CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

A comprehensive cradle-to-grave life cycle assessment (LCA) of asphalt was performed to evaluate the environmental impacts of hot-mixed asphalt (HMA) and warm-mixed asphalt (WMA) in terms of global warming potential (GWP) and energy input, with a focus on different end-of-life management scenarios of the asphalt pavement and the use of RAP LCA. For this purpose, an LCA-based tool was developed and implemented in a spreadsheet software application, which computes the impacts of asphalt pavements automatically.

The life cycle of road pavements was divided into six major stages: including raw materials, production, transportation, pavement (use), dismantling and end of life. The end-of-life processes focused in this study are: reuse (cold in-place recycling), recycle (hot in-place and in-plant recycling) and landfill (disposal). The functional unit was set to be 7 m x 1 km x 0.05 m of road pavement. For HMA and WMA, relevant data are come from previous study (Leedilok, S., 2013), considering only the stages of production, transportation and pavement. However, for dismantling and end-of-life, data for LCA analysis are estimated from literature based on Miliutenko et al. (2013).

The following points can be summarized as the conclusions of this study: The results clearly show that end-of-life phase plays very important role in determining whole life cycle environmental and energy performance of asphalt. If appropriate end-of-life management was used, it would significantly help to reduce the life cycle environmental impacts and energy consumption of asphalt pavement. Recycling has shown to be better than reuse and landfill both in terms of GWP and energy consumption. Among recycling technologies, hot in-place recycling, which the most environmental burden comes from propane used for heating and mixing, shows the whole life cycle benefit higher than hot in-plant recycling which the most environmental burden comes from transportation of RAP in term of energy consumption but lower benefit in term of GHG emission. The comparison between the BAU (business as usual) case and the best case (case 4 [Cold in-place recycling : Hot in-place recycling : Hot in-plant recycling = 40:30:30]) shows that case 4 is the highest reduction of energy consumption (for HMA 8.69% and WMA 8.40%) and GHG emission (for HMA 22.17% and WMA 22.00%). Whole life cycle assessment including end-of-life process of WMA shows the benefit higher than HMA about 2-3%. A key advantage both HMA and WMA is the potentially greater use of RAP. Thus, the decrease in the impacts achieved by adding large amounts of RAP in HMA and WMA could turn these asphalt mixes into a good alternative in environmental terms.

5.2 Recommendations

Although the life cycle environmental impact assessment was successfully conducted for two types of asphalt (HMA and WMA), several recommendations could be offered as follows:

5.2.1 Suggestions for Improvement of Inventory Data

In hot-mixed asphalt, we want more completed data. The completed data should be kept up for long term, because it will make the reliability for data.

In term of warm-mixed asphalt, it is very hard to set the WMA production condition in a plant in Thailand. Thus, the actual warm-mixed asphalt data from asphalt mixing plants are extremely limited. However, we can resort to get data by calculation based on information from literature; it may not be good representative of locally practical case. In order to get good results should seek information from the company that easily allows to give the data for our study.

Finally, as the inventory data from Miliutenko *et al.* (2012) which is the sole literature that was used as secondary data for the end of life of asphalt. It has several assumptions and estimations which were made in order to have enough data to assess the environmental impact as planned. This could be improved if more complete and transparent data were achieved.

5.2.2 Suggestions for Improvement of Environmental Performance

From the results, it can be seen that GWP impact mainly comes from the production of asphalt which covers the raw-material and production. We have shown that utilization of recycling asphalt help to reduce GWP significantly. Developing recycling asphalt system is an interesting choice to reduce GWP and can reduce energy input especially, hot in-place and hot in-plant recycling which show the benefit in term of energy consumption and GWP.

Nevertheless, Long-term ageing still needs to be studied in greater depth since this may be the area where there are more improvement of RAP technology including the greatest differences between HMA and WMA. Moreover, more data for actual performance of production should be collected to ensure the reliability of data.