CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

The goal of this study is to develop the life cycle impact assessment model for Thailand based on endpoint modeling. The aim is to integrate the characterization, damage, normalization, and weighting factors into an impact assessment model. This chapter provides the key points of the conclusion as follows:

7.1 Impact assessment model for Thailand

There are a variety of environmental problems that are occurring in Thailand today. This study only included five impact categories from environmental problems: global warming, human toxicity, ecotoxicity, eutrophication, and acidification. The impact assessment model included fate, exposure, midpoint indicator, midpoint category, endpoint indicator, endpoint category, normalization, weighting, and integrated models. The cause–effect chain of environmental problems might be used in the development of the model. It should include all possible effect chain and variables which affect the model. Therefore, the conclusion of each model is as follows:

7.1.1 Global warming model

There are a variety of effects from global warming that are occurring in the world. The Union of Concerned Scientists, (2013) had predicted that the main results of global warming which will occur are loss of biodiversity and intense heat waves which will affect human health. Those of effect were excluded from consideration in the impact assessment model. However, all possible effects from global warming should be included in the model. The global warming on human health shall include hot and cold stress, and diseases transmitted through insects as dengue hemorrhagic fever. Effects on social assets shall include both main agricultural production such as maize, cassava, and sugarcane, and wheat and oil production as oil palm and corn. Effects on primary production shall include loss of aquatic and freshwater ecosystems, while effects on biodiversity must be included.

The general calculation model was based on Schryver, *et al.*, (2009), which supported had many data requirements, such as relative risk and Disability Adjusted Life Years (DALYs) of disease. First, more data needed to be related, such as the DALY of disease from WHO was calculated before 2000, while relative risk is based on 2020–2030, and time horizon on 100 years. In the future, data must be based on updated and improved information. And more important for this damage is the fact that this approach does not enable improved studying of temperature factor and the midpoint impact category. In order to potentials of global warming insignificant within development the same as any impact models as LIME and ReCiPe (H) factors were using the IPCC database. The temperature factors of each greenhouse gas can be developed, which would have advantages in separating direct and indirect effects of greenhouse gases and including land use change within temperature factors.

Besides, not only Schryver, *et al.*, (2009) gave ideas of global warming damage, but Il, e*t al.*, (2012) also has adapted social–environment–economic estimations of global warming damage on human health. This is the required temperature increase (°C) in every year depending on population, economic growth, areas, and disease. In future, comparison models should be discussed.

Moreover, damage on human health can be reflected to Thai people if there is severity of disease that is an effect of global warming, but not only human health, other effects such as on social assets, primary production, and biodiversity should be included.

Uncertainty of damage function is also important to be elucidated. Preliminary studies have begun for the damage function of global warming for Thailand. Future analysis is required to comprehensively evaluate the uncertainty/sensitivity of the damage function.

7.1.2 Human toxicity model

Human toxicity in Thailand varies greatly depending on the location of emissions. This study selected the IMPACT 2002 model to estimate the human health effect of human toxicity due to cancer and chronic diseases. The IMPACT 2002 model includes indoor vs. outdoor, urban vs. non-urban, and regional scales, of which the regional scales can also be adapted to assess specific emissions for processes situated in a known location in Thailand. Applying the regional scale, as air zones or watershed zones, would mean changing parameters into Thai databases. The parameters need input such as area of lakes and watershed areas that it seems no database has because the boundary areas are not clear. For example, the water parameter input model required watershed, river, and lake areas, which had a total land area of 100 km^2, but the database presented 80, 20, and 50 km^2 for watershed, river, and lake areas, respectively. This is impossible data due to overlapping of the areas by government agencies. Next, the food consumption, such as pig and cow, model required the mass of Thai-consumed food per year, whereas the database reported numbers of production including export production. Also, for the main intake of toxic chemicals by Thai people from fishery production, the model required deep sea, offshore, coast, sea culture, inland water, culture fish, and fish in lakes. This study was estimated based on type of fishery lived due to lack of information. In future, those following should typically consider mass and number, types of fishery production, and types of land to benefit this model. Besides, USE-LCA, USEtox, and EDIP are models which can evaluate human damage. Comparison of damage from each model should be considered.

This study is based on mathematic equations including fate analysis, exposure analysis, potency, and severity. Fate and exposure analysis varied on data input in the model. Potency and severity was based on the concept of a benchmark dose from Crettaz, *et al*., (2002a, b) and Pennington, *et al*., (2012). In the future, these factors should be developed for Thailand, to be beneficial for research.

7.1.3 Ecotoxicity model

The chemical substances effect on ecosystems used the IMPACT 2002 model, which was modified to be suitable for Thailand, the same as the human toxicity model. The calculations for ecosystems required the status of biodiversity in Thailand such as algae, crustaces, fish, mollusca, annelida, and amphibians. The International Union for Conversion of Nature (IUCN) needs every country in the world to report the status of biodiversity. However, it did not report the status of biodiversity of all species in Thailand. This is very important to estimate the chemical effects on ecosystems.

This model applied the Assessment of Mean Impact (AMI) to calculate the chemical substances effects on ecosystems. The AMI model estimated effects on ecosystems by adapting a model from the statistical estimators of various databases, such as Derivation of Predicted no Effect Concentrations (PNEC), and No Effect Concentration (NEC). For the future, this is very helpful for development of a model for the Thai situation.

7.1.4 Eutrophication model

Eutrophication is one of the main environmental problems in Thailand. The main lakes to consider the eutrophication effect of in Thailand are Phayao and Songkhla lakes, but Cha-am beach, Hua Hin beach, Si Chang Island (Sahanawin and Torit, 2012), and Bung Boraphet (Kammuang, 2010) had also suffered the effects of eutrophication. Because these areas are in high economic zones, that they should be included for estimation of eutrophication effects in the model.

Estimating eutrophication damage on social assets involves three steps: fate analysis, damage assessment, and impact assessment. Fate analysis was excluded due to lack of information. This study used nutrient loading in each area, such as Nitrogen (N), Nitrate (NO_3^-), Phosphorus (P), and Phosphate (PO_4^{3-}), etc. to estimate eutrophication potential, but some of the data is not reported yet.

For damage assessment damage from Japan was adjusted due to lack of data. Damage assessment used an ecosystem model that included a material cycle model and hydrodynamic model to simulate the state of eutrophication in the area. Climate data, land use, and social situation are required input data for simulating hydrodynamic models, while water quality is required output data, using N, P, and C from water quality simulated under change of DO concentration. Ecosystem models can be simulated using other models, namely, the Coastal Marine Ecosystem Model (Sohma, *et al*., 2001) and the Basin Integrated Management Model (LBIM) (Sato, *et al*. 2008), which are developed from Japan, and the CARMEN model, developed from Europe (Struijs, *et al*., 2011). The eutrophication model is required to identify specific areas of the ecosystem model that help achieve.

Impact assessment required the economics of fishery production based on market production evaluated by environmental economics, which will be beneficial to evaluating damage more than using sales production.

7.1.5 Acidification model

The damage function of acidification for terrestrial ecosystems, wood production, and material degradation easily gives concrete Net Primary Production (NPP) and social assets damage due to an additional emission of its causative substance. Expansion of endpoints, not only NPP damage of terrestrial and social assets but also reproduction damage of aquatic ecosystems, human health damage with regard to drinking water toxicity, and of course the aspects of biodiversity, is an important subject for future work to comprehend the present impact assessment framework of the impact category of acidification.

The acidification model used the Source–Receptor Relationship (SRR) model to estimate the effects of a load of acid on the surface through to the atmosphere. But this research is not considered due to models being unavailable in Thailand. The future of model development will include SRR for acidification model development. Moreover, development of the acidification model only considered emissions of Thailand loading, but this regional impact level will allow a scale-up to regional level for future development.

Aluminum (Al^{3+}) toxicity is well known as one of the causes of forest and/or vegetation decay (Larssen, *et al*., 1999), which was selected in this study as the main cause of indirect effects on terrestrial ecosystems and separation into wood production induced by acidification. However, other causes of impact regarding indirect effects of soil acidification such as cation deficiency and heavy metal toxicity are considered.

The concentration of leachate Al^{3+} without threshold value, therefore being essentially toxic, was applied to express the aluminum toxicity in this study. Another index, such as the ratio between base cations and Al^{3+} in soil solution (BC/Al) (Pannatier, *et al.,* 2004), is considered for future analysis. It should be noted that only one area expressed concentration of leachate Al^{3+} due to no data in Thailand, and aluminum toxicity to plant growth rate was based on Japanese data of only one tree species. Damage on material was also based on Japanese data. These would be subjects to improve the model. Moreover, this research excluded acidification which may also possibly affect biodiversity due to lack of data. For wood production, the product of forests and the crop yield as a result of acidification was required. However, this was hardly possible to do, but if there was clear data then it would be possible to easily explain the effects of acidification to Thai people about.

7.2 Weighting factors for integrated model

This study weights safeguard subjects by applying the contingent valuation method technique. Contingent valuation was examined as a feasible method for calculation of monetary value of avoiding a unit amount of damage to a safeguard subject.

The current results indicate that human health is regarded as the most important factor, social assets the second most important factor, followed by primary production, and biodiversity.

7.3 Applying impact assessment to life cycle assessment of electricity in Thailand

This study investigated life cycle assessment of electricity in Thailand by using the impact assessment model developed in this study. Total economic cost of electricity is 0.10 – 147.94 Baht/kWh due to acidification damage from coal–fired power plants.

Based on the energy policy on electricity generated by fuel types in Thailand, in 2015, 62% will come from natural gas, 21% from coal/lignite, 14% from solar and renewable energy, and 3% from water (EPPO, 2012). The economic cost of power plants, based on share of fuel types in Thailand, found that the cost of power plants is 4.91 – 40.83 Baht/kWh, which is mainly from coal–fired power plants, followed by natural gas power plants. Based on the energy policy on power plants, natural gas fuel will be decreased and replaced with nuclear power plants in the next 6 and 15 years. The economic cost can be decreased 3.89% and then increased 2.57% in comparison with the year 2015 (Fig. 7.1).

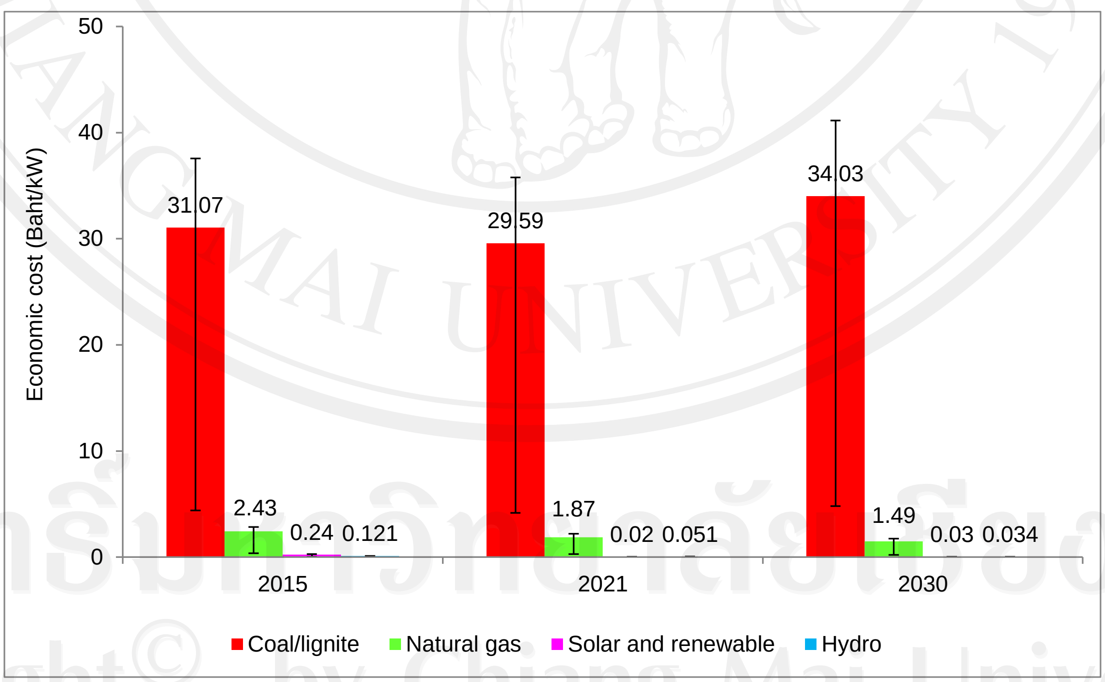

Figure 7.1: Economic cost electricity power plant in Thailand

7.4 Recommendations

Future recommendations for the impact assessment model based on endpoint modeling are to develop other damage and other impact categories under conditions for Thailand. Most importantly, expert specialists are required to help with the development model so that they will soon understand the model. For example, weighting factors required environmental–economic and social experts, who can help with the interviews and estimated economic costs. Second most important is the database required for development of the impact assessment model, which involves all research fields, and general information (population, education, climate data, etc,) of Thailand.

The impact assessment model based on endpoint damage can be improved in the future as follows:

- The global warming model should consider the relationship of predicted temperature with economic growth, and time horizon. Damage to hot and cold stress should be added into the model and also damage to biodiversity. Moreover, data should be improved to include amount of net primary production of local area in the world and yield of agricultural production such as rice, palm oil, and maize.
- The human toxicity model should be developed into an impact model based on other models such as IMPACT 2002, CalTox, and USE-LCA, under conditions for Thailand. Potency and severity should be improved in Thai databases. Type of fishery and area should be made clear beforehand. Effect on ocular (eyes) and respiratory systems should be added in the human toxicity model.
- The ecotoxicity model should be developed for both aquatic and terrestrial effect factors based on other methods (such as AMI). Damage on terrestrial ecosystems should be included. Finally, biodiversity status should be improved.
- The eutrophication model should develop an ecosystem model of each water area. However, primary information, such as temperature, pH, nitrogen, etc. should be collected for development of the model. Damage on human health and biodiversity should be included in the model.

- The acidification model should require a fate model of the atmosphere of Thailand, pH and Al^{3+} in soil, a database of types of soil related to international soil type, plant growth under acidification, and net primary production. Damage on respiratory systems is required for effects on human health, whereas fishery production is required for effects on social assets.
- Weighting factors should have an improved questionnaire, such as making double bid questions, sample data should include any location and any career in Thailand, and the experiment should be repeated two or three times.
- Electricity power plants should have an improved database, which covers input and output data if that is possible.
- All models' uncertainty and sensitivity must be considered.

For the future, the impact assessment model on endpoint damage is recommended to estimate environmental costs of products and services through their life cycle and it could become successful for decision-making and policy definition. For the application of this study it could be linked to LCA software, such as SimaPro and Gabi, after completion of the model and after critical reviews from experts.