Applied Mechanics and Materials
ISSN: 1662-7482, Vol. 815, pp 444-448
doi:10.4028/www.scientific.net/AMM.815.444

Submitted: 2015-08-27
Accepted: 2015-09-01
Online: 2015-11-30

Energy and Environment Implications of Long-Term Power Development Involving Renewable Energy: a Case of Timor Island, Indonesia

Yusak Tanoto[1,a], Daniel Rohi[2,b]

[1]Electrical Engineering Department, Petra Christian University, Surabaya 60236, Indonesia

[2]Center of Excellence Geopolymer & Green Technology (CEGeoGTech), School of Materials Engineering, Universiti Malaysia Perlis, Malaysia

[a]tanyusak@petra.ac.id, [b]rohi@petra.ac.id

Keywords: Timor Island, power development, renewable energy, environment.

Abstract. This paper presents a long-term electricity energy supply-demand model of Timor Island, Indonesia. Implications of projected demand growth within the observed area towards the available supply as well as the amount of CO_2 emission is taken into account. As its main objective is to review and to present initial comparison of the long-term electricity planning prepared by the utility, the analysis is carried out using the bottom-up energy system model. Unlike the common electricity long-term demand projection that is usually constructed based on the factors related to the electricity growth, the model is developed based on the simple projection considering historical electricity demand users. According to the analysis, the planned power plants would not able to meet the elecricity demand in the case of high growth demand scenario. The variation of CO_2 emission that is obtained from the considered scenarios is also shown.

Introduction

Electricity energy provisioning particularly for long term horizon is quite a challenging task due to several inter sectoral issues. In the macro perspective, there are uncertainty in economic condition, in addition to the increasing price of fossil fueled based energy. On the other hand, the technology development give ways to the better and more utilization of electricity. In turn, the demand is increased rapidly and the energy consumption pattern has been changed. The long-term electricity energy provisioning is therefore deal with the modeling of supply, demand, and conversion technology. The selection of appropriate method is often debatable in terms of how demand should be projected. Many studies have projected the demand using two broad methods, i.e. classic econometric and artificial intelligence based [1, 2, 3]. Nevertheless, to match the available energy conversion technology with the provided energy supply resources as well as the likely future demand is considered more important. In principle, a big picture of the model which consists of supply-demand relation should be initially provided before come into various in depth analysis.

This paper presents the modeling of long-term power sector development, in particular the supply, demand, and power plants involvement using the bottom-up energy system model. The main objective of the constructed model is to provide initial review to the long-term Timor Island electricity supply-demand and to provide the comparison of CO_2 emission among considered scenarios. The bottom-up energy system model is discussed in the following section, along with the background of applying the model framework, the utilized tool for making the model, the electricity and other relevant data of the observed area, and the scenarios of the supply-demand relation. Section 3 presents the results and discussion of the model simulation whereas conclusion is presented accordingly.

Methodology

Bottom-up energy system model. Two broad methods that can be used to model the long-term energy model are either top-down or bottom-up based. The top-down based methods works with macreconomic principle and the economic variables are processed under the econometric techniques. Although it is used in many studies, the top-down methods is suffering from drawback. The aggregate models applied, for instance, to climate policy do not capture the needed sectoral details and complexity of demand and supply. On the other hand, the bottom-up based models provide a more flexible way in handling the data and variables according to what required in the model. In bottom-up based model, system is evaluated based mainly on technological options and mitigation policy. In other word, the simplicity of the model could be achieved in the same time the detail demand variables could be easily introduced into the model. Hence, sectoral details could be seen clearly.

This study employed LEAP (Long range Energy Alternatives Planning System). An accounting framework based tool that work under the bottom-up method principles. Developed by SEI (Stockholm Environment Institute) and has been used in many studies [4, 5], the tool has the ability to calculate required resources to produce energy using selected fossil fuel or renewable energy based power plants technology along with the generation and other related costs. The tool is also able to make projection in electricity demand from simple function of growth to more complex relation between many affected variables. Moreover, the environment effect can also be added into the analysis by defining the amount of specific Green House Gases emitted per unit of fuel consumed.

Area of Observation and Relevant Data. The study is focused on the construction of Timor Island, also known as West Timor, long-term electricity model. The island is belong to Nusa Tenggara Timur province teritory. The area is chosen in this study as an example on how the electricity energy could be planned in the least developing region with rapid increased in electricity demand. As an initial path to work with more technical issues on power expansion, implication of energy sufficiency and CO_2 emission in ten years situation of Timor Island electricity supply-demand can be revealed through LEAP model, under considered scenarios. The map of Nusa Tenggara Timur province with West Timor Island is shown in Fig. 1 [6]. The island has land bordered with Democratic Republic of Timor Leste.

Fig. 1. (Left) The map of Timor Island (West Timor), (Right) Location of the province.

The West Timor Island has four districts and one city, namely Kupang district, Timor Tengah Utara district, Timor Tengah Selatan district, Belu district, and Kupang City as the province capital. The number of local utility's electricity customers and their consumption in year 2013 is shown in Table 1.

Table 1. Number of utility's electricity customers and their consumption in 2013

District/City	Number of customer	Electricity cosumption (MWh)
Kupang City	89,564	246,382
Kupang District	37,301	20,236
Timor Tengah Utara	28,178	20,083
Timor Tengah Selatan	40,535	22,809
Belu	29,638	32,872

As seen in Table 1, Kupang City had the highest consumption per customer with roughly 2.75 MWh, meanwhile Timor Tengah Selatan was the lowest with just 0.56 MWh. The poor electrification ratio condition can be represented through the percentage of household that used non-electricity based lighting, as seen in Fig. 2. Except Kupang city, others districts still rely much on the non-electricity fuel based lighting.

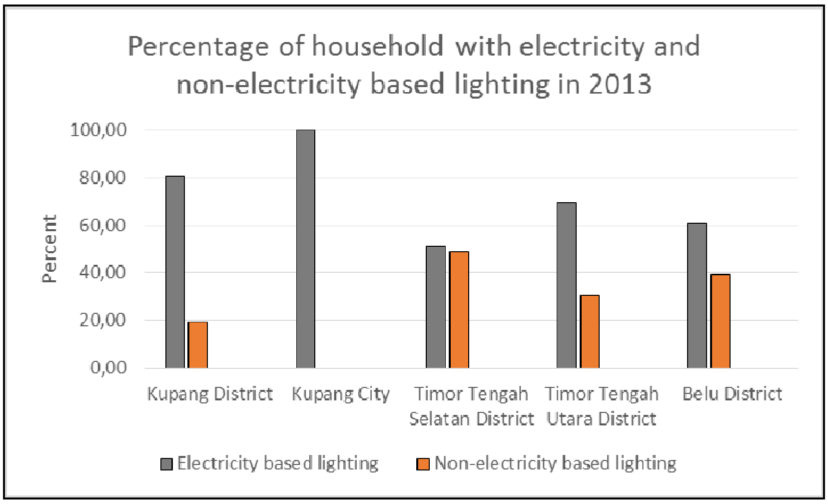

Fig. 2. Percentage of household with electricity and non-electricity based lighting.

Existing capacity of power plants is taken into account the available capacity only, instead of installed capacity. The main power plants available within the island are diesel power plant with a total of 57,724 kW and the new commissioned coal fired power plant with 33,000 kW. There are few solar communal power plants as well as solar home system available scatterly. The island has wind energy potential and micro hydro potential.

The planned power plants during the simulation period is presented in Table 2. The potential power plants in terms of type, capcity, and estimated year to be involved in the simulation time frame are referred to the national electricity general planning 2015-2014, issued by the "Perusahaan Listrik Negara", a national utility company owned by government.

Table 2. Available existing and mimimum planned capacity in the model

Power plant type	Simulation year	Available or potential capacity
Diesel	existing	57,724 kW
Coal fired	existing	33,000 kW
Micro hydro	2017^1, 2020^2	2,400 kW^1, 4,800 kW^2
Wind	2020	2,000 kW
Solar communal and SHS	Existing, 2015^1, 2018^2, 2020^3	2,000 kW^1, 4,000 kW^2, 6,000 kW^3

The averaged total region's transmission and distribution losses was varied in the range of around 8-12 percent over the last five years. The environmental loading is calculated based on the amount of specific gas contain in kilogramme per Terajoule energy consumed, as listed in the LEAP database.

The Scenarios of Future Electricity Supply-Demand. The future electricity supply refer to the data given in Table 2 in accordance to the planning made by the utility. On the other side, electricity demand refer to the annual electricity consumption over five area within the island. The anticipated demand growth consists of three level, i.e. low, medium, and high growth. Over the simulation time frame, i.e. 2014 to 2014, the demand growth is set 10%, 15%, and 20%, respectively, considering the typical range of the last five years historical demand growth as well as number of customer growth In addition, the number of customer growth is set the same way, except for Kupang city is set at 5% to 15% from low to high growth level due to high electrification ratio of the city.

Results and Discussion

Electricity consumption projection over all areas within the island is calculated based on the three level of growth as described in earlier section. Demand projection in case of the low demand growth over the simulation time frame is depicted in Fig. 3. In addition, the variation of demand projection for low to high growth is presented in Table 3.

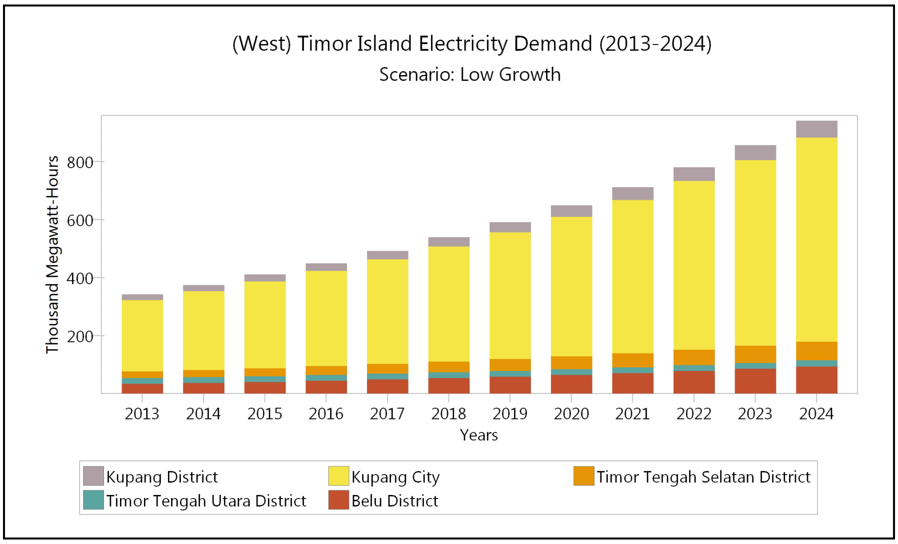

Fig. 3. (West) Timor Island electricity demand in all areas over 2013-2024.

Table 3. Variation of demand projection (Thousand MWh)

Demand Scenario	2013	2015	2017	2019	2020	2021	2022	2023	2024
Low growth	342.4	410.1	492	591.1	648.2	711	780	856	939.6
Medium growth	342.4	452.8	598.8	792	910.7	1,047	1,205	1,385	1,593
High growth	342.4	493	710	1,022	1,227	1,472	1,767	2,120	2,544

In the supply poin of view, there will be unmeet energy supply in case of high growth demand scenario due to generation available capacity. The energy supplied for the case of high growth demand scenario is shown in Fig. 4.

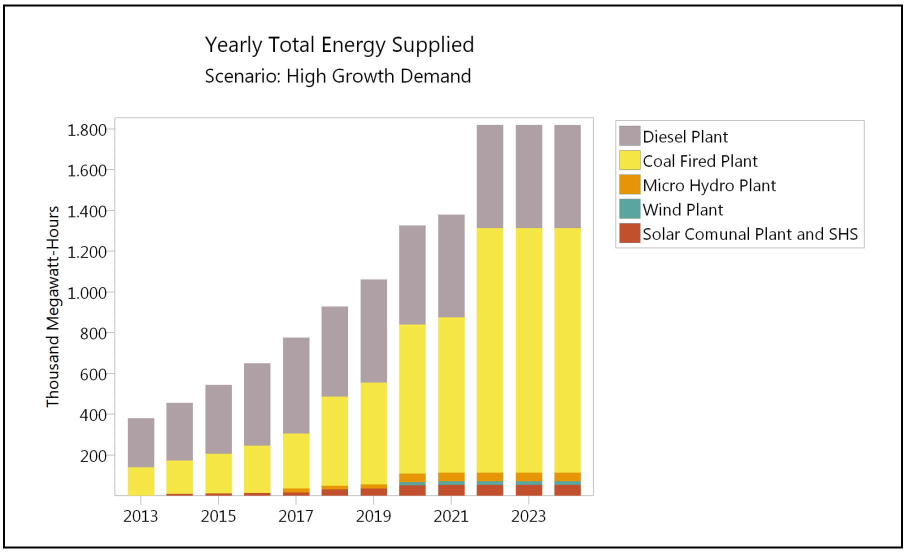

Fig. 4. Yearly total energy supplied for high growth demand scenario.

In the case of high growth demand, the unmeet demand may occur in 2019 with 48 thousand MWh, in 2021 with 204.6 thousand MWh, in 2022 with 76.1 thousand MWh, in 2023 with 446.1 thousand MWh, and eventually in 2024 with 888.4 thousand MWh. Hence, the total imported electricity should be around 1,663.2 thousand MWh. The penetration of wind power plants would be benefit in 2020 as no shortage of energy suffered. On the other hand, a slight deficit could be overcome with add more renewables in 2019 and 2022. On the other hand, the fossil fuel based power plants would still be needed to overcome large shortage in 2021, 2023, and 2024, as internconnection from other island is mostly a difficult task.

CO_2 Emission Impact and Mitigation. The CO_2 emission due to electricity consumption would vary between 871 thousand metric tonnes in the case of low growth demand up to 1,584 thousand metric tonnes in the case of high growth demand, provided the unmeet energy as explained earlier. The emission could be mitigated using two schemes. The first one is by having low to medium demand growth level, and the secondly is by putting additional renewable based power plants, for example solar communal plants. However, the capital costs and the energy intensity of the typical plants could be one factor of consideration.

Conclusion

This paper presents the inital assessment of energy and environment impact for the long-term power sector developmet. The (West) Timor Island that consists of five district/city is the area of observation. According to the analysis, provided high growth demand scenario, there would be shortage of energy supplied by the planned power plants whereas for other demand growth levels, the energy supplied would be sufficient. Additional power plants which most likely consists of fossil fuel and renewable energy based should be taken into account to overcome energy deficit. The penetration of renewable energy could potentially be increased. The solar home system or communal based plants would be the best alternatives considering the high solar energy intensity throughout the year. In further, the analysis will deal with the hybrid method, considering more detail data to involve the sizing and economical aspect.

Acknowledgements

This work was financially supported by the Institute of Research and Community Outreach, Petra Christian University, Indonesia using the internal research grant 2015. Therefore, the authors conveys their gratitutes.

References

[1] E. Pourazam, A. Cooray: Estimating and forecasting residential electricity demand in Iran. Economic Modelling Vol. 35 (2013), p. 546-558.

[2] S. Nawaz, N. Iqbal, and S. Anwar: Modelling electricity demand using the STAR (Smooth Transition Auto-Regressive) model in Pakistan. Energy Vol. 78 (2014), p. 535-542.

[3] M. S. Kiran, E. Ozceylan, M. Gunduz, and T. Paksoy: Swarm intelligence approaches to estimate electricity energy demand in Turkey. Knowledge-Based Systems Vol. 36 (2012), p. 93-103.

[3] Stockholm Environment Institute: *Long-range Energy Alternative Planning System, User Guide* (Boston, USA, 2006)

[4] Information on http://www.energycommunity.org/default.asp?action=45

[5] Information on http://www.goseentt.com/

Design and Development of Sustainable Manufacturing Systems
10.4028/www.scientific.net/AMM.815

Energy and Environment Implications of Long-Term Power Development Involving Renewable Energy: A Case of Timor Island, Indonesia
10.4028/www.scientific.net/AMM.815.444

DOI References

[1] E. Pourazam, A. Cooray: Estimating and forecasting residential electricity demand in Iran. Economic Modelling Vol. 35 (2013), pp.546-558.
10.1016/j.econmod.2013.08.006
[2] S. Nawaz, N. Iqbal, and S. Anwar: Modelling electricity demand using the STAR (Smooth Transition Auto-Regressive) model in Pakistan. Energy Vol. 78 (2014), pp.535-542.
10.1016/j.energy.2014.10.040
[3] M. S. Kiran, E. Ozceylan, M. Gunduz, and T. Paksoy: Swarm intelligence approaches to estimate electricity energy demand in Turkey. Knowledge-Based Systems Vol. 36 (2012), pp.93-103.
10.1016/j.knosys.2012.06.009
[3] Stockholm Environment Institute: Long-range Energy Alternative Planning System, User Guide (Boston, USA, 2006).
10.1016/s0024-6301(97)84579-7
[4] Information on http: /www. energycommunity. org/default. asp?action=45.
10.1007/978-3-642-95855-7_10
[5] Information on http: /www. goseentt. com.
10.1007/978-3-642-95855-7_10