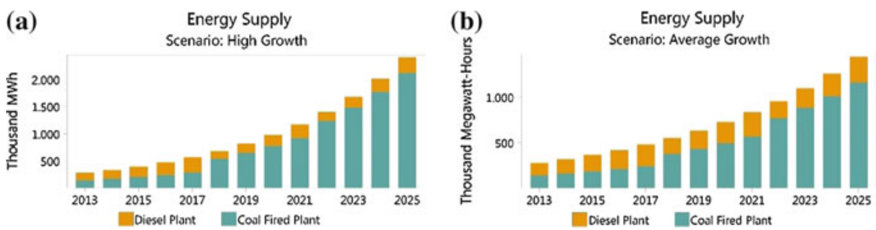

Fig. 27.1 **a** Required energy supply for high growth, **b** required energy supply for average growth

Table 27.4 Required additional power plant capacity for scenario-2

Demand scenario	Power plant	Sizing (MW)	Year
High growth	Coal fired	33	Existing
		60	2018
		158	2022
	Diesel	33.15	Existing—2025
	PV	10	2018
		15	2022
Average growth	Coal fired	33	Existing
		27	2018
		50	2022
	Diesel	33.15	Existing—2025
	PV	10	2018
		15	2022

The electricity generation costs for scenario-2 is shown in Fig. 27.2. The cost component are capital cost, fuel cost, and operation and maintenance cost over the simulation years. The cost comparison between scenario-1 and scenario-2 is given in Table 27.5.

From Table 27.5, we can see that the implementation of renewable energy resources while reducing the share of diesel power plant capacity would result the competitive generation cost compared to the condition without Photovoltaic. Moreover, the total sizing of coal fired power plant could be significantly reduced

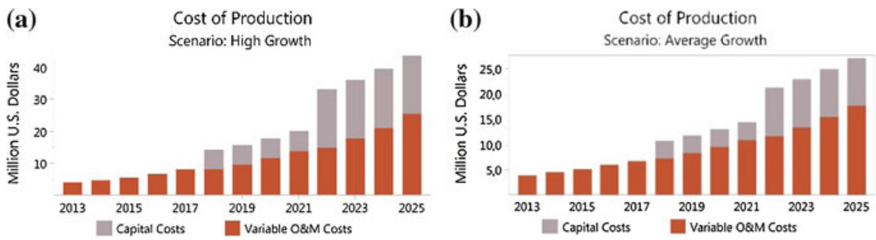

Fig. 27.2 Electricity generation cost for scenario-2. **a** High demand growth, **b** average demand growth

Table 27.5 Cost comparison between scenario-1 and scenario-2 (in USD million)

Year	Scenario-1		Scenario-2	
	High demand growth	Average demand growth	High demand growth	Average demand growth
2018	15.7	10.9	14.3	10.7
2021	20.9	14.2	20.1	14.4
2025	43.3	26.6	45.8	27.1

by introducing Photovoltaic plant. In this study, however, the sizing of Photovoltaic plant is used as indication to help find the possible contribution of the renewable energy resources.

27.4 Conclusion

This paper presents the study of three possible options. One of feasible option to meet the ever growing electricity demand in Kupang City is by having higher share of coal fired power plants, in addition to the possible implementation of centrally located Photovoltaic plants. To reduce the generation costs originating from non-renewables, no additional capacity of diesel power plants is considered. The study also captures the potential benefit of involving Photovoltaic plant so that the generation cost can be competitive with that achieved by the scenario without energy supplied from renewables.

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