CHAPTER I
INTRODUCTION

Greenhouse gas emissions, climate change and energy resources depletion are the main problems in the present world. Every country needs to develop their economy and society in compliance with the environmental development. The impacts on energy consumption and potential environmental burdens are effectively analyzed by using many indicators such as energy intensity per GDP, CO_2 emission, global warming potential (GWP), etc. (David *et al.*, 2004). Thus, all sectors must help reduce the consumption of fossil-based resources and greenhouse gas emissions. In this perspective, petroleum industry is closely related to energy and environment in both direct and indirect ways. The main feedstocks for this industry are crude oil and natural gas, which are non-renewable fossil-based resources. In addition, most petroleum processing involves energy-intensive processes which results in high environmental impacts associated with the petroleum products and the subsequent downstream processes and/or the applications of these products.

One of the main petroleum products of the oil refineries is bitumen. Almost of bitumen has been used to produce asphalt, which is consequently used to paving all kinds of road for transportation. At present, most of the construction of typical road in Thailand utilizes conventional hot-mixed asphalt technology (HMA) for pavement. It is known that both production and pavement of HMA requires high temperature and high energy consumption. As a result, a new technology of asphalt production and paving at much lower temperature has been developed which is warm-mixed asphalt technology (WMA). Several countries including Thailand have paid interest in this new technology with the attempt to help reduce both energy resource consumption and global warming impact. The benefits of WMA are energy saving and less environmental impacts than HMA which come from the reduction of mixing and pavement temperatures of approximately 20-55 °C lower than HMA. This could result in as high as 55% reduction in the energy consumption (Kristjansdottir, 2006).

Not only the production of asphalt and pavement that have threatened the environment and public health, but also waste materials from end-of-life of the pavement. When an asphalt concrete pavement reaches the end of its design life, the road surfacing is milled, creating a milling waste material known as Reclaimed Asphalt Pavement (RAP). The RAP materials contain aggregates and asphalt binder, which are transported to an asphalt plant for recycling. RAP is 100% recyclable and has become a popular waste material in pavement construction and rehabilitation. The use of RAP has been favored over virgin materials due to the increasing cost of asphalt, the scarcity of quality aggregates and the pressing need to preserve the environment (Al-Qadi *et al.*, 2007). Many studies claim that the use of RAP in asphalt pavements can help to offset increased initial costs, reduce energy consumption, conserve natural resources, avoid disposal problems, and ease pressures on landfills (Chiu et al., 2008; Huang et al., 2007; Chowdhury *et al.*, 2010; Rubio *et al.*, 2012). In this aspect, it has been reported that WMA has highly potential use of RAP. The improved workability of WMA leads to a lower production temperature, with less ageing of the binder, thus counteracting the stiffer RAP binder (Rubio *et al.*, 2012). Some studies have reported as high as 50% RAP for WMA (D'Angelo *et al.*, 2008; Vaitkus *et al.*, 2008).

In previous study of the project, the life cycle assessment of HMA was evaluated by collecting inventory data covering raw materials acquisition, production, transportation, and road pavement, mostly at Bangbuathong site of THAIWAT ENGINEERING CO., LTD. The inventory data were analyzed energy consumption and environmental impacts based on LCA approach. The results of HMA were compared with the results of WMA, which were calculated based on simulation and secondary data found in the literatures since there were no primary production data available for WMA in the period of previous project. The comparison of the environmental impacts between hot-mixed and warm-mixed asphalt in terms of energy (MJ per functional unit) and GWP (kg CO_2 eq. per functional unit) revealed some benefits of WMA over HMA, but not significant (approximately 5%). It should be noted that limited amount of data were used in the analysis of this study as the primary production data of HMA provided by

THAIWAT ENGINEERING CO., LTD. were from only 3 months of their operation in 2012. Moreover, the end-of-life (demolishing/disposal/recycling) was not included in the scope of the previous study as well as the use of RAP.

Therefore, this research focuses on whole the life cycle assessment study of WMA in comparison with HMA, covering the entire life cycle from raw materials acquisition, production, transportation, pavement, and end of life (disposal, reuse or recycling) including the study of scenario analysis for suggestion the best scenario of end-of-life asphalt management. The inventory data of whole the life cycle asphalt both HMA and WMA in term of raw materials acquisition, production, transportation and pavement were used from previous study. However, the study aims to collect the inventory data of WMA and HMA at actual production, pavement and end-of-life sites. The inventory data were analyzed by life cycle assessments (LCA) software in order to quantify the environmental impacts in terms of energy consumption and global warming potential (GWP). In this study, attempts were especially focused on end-of-life of asphalt pavement is treated either by landfill, reuse, or recycle as RAP. Scenario analysis was performed in order to find the best end-of-life process scenario which can mostly reduce energy consumption and GWP both of HMA and WMA. In addition, suggestions for scenario were offered to make the best way to manage end of service of and how to improve it.