Comprehensive Evaluation of Energy Structure Transformation Policies to Reduce GHG Emission in Kupang, NTT, Indonesia: Assessment of Renewable Energy Technologies with Extended Dual Input-Output Analysis

（インドネシア、**NTT**、クパンの **GHG** 排出量削減のためのエネルギー構造変換政策の総合評価：拡大双対型産業連関表を用いた再生可能エネル ギー技術の評価）

Adrianus Amheka (201235023)

Doctoral Program in Sustainable Environmental Studies

Graduate School of Life and Environmental Sciences

Abstract

The Indonesian government set the target agreed at COP-15 Copenhagen to reduce greenhouse gases (GHG) emission between 26% or around 0.767Gt for self-effort and 41% or around 1.2095Gt if assisted by international support by 2020 based on 2005 emissions. The aims of this study are to produce a comprehensive mechanism and/or policies of energy structure transformation to reduce GHG emission in Kupang City. These include improvement of regional economic development and preparation for entering Sustainable Development Goals (SDGs) as post Millennium Development Goals by 2015, facilitating success in the National/Regional Action Plan-GHG emission of the Kupang government as well as improving regional competitiveness prior to involvement in the ASEAN Economic Community (AEC) in 2015.

We use a mixed quantitative and qualitative research design to address the objectives of the study while assumptions, including assumption of RET are applied as accurately as possible. The cases are set without introduction of both the carbon tax and renewable energy technology (RET) (case1), with introduction of the carbon tax and without introduction of RET (case2), and with introduction of both a carbon tax and Feed-in tariff with RET available (case3). All cases are under the GHG emission reduction rate (n) and prices are changeable. The hypotheses are the introduction of RET will improve the trade-off between Kupang GRP and GHG reduction and we

expect that the trade-off is further improved by introduction of consumption carbon tax and RET; The introduction of RET is more effective in improving the trade-off between Kupang GRP and GHG reduction as *n* increases and the efficiency index (EI) of every RET increases as *n* increases, and holds, though higher EI's through optimization are not automatically selected; and GHG reduction cost decrease drastically compared among cases with same/any *n*, the marginal cost increases as *n* increases in any cases and then decreases sequentially after introduction cases with same/any *n*.

The study first introduces the trends for GHG emission and RET conditions in Indonesia, creates a Kupang input-output model for year 2010, determines the polluting sectors and assumes an increase in final demand and changes in prices index for some priority sectors. It then investigates the impact on related sectors and estimates the indirect GHG emission coefficient along with the total and shared amount of GHG emission caused by economic activities in Kupang. The current electricity systems and potential to develop RET in Kupang as well as issues regarding the Feed-in tariff for RET are also described. We also construct a comprehensive model with reference to market flow condition, added value distribution such as carbon tax and Feed-in tariff of RET for improving the trade-off between economic development and GHG emission reduction in order to transform new energy industries (solar power, wind power and biomass methane fermentation technology) in Kupang while GRP is kept as high as possible.

As a result optimization, through the introduction of a special set carbon tax and subsidy flow back to related sectors is very effective in improving Kupang GRP between 12.86%~19.43% compared to current GRP and decreases GHG emission in Kupang up to 20% or around 0.028% compared to total GHG emission in Indonesia by 2020. With subsidy from the special tax the development of new energy industries is possible with total electricity produced from solar power around 15.91%~16.07%, wind power around 8.80%~9.94% and biomass power around 0.26%, while total shared electricity consumed by households compared to diesel power plant is 17.89%~28.79%. The Feed-in tariff is stable around (14.312~16.632) Billion Rp/MWh while electricity price rose to stabilize around 11.68%~12.03% compared to before optimization. The comprehensive social cost-benefit analysis of every RET in the EI could be a reference develop RET due to an increased EI in line with an increase in *n*, however, in combination with RET it is necessary to consider the Feed-in tariff system as well as supply and demand in electricity. All estimated amounts mentioned are under the same *n* between 14%~20%. For GHG reduction cost take sample *n*=14%~20% the cost reduced around (15~25) Billion Rp compared between case1 and case2 (22.7~51.8) Bilion Rp compared between case2 and case3. The marginal cost for *n*=15%~17% decreased around (3.2~204) Billion Rp and (895~45.7) Billion Rp compared with the same case as GHG reduction.

We provide evidence to government, which indicates that within the current energy structure in Kupang is possible to optimize solar power, wind power and biomass methane fermentation technology, and also control GHG properly. It is possible to adopt or adapt the method we offer on a regional or national scale. Besides lack of RET data, the GHG emission coefficient data must be more detailed in order to obtain the exact amount of GHG emission in a region based on its economic activities.

The simulation model has no idea of stocks. So our analysis of simulation results is limited to static analysis. To complement this dynamic path analysis should be conducted as it can be realized in a real setting. Therefore, any scholar using this Inventory data for further research and/or extending the study complexity through mechanics and/or policy proposal should be as accurate as possible.

The study contributes to Indonesia in terms of creating a certainty for the estimated amount of GHG emission caused by economic activity on a regional scale, especially integrating Kupang green economic growth and creating a new clean energy industry in order to facilitate regional competitiveness in preparing AEC and SDGs by 2015.

Summary

Indonesian government is targeted to success National/Regional Action Plan-Reduce GHG emission called RAN/D-GRK. Kupang as capital city of NTT province is dedicated to promote programs for purpose support reduces GHG emission in society while promoting prosperity. The thesis introduce application of carbon tax and renewable energy technology (RET) to reduce GHG emission in Kupang by extended dual input-output (IO) model and conducts with a broad comprehensive analysis taking into account economic implication of GHG emission restriction.

Structure of the thesis consists of seven chapters. Chapter 1, describe study background covering various aspects associated to GHG emission trends in national and regional Indonesia including activities in pursue GHG reduction target by 2020, motivation and aim of the research linked to readiness of Kupang to enter sustainable development goals and ASEAN economic community, followed by literatures review, reviewing past and current studies regarding GHG emission reduction from different perspectives as well as figure out originally of the study predict GHG emission as revealed in study objective in a different way and comparing achievement and limitation from previous study. The chapter also describe how interconnection of Kupang city vision into globally cooperation among ASEAN countries. For chapter 2, introduce how to construct a Kupang IO model 2010 through a detailed approach of NTT IO model 2006. Considers geography, population and socio-economic condition as well as accurate assumption which applied in NTT province and Kupang city which make it more certain and optimum. Leontief inverse matrix is applied in the model, then analysis a prediction increase in final demand and added value coefficient (to get price index) in some priority sectors based on the model. It has found the ratio between additional total output and additional final demand biggest from gross domestic fixed capital formation of building sector and import of industry goods from metal sector where around 1.90 and 1.95 respectively, while the price index that most influenced to almost all sector is when increase added value coefficient of trades sector. In chapter 3, identify the pollutant emission structure by estimated amount of indirect GHG emission coefficient each sector. The largest emissions are from the fertilizer, chemical and refining industry,

electricity and water supply, construction or building, trades and government sectors. For estimated amount of total GHG emission in 2010 for GWP 20 years is 0.049% and 0.047% for GWP 100 years and both is compared to total GHG in Indonesia at the same year. In chapter 4, inform central government planning to integrate network management of power plant around Indonesia including Kupang, NTT and explained their current electricity system such as electrification ratio and potential to develop RET. The chapter 5, explain widely and deeply understanding relationship environmental policies and economic structural with emphasis on introduce formula specification on carbon tax, RET sectors as well as optimal formula of Feed-in tariff of RET where it has set in the form cases under GHG emission constraints (n); and the assessment covering market flow condition includes demand and supply for goods and services, added value and distribution such as income and expenditure of household and government including carbon tax and subsidy as well as macro-economic account includes maximize Kupang economic and a formula to estimate Kupang GHG emission. There is no capital stock identified in the model. In early of the chapter, has placed assumption scales of capacity of solar panel, wind mills and a biomass methane fermentation technology as well as framework of current and future conditions describe comprehensive condition before and after introduce proposed mechanism and/or polices to control GHG emission in Kupang. For chapter 6, examined results of the simulation which informing detailed analyses after introduce proposed policies in terms of improve Kupang GRP, GHG reduction, energy transformation from current energy structure as well as social cost-benefit analysis including GHG reduction cost. It has found the current industrial structure can increase GRP but is not optimal in terms of GHG emission control, thus by specifying a carbon tax with n=14%~20% and subsidy back to designated sectors are effective in developing RET while GHG decreases up to 20% and GRP improves 19.43% compared to current GRP. The Feed-in tariff of RET acceptable use as subsidy to a total amount of (14.312~16.632) Billion Rp/MWh. The electricity sector price index increases 11.68%~12.03%. Change in energy structure transformation is dominated by solar power with a percentage share of electricity supplied is 14%~16% and wind power around 8%~10% compared to current electricity production. The electricity supply from these new energy industries are 27%~28% compared to current electricity supply (diesel power plant). Electricity supplied from biomass methane fermentation technology is limited at 0.23%~0.26% because this power plant is not a priority in Kupang. The efficiency index is improved in line with the increase of *n*, but it should be linked to the Feed in tariff system as well as supply and demand of electricity. The reduction cost is significantly decreases by introducing carbon tax and RET in any *n*. For average GHG reduction cost at *n*=14%~20% the cost reduced around (15~25) Billion Rp compared *with* and *without* introduction carbon tax and (22.7~51.8) Bilion Rp compared *with* introduction both, carbon tax and Feed-in tariff of RET. The marginal GHG reduction cost at *n*=15%~17% decreased around (3.2~204) Billion Rp and (895~45.7) Billion Rp compared with the same cases as mentioned in same/any *n*. Overall, optimization substitution of the electrical system could encourage growth of a sustainable green economy while mitigating optimally controlled GHG. In chapter 7 contained conclusions, limitation and future work. The data limits such as no capital stock is identified, thus the model must be limited as far as static analysis. We pleased if scholars use the inventory data we provided for further research (dynamic analysis). The method offered here can be adopted and adjusted in any region, or in Indonesia as a whole.