Energy Mix Simulation to Reach Regional Energy Strategy: A National Impact of East Nusa Tenggara Province Energy Mix

Adrianus Amheka[1], Julius Tanesab[2], Nonce Farida Tuati[3], Kathleen Aviso[4] and Krista Danielle Yu[5]
[1]*Department of Mechanical Engineering, State Polytechnic of Kupang, Indonesia*
[2]*Department of Electrical Engineering, State Polytechnic of Kupang, Indonesia*
[3]*Department of Accounting, State Polytechnic of Kupang, Indonesia*
[4]*Department of Chemical Engineering, De La Salle University, Manila, Philippine*
[5]*School of Economics, De La Salle University, Manila, Philippine*

Keywords: NTT Province, Regional Energy Mix, GHG Emission.

Abstract: More than 70% of global energy demand growth was met by fossil fuels as a trigger for increasing GHG emissions and the Indonesian itself has contributed around 6.678 million stock tank barrels (MMSTB) for that. Indonesian primary energy demand in 2025 from oil is 98.7 million tonnes of oil equivalent (MTOE) or 24.7% from energy mix and expected to be increased up to 197.7 MTOE or around 19.5% from energy mix in 2050. In fulfilling national energy needs, regional functions in achieving energy security are indispensable. For that through national energy general plan is targeted to reach renewable energy (RE) mix in 2025 is a minimum of 23% of total primary energy. In this study, several indicators were used such as social economy, energy, and the environment using LEAP simulation. The results show that East Nusa Tenggara (NTT) Province has the potential to develop RE, with the potential of primary energy resources of 23.8 GW enabling the province to reach the RE mix target of up to 24% in 2025 and 31% in 2050 while GHG emission decreased 9% and 11% from the usual condition in 2025 and 2050 respectively. Therefore, the current energy structure has space to restructure the energy system to be more optimal in achieving regional energy independence as well as support for the achievement of the SDGs and global competitiveness.

1 INTRODUCTION

Indonesia is an archipelago countries with a population of 265 million peoples spread across 35 provinces with diverse socio-economic conditions (A. Amheka & Higano, 2015, 2018) has the potential for primary energy which is adequate in supporting the economy at both national and local levels and currently as G-20 member countries which have actually made this country potentially to become a contributor to the achievement of world prosperity which is currently positioned in 16th the largest GDP level between Mexico and Turkey. At present, 70% of global primary energy supply comes from fossil fuels and as a consequence trend of increasing global emissions will absolutely increase (A. Amheka & Higano, 2015; Kumar, 2016). Taking part of that, Indonesia government through national energy were supplied as 6.678 million stock tank barrels (MMSTB) to support national development (INEP, 2017).

Strengthening the national energy buffer through regional primary energy supply, instead of costly fossil fuel imports (Kumar, 2016). The current fossil fuel subsidies, which make the present energy supply affordable for the population, cost Indonesia over 100 trillion IDR/year (~USD7.04 million/year) and despite fossil fuel reserves, the dependence on fossil fuel imports is steadily growing. Although Indonesia made great advances in the electrification across the country, some provinces in East and Central Java, East Nusa Tenggara (NTT) and Papua are proving particularly hard to reach and 2,110 out of 2,424 villages remain without any access (International Energy Agency (IEA), 2018). In order to achieve global sustainable development goals (SDGs) no.7 “Affordable and clean energy” while meet Indonesia’s national energy policy targets and national energy general plan (INEP, 2017; Indonesia National Energy Policy (INEP), 2014; Nusa Tenggara Timur Government, 2019), mentioned that Indonesian primary energy demand in 2025 from oil

Amheka, A., Tanesab, J., Tuati, N., Aviso, K. and Yu, K.
Energy Mix Simulation to Reach Regional Energy Strategy: A National Impact of East Nusa Tenggara Province Energy Mix.
DOI: 10.5220/0010950600003260
In *Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2021)*, pages 657-663
ISBN: 978-989-758-615-6; ISSN: 2975-8246

is 98.7 million tonnes of oil equivalent (MTOE) or 24.7% from energy mix and expected to be increased up to 197.7 MTOE or around 19.5% from energy mix in 2050 and a minimum of 23% of total primary energy must be supplied by renewable energy (RE) by 2025 and increased to be 31% of energy mix or around 92.3 MTOE and 315.7 MTOE respectively. Optimization of energy balance to support the responsibility of achieving SDGs at the local level in Indonesia focused on NTT Province become a motivation for this study as well as an inventory of information and references for regional energy policies. Current RE potential at NTT Province in 2015 as baseline shown in Table 1.

Table 1: Potential and utilization of RE in NTT Province in 2015 (base year).

No	Type of Energy	Potential (MW)	Installed capacity (MW)	Utilization (%)
1	Geothermal	629	12.5	1.99
2	Water	53	-	-
3	Mini & Micro Hydro	95	5.2	5.47
4	Bioenergy	240.5	1	0.42
5	Solar	7,272	7.43	0.1
6	Wind	10,188	3.1**	0.03
7	Tidal	5,335	-	0
	Total	23,812.5	29.23	0.12

Source: (INEP, 2017; Indonesia National Energy Policy (INEP), 2014; Nusa Tenggara Timur Government, 2019).

Baseline data is used among other the total population is 5,120,061 souls with a rate of population growth is 1,67%; total of households are 1,108,400; electrification ratio 58.64%; the GDP is 56,821 billion IDR with its growth rate 5.05% per year; the GDP per capita is 11 billion IDR with annual growth rate is 3.31%; the growth elasticity is around 1.15 per year. While as baseline of GHG emission in beginning of 2015 was expected around 2,2 Million tons with a emission per capita is around 0,45 million tons (A. Amheka & Higano, 2015; Nusa Tenggara Timur Government, 2019). There are some data trends in terms of social economy, energy and environment was entered into the model.

2 MATERIALS AND METHODS

This study investigates the energy balance analysis of taking into account the quantity of energy demand and energy supply of each sectors activity for a province which is NTT Province in Indonesia. The indicators used for the optimization are the social-economy, energy and environment which means GHG emission. The Long-range Energy Alternatives Planning (LEAP) was developed by the Stockholm Environment Institute, which is a system optimization software was used for the system analysis which is allowed users input current quantitative data and future energy demands as a good accounting tool for energy supply and demand model (Aized et al., 2018; Emodi et al., 2017; Ferrão, 2017; Halkos et al., 2015; Kusumadewi et al., 2017; Ouedraogo, 2017; Pan et al., 2013; Phdungsilp & Ã, 2010; Wongsapai et al., 2016; Zhang et al., 2019). The LEAP basically a description or plan that describes the complex system of production, distribution, and consumption of energy into a mathematical formula to display a reference to describe the energy system in a region within a period of time. Every country has specific model customized depends on social, economic and environmental conditions and other parameters and indicators (Awopone et al., 2017; Emodi et al., 2017; Huang et al., 2011; Kemausuor et al., 2015; Mirjat et al., 2017; Yang et al., 2017). For Indonesia the model is customized to fully describe a comprehensive social-energy-environment analysis in evaluate the alternative configuration and design based on general standard indicators (HaCohen-Kerner & Mughaz, 2010; Heaps, 2008). The customized model structure allowed by Indonesia government as business as usual (BAU) condition as shows in Fig. 1. (INEP, 2017; HaCohen-Kerner & Mughaz, 2010; Nusa Tenggara Timur Government, 2019).

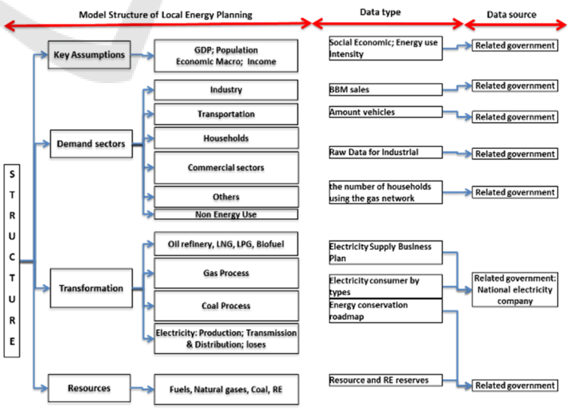

Figure 1: Framework and model structure.

In the household, commercial, transport and industrial sectors, the LEAP model has helped to assess their energy consumption and greenhouse gas emissions. Because of LEAP only as a tool, so that primary data collection is still needed as a reference key assumption, demand sectors, transformations, dan potential natural resources for a period 6 years between 2010 to 2015. Lack of data availability become a barrier. The scenario assumption is based on current data collection on energy system conditions including electricity in NTT Province was obtained through FGD activities involving various stakeholders. The output of the activity is met through update the latest data inventory as primary data for a period of 6 years from 2010 to 2015. Basically, we choose the selection of the 6-year period is to anticipate if the collection data information obtained is not as complete as expected so that we may able to make assumptions accurate as possible due to the primary data range used is not too far.

The algorithm structure for a total energy consumption as follow (Emodi et al., 2017):

$$E_i = \sum(GDP\ subsector\ industry\ x\ I_i) \quad (1)$$

where, E_I is total energy demand of industrial sector (en); I_i is intensity energy consumption of Industrial sector (ex)

$$E_h = \sum_{i=1}^{i=n} Q_i . I_i = \sum_{i=1}^{i=n} (N_i . P_i) . I_i \; ; E_{R_i} = N_i . P_i . I_i \quad (2)$$

Where, E_h is total energy consumption of household sector (en); E_{R_i} is final energy consumption of using technology (en); Q_i activity level of energy use (en); N_i is number of households using equipment/technology (ex); and P_i is penetration of equipment/technology (en).

$$E_{Ti} = \sum Q_i \ . \ I_i \quad (3)$$

E_{Ti} is energy demand of transportation sector (en)

$$E_{KSi} = \sum(GRP\ subsector\ commercial\ x\ I_i) \; ; E_{KPi} = \sum(A\ x\ I_i) \quad (4)$$

E_{KSi} is energy demand of subsector private (en); A is floor area; E_{KPi} is energy demand of subsector government (en).

$$E_{Li} = \sum(GRP\ other\ sector\ x\ I_i) \quad (5)$$

E_{Li} is energy demand of other sector (en).

$$CE = \sum_p \sum_f EF_{f.p} . \frac{1}{E_p} . P_p \quad (6)$$

CE is CO_2 emission (en) (Cai et al., 2008; Emodi et al., 2017; Handayani et al., 2017); $EF_{f.p}$ is emission factor of primary energy f which is consumed to produce electricity from technology p (en); E_p is technology efficiency (ex); dan P_p is power outputs are required p (ex).

2.1 Results and Discussion

The structure of the social, economic and environmental conditions of NTT Province during the period of 2012 to 2015 can be well-controlled and conducive situations (A. Amheka & Higano, 2015; Adrianus Amheka et al., 2016, 2014) which allow the minimum condition to the transition of energy structures from conservative consumption patterns towards a better direction in supporting national energy development. The simulation results as in Fig. 2, Table 2 and Table 3 respectively, show NTT Province of NTT Energy mix 2015 to 2050.

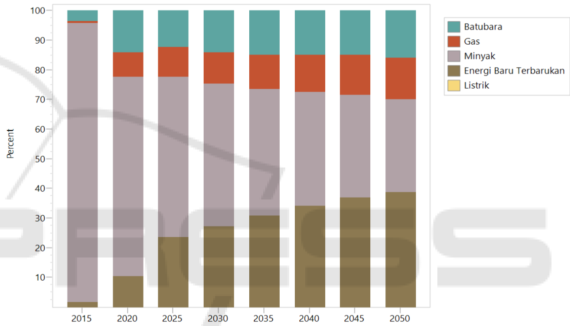

Figure 2: Energy mix of the NTT Province 2015 to 2050.

Table 2: NTT Province's Energy mix 2015 to 2050.

(Unit: percentage)

Fuels	2015	2020	2025	2030	2035	2040	2045	2050
Coal	4.%	14.%	12.%	14.%	15.%	15.%	15.%	16.%
Gas	1.%	8.%	10.%	11.%	11.%	12.%	14.%	14.%
Oil	94.%	67.%	54.%	48.%	43.%	38.%	35.%	31.%
RE	2.%	10.%	24.%	27.%	31.%	34.%	37.%	39.%
Total	100.%	100.%	100.%	100.%	100.%	100.%	100.%	100.%

At the base year 2015, primary energy use sourced from oil is dominated this shows how massive the supply and demand of energy from oil to support the region where it reaches 94% or equals to 1.1 MTOE of the total energy mix in NTT Province. In the same year, the primary energy use from RE sources was only 2% or equivalent to 20 TOE and followed by coal by 4% and the rest of 1%.

Table 3: Province of NTT Energy mix 2015 to 2050.

Unit: TOE

Fuels	2015	2020	2025	2030	2035	2040	2045	2050
Coal	40	248	312	460	610	754	917	1,177
Gas	7	146	258	348	474	634	837	1,040
Oil	1,072	1,193	1,380	1,580	1,764	1,949	2,142	2,326
RE	20	186	609	901	1,273	1,743	2,290	2,893
Total	1,139	1,774	2,560	3,289	4,121	5,079	6,186	7,436

The primary energy mix trend continues to vary where the portion of petroleum use has drastically reduced in the next 5 years, which is down 40% in 2025 compared to the base year of 2015, while the portion of RE usage has increased to 24% and gas use has increased 9% in 2025 which is to be 10% compared to the initial year. This is in line with the spirit of Indonesia's national energy policy (INEP, 2017; Indonesia National Energy Policy (INEP), 2014) which implies maximizing the use of the RE from every year while minimizing energy use from oil and optimizing the use of gas. Whereas if it is still lacking, it will be filled by energy supply from coal, where for the condition of NTT the use of gas has increased sharply in the first 5 years, namely between 2015 and 2025, up 10% in 2025 compared to the base year. This indicates that the economic structure of NTT Province will be able to be optimized well, while the contribution of sustainable long-term regional energy management is maintained as seen in 2050 the share of energy use sourced from the RE increased to be 39% increased 15% from 2025 or equivalent to 2.9 MTOE. Sharp increase in RE according to national energy policy targets especially between 2040 and 2050 where it is assumed that in those years the development of power plant technology has been very good, especially from RE plants while coupled by the quality of human resources in the management and utilization of RE technology, but still around 33,18% of electricity supplied is still from coal. The portion of fossil energy in providing electricity generation capacity continues to be reduced. Based on installed electricity generation capacity, the portion of fossil plants in 2015 was around 93.38% and will be reduced to 42.73% in 2025 and 48.58% in 2050 (Nusa Tenggara Timur Government, 2019). But if we compared globally, the proportion of coal and oil in global primary energy consumption was only reduced 61.4% in 2016 (BP Statistical Review, 2017), while proportion of natural gas and non-fossil energy in total primary energy consumption globally increased by 2.7% in the last 10 years. This indicates that the NTT province's energy system transformation will have a major impact not only at the national level but also have a global impact to support achieving the SDGs through local good practice specifically in the energy sector and secure national competitiveness (A. Amheka & Higano, 2018). The achievement of national energy policy targets will have a significant impact on GHG reduction, as shown in the simulation when compared to BAU condition of Province of NTT. The GHG emissions projection in 2025 is 37.1 $MtCO_2e$ equivalent to 4% of total national emissions and the amount of GHG emissions per capita is 6.20 tCO_2e. For 2050 GHG emissions are 172 $MtCO_2e$ is equivalent to 9% of total national and the amount of GHG emissions per capita is 20.78 tCO_2e as shows its trends on Fig.3 ad Table 4.

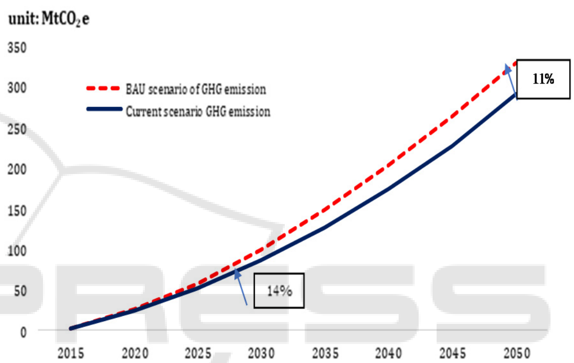

Figure 3: Trend of GHG emission reduction BAU scenario v.s current scenario.

Table 4: Trend of GHG emission reduction BAU scenario v.s current scenario.

YEAR	2015	2020	2025	2030	2035	2040	2045	2050
BAU scenario	3	26	58	99	149	203	263	329
Current scenario	3	25	52	86	126	173	228	291
Optimal scenario	0	1	5	14	23	30	36	38
GHG reduction (%)	0	4	9	14	15	15	13	11

The simulation results also show, the controlling of GHG emissions in 2025 able to reduce up to 9% while in 2050 it is only reached by 11% compared to BAU condition where both scenarios have taken into account the contribution of GHG emissions from power plants.

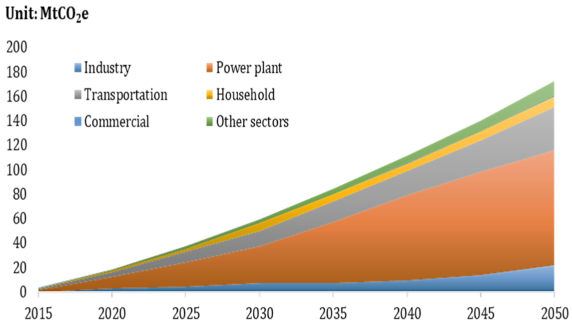

Figure 4: Trend of GHG emission in NTT Province 2015-2050.

In Fig. 4 shows, the power plant sector is projected to be the largest contributor to GHG emissions, followed by sectors of transportation, industrial, household, other sectors and commercial. Power plant, transportation and household sectors make a substantial contribution to the base year, which is more than 30% of each. However, the household sector since 2020 shows a flat increase until 2050, which is in the range of 5% to 6%, this is because after 2020 the policy of using non-fossil energy has been well massively implemented through the utilization of RE potential, for example, to support local and urban and rural gas networks which are getting better, even though infrastructure development to support these two things is still needed. The opposite is happening in the power plant sector, where the emissions released continue to increase dramatically, in 2015 the amount is less than 33% but since 2020 until 2050 the increase is in the range of 50% to 60% of the total emissions of NTT Province. This shows that although national and regional energy policies have been implemented well, they still have not been able to reduce the contribution of emissions from this sector, due to the slow innovations in clean technology management that are implemented in all power plants (Adrianus Amheka et al., 2016). Even though the technology is already available, maintenance from the technical side of these plants has not been optimally carried out due to various constraints both financially and the readiness of established human resources in the operation of clean technology-based plants. Similar to the transportation sector, the upward trend is quite large after the power plant sector, which is due to the economic conditions of the people who have not been able to realize emissions-free vehicles such as electric vehicles, gas vehicles, and maintenance and spare parts due to far from the automotive industry which are all centralized on the island of Java.

For the industrial sector, there is a significant increase in 2020 and after that the trend of flat emission runs in the range of 10% to 11% until 2050, this gives a good meaning where the governance in regional regulations and their implementation is already well done which is able to provide conducive for investors to invest in various industrial fields cleaner production-based such as the use of environmentally friendly industrial technology.

3 CONCLUSIONS

The contribution of sustainable long-term regional energy management will be able to improve national competitiveness and become one of the concrete forms of support for achieving the SDGs through local good practice in the energy sector by reach proportion of natural gas and non-fossil energy in total primary energy consumption globally increased by 2.7% within 10 years. Participation of government and community are very necessary so as the development of an integrated energy system model can be achieved optimally by considering social, economic and environmental factors. Further the discussion give meaning that the current economy structure will able to provide space for optimization in order to achieve local energy security and management target in secure the RE mix target of up to 24% in 2025 and 31% in 2050 while GHG emission decreased 9% and 11% from the usual condition in 2025 and 2050 respectively. Further, controlling to the growth of energy demand and energy consumption is necessary, where it can be probably done through enhance coordination among stakeholders such as government from any aspects, community, business, NGOs locally and the development partners from foreign governments to achieve smart energy systems (Lund et al., 2017). The preparation and availability of qualified human resources in various fields are very necessary in order to maintain the energy and environmental system links, especially in environment-based energy management in the NTT Province and Indonesia in national level and the global world generally.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support from State Polytechnic of Kupang, Ministry of Education, Culture, Research and Technology, Republic of Indonesia.

REFERENCES

Aized, T., Shahid, M., Bhatti, A. A., Saleem, M., & Anandarajah, G. (2018). Energy security and renewable energy policy analysis of Pakistan. *Renewable and Sustainable Energy Reviews*, *84*, 155–169. https://doi.org/10.1016/j.rser.2017.05.254

Amheka, A., & Higano, Y. (2015). An introduction to regional government in Indonesia to success RAD-GRK program: Literature review of GHG emission trends in Indonesia. *Regional Science Inquiry*, *7*(1).

Amheka, A., & Higano, Y. (2018). A novelty design of GHG Emission Reduction Cost for the Province of Nusa Tenggara Timur, Indonesia: A quantitative-based scientific view. *IOP Conference Series: Earth and Environmental Science*, *207*(1), 012062. https://doi.org/10.1088/1755-1315/207/1/012062

Amheka, Adrianus, Higano, Y., Mizunoya, T., & Yabar, H. (2016). Emission reduction strategies in indonesia: Evaluation of socio-economic development trends in Kupang city based on an I/O analysis. *Studies in Regional Science*, *45*(1), 41–60. https://doi.org/10.2457/srs.45.41

Amheka, Adrianus, Higano, Y., Mizunoya, T., & Yabar, H. (2014). Comprehensive Evaluation of the Feasibility to Develop a Renewable Energy Technology System and Waste Treatment Plant in Kupang City, Indonesia based on a Kupang Input Output Table. *Procedia Environmental Sciences*, *20*, 79–88. https://doi.org/10.1016/j.proenv.2014.03.012

Awopone, A. K., Zobaa, A. F., & Banuenumah, W. (2017). Techno-economic and environmental analysis of power generation expansion plan of Ghana. *Energy Policy*, *104*, 13–22. https://doi.org/10.1016/j.enpol.2017.01. 034

BP Statistical Review. (2017). *BP Statistical Review of World Energy June 2017*. https://www.bp.com/content/dam/bp-country/de_ch/PDF/bp-statistical-review-of-world-energy-2017-full-report.pdf

Cai, W., Wang, C., Chen, J., Wang, K., Zhang, Y., & Lu, X. (2008). Comparison of CO2 emission scenarios and mitigation opportunities in China's five sectors in 2020. *Energy Policy*, *36*(3), 1181–1194. https://doi.org/10.1016/j.enpol.2007.11.030

INEP, Pub. L. No. Presidential Regulation No. 22 (2017).

Emodi, N. V., Emodi, C. C., Murthy, G. P., & Emodi, A. S. A. (2017). Energy policy for low carbon development in Nigeria: A LEAP model application. *Renewable and Sustainable Energy Reviews*, *68*(September 2016), 247–261. https://doi.org/10.1016/j.rser.2016.09.118

Ferrão, P. (2017). ScienceDirect ScienceDirect The energy Long-term savings and GHG mitigations in Thailand ' s Long-term energy savings and GHG mitigations in Thailand's building sector : impacts of energy efficiency plan Assessing the feasibility of using the heat build. *Energy Procedia*, *138*, 847–852. https://doi.org/10.1016/j.egypro.2017.10.110

HaCohen-Kerner, Y., & Mughaz, D. (2010). Estimating the Birth and Death Years of Authors of Undated Documents Using Undated Citations. In *Stockholm Environment Institute* (pp. 138–149). https://doi.org/10.1007/978-3-642-14770-8_17

Halkos, G., Tzeremes, N. G., & Tzeremes, P. G. (2015). A nonparametric approach for evaluating long-term energy policy scenarios: an application to the Greek energy system. *Journal of Economic Structures*, *4*(1). https://doi.org/10.1186/s40008-015-0011-x

Handayani, K., Krozer, Y., & Filatova, T. (2017). Trade-offs between electrification and climate change mitigation: An analysis of the Java-Bali power system in Indonesia. *Applied Energy*, *208*, 1020–1037. https://doi.org/10.1016/j.apenergy.2017.09.048

Heaps, C. (2008). An introduction to LEAP: Long range Energy Alternatives Planning System. In *Stockholm Environment Institute*.

Huang, Y., Bor, Y. J., & Peng, C. Y. Y. (2011). The long-term forecast of Taiwan's energy supply and demand: LEAP model application. *Energy Policy*, *39*(11), 6790–6803. https://doi.org/10.1016/j.enpol.2010.10.023

International Energy Agency (IEA). (2018). *Southeast Asia Energy Outlook 2017*.

Kemausuor, F., Nygaard, I., Mackenzie, G., Energy, G. M.-, & 2015, U. (2015). Prospects for bioenergy use in Ghana using Long-range Energy Alternatives Planning model. *Energy*, *93*, 672–682. https://doi.org/10.1016/j.energy.2015.08.104

Kumar, S. (2016). Assessment of renewables for energy security and carbon mitigation in Southeast Asia: The case of Indonesia and Thailand. *Applied Energy*, *163*, 63–70. https://doi.org/10.1016/j.apenergy.2015.11.019

Kusumadewi, T. V., Winyuchakrit, P., & Limmeechokchai, B. (2017). Long-term CO2 Emission Reduction from Renewable Energy in Power Sector: The case of Thailand in 2050. *Energy Procedia*, *138*, 961–966. https://doi.org/10.1016/j.egypro.2017.10.089

Lund, H., Østergaard, P. A., Connolly, D., & Mathiesen, B. V. (2017). Smart energy and smart energy systems. *Energy*, *137*, 556–565. https://doi.org/10.1016/J.ENERGY.2017.05.123

Indonesia National Energy Policy (INEP), (2014).

Mirjat, N. H., Uqaili, M. A., Harijan, K., Valasai, G. Das, Shaikh, F., & Waris, M. (2017). A review of energy and power planning and policies of Pakistan. *Renewable and Sustainable Energy Reviews*, *79*, 110–127. https://doi.org/10.1016/j.rser.2017.05.040

Nusa Tenggara Timur Government. (2019). *General Regional Energy Plan of NTT Province*.

Ouedraogo, N. S. (2017). Africa energy future: Alternative scenarios and their implications for sustainable development strategies. *Energy Policy*, *106*, 457–471. https://doi.org/10.1016/j.enpol.2017.03.021

Pan, L. J., Xie, Y. B., & Li, W. (2013). An Analysis of Emission Reduction of Chief Air Pollutants and Greenhouse Gases in Beijing based on the LEAP Model. *Procedia Environmental Sciences*, *18*(X), 347–352. https://doi.org/10.1016/j.proenv.2013.04.045

Phdungsilp, A., & Ã, A. P. (2010). Integrated energy and carbon modeling with a decision support system : Policy scenarios for low-carbon city development in

Bangkok. *Energy Policy*, *38*(9), 4808–4817. https://doi.org/10.1016/j.enpol.2009.10.026

Wongsapai, W., Ritkrerkkrai, C., & Pongthanaisawan, J. (2016). Integrated Model for Energy and CO2 Emissions Analysis from Thailand’s Long-term Low Carbon Energy Efficiency and Renewable Energy Plan. *Energy Procedia*, *100*, 492 – 495. https://doi.org/10.1016/j.egypro.2016.10.208

Yang, D. D. D., Liu, B., Ma, W., Guo, Q., Li, F., & Yang, D. D. D. (2017). Sectoral energy-carbon nexus and low-carbon policy alternatives: A case study of Ningbo, China. *Journal of Cleaner Production*, *156*, 480–490. https://doi.org/10.1016/j.jclepro.2017.04.068

Zhang, D., Liu, G., Chen, C., Zhang, Y., Hao, Y., & Casazza, M. (2019). Medium-to-long-term coupled strategies for energy efficiency and greenhouse gas emissions reduction in Beijing (China). *Energy Policy*, *127*, 350–360. https://doi.org/10.1016/j.enpol.2018.12.030