CHAPTER 1
INTRODUCTION

1.1 Rationale

Biofuels nowadays have gained recognition as one of the most important alternative fuels for transport. From 2001 to 2007, the global annual production of bio-ethanol and biodiesel grew by 23% and 43%, respectively [1]. This boom in the biofuels industry is likely to continue in the near future driven by high oil prices [2-4] and energy policies of many nations which have established goals for substituting biofuels for petrol fuels [5-6]. For examples, the US proposed target of increased producing bioethanol to 36 billion litre by 2022; the EU expected that 10% of transportation fuel must be replaced by biofuels by 2020. China, the emerging giant of the world economy and international energy markets, also promoted biofuels by setting at 10 M ton/year for bioethanol and 12 M ton for biodiesel by 2020; meanwhile, India announced the target of 20% biofuels in the transport mix by 2017 [1,5,7].

The commercial biofuels, presently, are first-generation bio-ethanol and bio-diesel produced from agricultural commodities such as sugarcane, cassava, corn, soybeans, grains and oil seeds. Both of them can be used to replace conventional fuel in modified spark-ignition engines in pure form and blended with oil. The development of biofuels for transport is supposed to provide new economic opportunities and to drive society with high standard of living and reduced environmental impacts. Several benefits are expected from biofuels, i.e. decreasing on the dependency of oil imports, mitigation of global warming impact and boosting rural economy such as farmers, labour and employment in local community. This is especially for the developing countries which are agricultural based countries and highly relied on imported oil such as Thailand. An increasing of oil prices is leading country face political, economic and social challenges. Therefore, using biofuels produced from local feedstocks have a great potential to reduce country's oil bills and strengthen access to energy. Nevertheless, an increasing of use and trade in first generation biofuels also led to some concerns that have been discussed seriously among people, communities and governments throughout the world e.g., food versus fuels, competitiveness of biofuels versus petrol fuels, impacts on land use and land transformation, Net Energy and GHG Balance of full biofuels system and the other environmental and social consequences from an increased demand for biofuels.

For Thailand, the Royal Thai Government (RTG) hurried to press promotion of biofuels production and used in the country as one of the important strategies to against the energy crisis caused by the raised oil price in the world market as it had reached the historic zenith at range 115 - 120 $US per barrel (in June, 2008). Bio-ethanol derived from cane molasses, cassava and sugarcane has been strongly receiving attention by the RTG to partially substitute conventional gasoline. Currently, there are three types of gasohol blends in the market i.e. E10, E20 and E85. Gasohol blends E10, a 10% blend of bio-ethanol with 90% gasoline, was first introduced in 2004 while, E20, a 20% ethanol blend, was introduced in 2008 after E10 had penetrated the market. E85 gasohol has been recently launched but at a very limited level since August 2008. Bio-ethanol production has continuously increased from 0.37 M.litres/day in 2006 to 1.03 M.litres/day in 2009 [8] and is inclined to continue as per Thailand's 15 years renewable development plan (2008-2022) [9]. The ambitious goals of bio-ethanol production have been set at 3, 6.2 and 9.0 M.litre/day for short-term (by 2011), medium-term (by 2016) and long-term (by 2022), respectively. The promotion is mainly for domestic consumption; however, there would also be a great potential for export as the statistics reveal that 91 M.litre surplus bio-ethanol was exported to other countries such as Singapore, EU, Australia and the Philippines since 2007 up to the end of 2009 [10]. While, the targets of biodiesel production in Thailand by the years 2011, 2016 and 2022 are set at 3, 3.64 and 4.5 million litres/day, respectively [9]. B5 biodiesel, a mix of 5% B100 with 95% of diesel oil, has already been launched on the market as a voluntary program. According to policy targets set by the government for biodiesel, B10 is expected to be available for use nationwide by the year 2012 [11].

Regarding these policy goals of biofuels development, the today question for Thailand is not whether biofuels will play a significant role in providing energy for transportation, but rather what the consequences and sustainability of their use will be – for the economy, for the environment, for country and global security and for the health of societies. In other words, the sustainability of biofuels in Thailand needs to be assessed in order to identify and evaluate whether biofuels have any barriers in the context of sustainability and how to improve biofuels system.

1.2 Literature Reviews

The term *"sustainable development"* has a variety of meanings, however, the standard definition provided by the Brundtland Commission *"to make development* *sustainable — to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*" [12]. The concept of *"sustainable development"* or *"sustainability"* aimed at consideration, integration and balance on the "triple bottom lines (TBL)"—economic, ecological and social dimension in every decision making. This is as well as a decision making on biofuels policy which nowadays biofuels are a subject that has triggered sharply polarized views among policy-makers and the public [13]. The expectations with regard to biofuels derived from energy crops as a source of sustainable energy for transport are high; but there are also certain risks and undesirable developments attached to the large-scale use of crops for fuels or the unregulated biofuels expansion. It may lead to damage to nature and the environment and to detrimental social and economic effects. Therefore, towards sustainable production and use of biofuels, the following sustainability issues needs to be investigated by considering on the full life cycle of biofuels system.

1.2.1 Sustainability issues related to biofuels

1.2.1.1 Net energy and Greenhouse gases (GHGs) balance

GHGs emission from fossil fuel combustion is a major cause of climate change. According to the principle that the plants grown as feedstocks for biofuels production absorb carbon dioxide (CO_2) from the atmosphere through the photosynthesis process, then combustion of the biofuels simply releases the CO_2 previously absorbed by the plant. However, one of the controversial issues in relation to biofuel system is that whether it can help reduce dependency of fossil energy and reduce GHG emissions when considering on its entire life cycle. Net Energy Balance (NEB) and Life Cycle Assessment (LCA) are useful tools for the evaluation of environmental sustainability and for identifying opportunities to improve the environmental efficiency of biofuels. In general, NEB is used to measure energy efficiency and effectiveness in fossil resources reduction from using fuels by looking at the overall fuel cycle. On the other hand, LCA can be used to identify and evaluate potential environmental implications of biofuels in order to improve environmental performance.

A variety of bio-ethanol and biodiesel systems have been assessed by these two methods in the past decades. For example, Hodge (2002) concluded that using ethanol for US gasohol should be banned because the net life cycle energy indicated that more energy was needed [14]. However, the recent study of Shapouri et al. (2004) summarized that corn ethanol was energy efficient as indicated by the net energy ratio greater than 1 and a positive net energy value [15]. Not only corn ethanol but the NEB & LCA of other feedstocks such as cassava, sugar cane and cane-molasses have also been studied to identify energy and environmental performance of biofuels [16-23]. For instance, Leng et al. (2008) conducted a life cycle inventory to compute the energy conversion efficiency and environmental impacts related to cassava ethanol in China. The results indicated a positive conversion efficiency of fuel ethanol at 1.28, the main contribution of energy consumption was from the unit of denatured ethanol conversion, while, air emissions such as SO_x resulted mainly from the combustion of coal in the ethanol plant [23]. Nguyen et al. studied life cycle energy and GHGs assessment of cassava and molasses utilization for fuel ethanol in Thailand [19-20]; the results indicated that cane molasses and cassava-based ethanol proved to be good substitutes for gasoline because of the positive energy balance and fossil energy savings i.e. cassava ethanol could provide 1.6 kg CO_2 eq./L reduction in GHG emissions when compare to gasoline it displaces . While, molasses ethanol could provide reductions on the GHG 60.6% in case that the ethanol production system had 100% recovered of biogas from spent wash to substitute coal. However, these results of Thailand are limited based on a pilot plant for cassava ethanol and a single molasses ethanol plant.

In addition, the review of assessments conducted on bio-ethanol as a transportation fuel by Blottnitz and Curran (2007) showed that there are differences in the assessment results even for the same crop or same kind of biofuel [24]. The energy efficiency and environmental performance of biofuels are dependent on many factors, such as farming practices, industrial operation and technology, and crop residues. Therefore, the specific biofuels system it is necessary to estimate a full life-cycle energy balance and GHG assessment.

1.2.1.2 Environmental consequences and shifting of environmental problems

The benefits of biofuels are not only fossil energy saving and GHG emissions mitigation but biofuels can also result in reduction of emissions of various air pollutants such as CO, SO_2, HC and PM from vehicles [7, 25-28]. This is due to biofuels are free of sulfur, unlike some fossil fuels that can have high sulfur contents, and can have lower unburned hydrocarbon, particulate, and carbon monoxide emissions [29]. However, the drawbacks of biofuels on environment have also been concluded from several studies. For example, Hodge (2002) concluded that using ethanol for US gasohol result in an increase of NO_x and VOC emissions relative to conventional gasoline [14]. Pimentel (2003) also showed that corn based ethanol degraded natural environment via water and air pollution [30].

Moreover, an increased demand for first generaition biofuels in the future will result in land-use changes which its consequential impacts needs to be considered e.g. GHG emissions from losses of carbon stocks, biodiversity loss due to the unregulated expansion of energy crops cultivation, water over-use and contamination, emissions of pollutants from combustion process that can make damage to ecological health, human health and social assets [24, 29, 31-33]. For example, palm oil and soy bean grow very well in rain forest climates; therefore, a large forest area has been cleared in a number of countries [29]. Feedstocks cultivation requires water, fertilizers and agrochemical as well as biofuels conversion processes also require large amount of water and create high organic wastewater. Eutrophication, a situation that nutrient such as nitrogen and phosphate are excessive discharged to natural waters and make over expansion of algae in waters, may occur if do not properly managed [24]. As well as, the problem related to shifting of environmental burdens when biofuels are traded is also an essential issue that needs to be investigated in order to prevent the supply of polluting commodities.

1.2.1.3 Cost competitiveness of biofuel versus petrol fuel

One of the economic risks is whether biofuels can compete to fossil fuel if the subsidies are removed [34]. This issue depends on the current prices of crude oil bioenergy crops. For example, after adjusting the difference in energy content, the price of ethanol produced from sugar cane in Brazil is competitive with gasoline when crude oil prices rise above the US$35 per barrel range, while ethanol produced from corn in the US is competitive when crude oil prices exceed roughly US$55 per barrel [7]. The European Union (EU) produced biodiesel is competitive with oil prices at about US$90 per barrel [7]. However, except sugarcane ethanol in Brazil, production costs of bioethanol and biodiesel, either in pure or blended form, are generally higher than gasoline and diesel when comparing at the same performance. Nevertheless, such a cost comparison is not a true reflection of the various potential benefits of biofuels. Therefore, externalities of biofuels should be accounted for in order to procure the highest benefits for society.

The term *"externalities of energy"* is generally defined as the costs imposed on the environment and society that are not accounted for by the producer or consumers of energy [35]. By assessing externalities over the life-cycle of biofuels and internalizing them into economic decisions, it would be possible to have an biofuel system at the lowest possible full cost – "full" in the sense that all environmental and social cost would be accounted for [36]. Several studies have attempted to assign prices to these factors. For example, Johansson (1999) compared the economy of alternative fuels by including the environmental cost associated with the emission of CO_2, VOC, NO_x and particulate matter (PM). The results showed that alternative fuels can be competitive with petrol and diesel in urban traffic, if the environmental impact of emission is valued monetarily. However, no alternative fuels can compete with gasoline and diesel in rural traffic when the economic valuation of CO_2 emission is taken as Swedish CO_2 taxes ($200/tonne C) [37]. Nguyen et al. (2008) estimated external benefits of fuel ethanol from cane molasses in Thailand by adaptation of the willingness to pay (WTP) of the society from the Swedish EPS (Environmental Priority Strategies in product design) system to the Thai context. The results showed that although E10 provides reduction in fossil energy use, CO_2 and NO_x emission, however, its total social costs are higher than gasoline due to higher direct production costs and external costs for other air emissions, e.g. CH_4, N_2O, CO, SO_2, VOC and PM_{10} [22]. Even though, various externalities assessment methodologies [38-40] and researches [37, 41-43] have been proposed and conducted, nevertheless, the suitable hypothesis to convert effect on environmental and social into monetary value and accurate quantification of these variables still proves challenging.

1.2.1.4 Food versus Fuels

Concerns over the impacts of the biofuel boom on food security aspect have been worldwide discussed in recent years. Arable land is very limited while land demand for growing crops to serve both food and energy are continuously increasing. This could result in an increased food prices. FAO has estimated the number of hungry people at 923 million in 2007 and it is likely to increase due to high food prices [44]. For instance, with the prices of commodities such as corn, soybeans, wheat and rice suddenly got more expensive; many argued that it is due to the increasing use of agricultural commodities for biofuels [45-47]. Of course, biofuels could not be responsible for all of the prices rise, or even most of it because there are various factors combined to increase the food prices e.g.

increasing of food production costs due to the rising oil prices, production shortfalls because of the climatic events such as drought, changing of consumption patterns when the people have changed in incomes, the weak in currency exchange, stock level and market volatility [44-46, 48]. However, biofuels are also playing an important role in the food crisis as it was identified by the UN, World Bank, and International Monetary Fund (IMF). The IMF estimates that in 2007 biofuels accounted for almost half of the increase in demand for major food crops [49]. In the USA, ethanol requirements are met predominantly by the fermentation of maize starch to bioethanol [47]. Yang et al. (2009) reported that in China, 3.5–4% of total maize production is used for bioethanol [50-51]. The OECD has estimated that between 2005 and 2007, almost 60 per cent of the increase in consumption of cereals and vegetable oils was due to biofuels [52]. Mitchell (2008) concluded that the most important factor was the large increase in biofuels production in the U.S. and the EU and reported that more than 70% of food price increases were due to biofuels [45]. Tollens (2009) mentioned that 33% of the increase in U.S. maize price from 2007-2008 was related to US bioethanol production [53].

One of the principles for increasing crop prices caused by biofuel is that the increased demand for biofuels would result in the competition for arable land and also agricultural resources between food and feed production and biofuel production. Where the arable land competition exists and the bioenergy crop cultivation is an alternative land use, prices of agricultural inputs rise and so that this would in turn lead to the rising prices of staple foods [54-55]. The rapid rise in staple food prices would be a burden on the poor and consumers in developing countries, who spend roughly half of their household incomes on food. However, it also provides benefit to rural farmers by generating more and stable income. This poverty reduction of the poor and small-scale farmers can lead to enhance food security in term of ability to access food. In addition, high food prices would be an opportunity for agricultural sector in the long run as it can help foster the development of infrastructure to support agricultural sector. Therefore, the biofuels development and it overall effects on agricultural commodity prices and food security would be the country specific issue and the effects depend upon whether that country is net agricultural commodity importers or net exporters. The net exporter country will take benefit from higher prices, but the countries particularly the least developed countries which have been experiencing a widening agricultural trade deficit are expected to be considerably worse off. Due to the complexity of this issue as there are many factors involved as macro-economic; therefore, further modeling and research is required to determine to what extent this risk will materialize.

1.2.1.5 Rural economy benefits and social responsibility

Production of biofuels from local crops such as sugarcane and cassava can be a tool to spur rural development because their supply chains involve agricultural sector, transport and conversion industries. Agriculture sector in developing country is labour-intensive, thus, expansion of the biofuels industry has a large potential to create jobs and to increase in personal income in the rural community. At the same time, the multiplier benefits from the development of rural areas contribute to lowering the migration rates from rural to urban [7, 29].

However, large scale industrialized investment and labour working conditions are two social risks that relevant to biofuels. The form of family businesses or cooperatives in rural agriculture may be displaced by large scale industrialized farms. Even though it cannot say this strong or weak of this transformation because large scale industry may able to produce much larger yield of crops supply than small farms. However, it also leads to dispossession of land from local farmer which is a very sensitive issue as well as employment issue. The standard of labour conditions need to be taken into account to ensure that workers will get acceptable levels of wages and working hours and preventing child labour [29, 31-32].

1.2.2 Standards for sustainable biofuels

Over the past few years, a variety of initiatives has been developed to address the environmental and socio-economic impacts associated with the production of biofuels or of specific biofuel feedstocks. These initiatives include regulatory frameworks, voluntary standards/certification schemes, and scorecards. Some of them cover the entire supply chain, while others deal only with parts of it. The Bioenergy and Food Security Criteria and Indicators (BEFSCI) project reviewed seventeen of these initiatives. A portion of them are still under development or are being tested, while others are already in operation or implementation. A few of these initiatives were completed but never adopted. The compilation results of the sustainability issues that were addressed under those 17 reviewed initiatives by the BEFSCI project was shown in **Table 1.1**.

Table 1.1 Sustainability issues addressed under the initiatives reviewed [56]

	Regulatory frameworks					Voluntary standards/ Certification schemes										Score-cards	
	BioNachV	*RED*	*RTFO*	*SFS*	*Cramer*	*BCRSP*	*BSI*	*CSBP*	*GBEP*	*GGLS2*	*ISCC*	*RTRS*	*RSB*	*RSPO*	*SEKAB*	*IDB*	*WB/WWF*
1. Environmental																	
1.1 Land-use changes (both direct and indirect)		■			■			■	■	■	■	■	■	■	■	■	■
1.2 Biodiversity and ecosystem services	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■
1.3 Productive capacity of land	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1.4 Crop management and agrochemical use	■		■		■	■	■	■	■	■	■	■	■	■		■	■
1.5 Water availability and quality	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■
1.6 GHG emissions	■	■	■		■		■	■	■		■	■	■	■	■		■
1.7 Air quality	■	■	■		■	■	■		■		■	■	■	■		■	■
1.8 Waste management		■	■		■	■	■	■	■	■	■	■	■	■		■	■
1.9 Environmental sustainability (cross-cutting)		■		■	■	■	■	■	■	■	■	■	■	■	■	■	
2. Socio-economic																	
2.1 Land tenure/access and development		■	■		■	■	■		■	■	■	■	■	■		■	■
2.2 Rural and social development			■	■	■	■	■		■	■	■	■	■		■	■	
2.3 Access to water and other natural resources			■			■	■	■	■		■		■	■		■	■
2.4 Employment, wages and labour conditions		■	■		■	■	■	■	■		■	■	■	■	■	■	■
2.5 Human health and safety			■		■	■	■	■	■		■	■	■	■		■	
2.6 Energy security and access					■		■		■			■	■	■		■	
2.7 Good management practices and continuous improvement					■	■	■	■	■	■	■	■	■	■		■	■
2.8 Social sustainability (cross-cutting)		■		■	■	■	■		■		■	■	■	■		■	
3. Governance																	
3.1 Compliance	■	■	■		■	■	■	■	■		■	■	■	■	■	■	■
3.2 Participation & transparency		■	■		■	■	■	■	■	■	■	■	■	■		■	■
4. Food security																	
4.1 Food availability		■			■				■	■	■		■			■	■
4.2 Food access		■			■				■		■	■	■			■	■
4.3 Food utilization			■		■	■	■		■		■	■	■	■		■	
4.4 Food stability				■					■				■			■	
4.5 Food security (cross-cutting)				■					■				■				

Note:

Regulatory frameworks include (1) BioNachV: Biomass Sustainability Order – Germany; (2) RED: EU Renewable Energy Directive; (3) RTFO: Renewable Transport Fuel Obligation – UK; (4) SFS: Social Fuel Seal – Brazil; and (5) Cramer: Testing Framework for Sustainable Biomass "Cramer Criteria" – The Netherlands.

Voluntary standards/Certification schemes include (1) BCRSP: Basel Criteria for Responsible Soy Production; (2) BSI: Better Sugarcane Initiative; (3) CSBP: Council on Sustainable Biomass Production; (4) GBEP: Global Bioenergy Partnership; (5) GGLS2: Green Gold Label 2: Agriculture Source Criteria; (6) ISCC: International Sustainability & Carbon Certification; (7) RTRS: Roundtable on Responsible Soy; (8) RSB: Roundtable on Sustainable Biofuels; (9) RSPO: Roundtable on Sustainable Palm oil; and (10) SEKAB: SEKAB Verified Sustainable Ethanol Initiative.

Scorecards include (1) IDB: IDB Biofuels Sustainability Scorecard; and (2) WB/WWF: WB/WWF Biofuels Environmental Sustainability Scorecard.

1.3 Research objectives

The objective of this study is to perform sustainability assessment of biofuels for transport in Thailand. The assessment centers on four areas as follows:

- To determine the environmental consequences of biofuels production in Thailand. Life cycle assessment (LCA) of biofuels is performed to identify the environmental hotspots and to evaluate the environmental performance of Thai biofuel systems.
- To determine the influence of externalities on the cost performance of biofuels in Thailand. Life cycle cost assessment (LCC) and preliminary assessment of externalities related to production and use of biofuels in Thailand are conducted to evaluate the cost performance of biofuels in Thailand when comparing with conventional petroleum fuels.
- To determine the availability of feedstocks supply for future biofuels production in Thailand. Feedstock resource estimates and net feedstock balances are investigated to describe the availability of feedstocks to supply for future biofuels production in Thailand.
- To determine the employment impacts caused by biofuels production in Thailand. The analytical method and Input-Output Table are applied to examine the direct and indirect employment effects of biofuels production in Thailand.

1.4 Scopes of research work

The research framework as shown in **Figure 1.1** is designed by dividing the work into five phases in order to accomplish these following tasks:

- *Phase I:* To perform LCA of cassava ethanol, molasses ethanol and palm oil biodiesel in Thailand.

- *Phase II:* To conduct LCC and preliminary assessment of externalities related to gasohol blends and biodiesel blends compared to gasoline and diesel in Thailand.
- *Phase III:* To examine the net balances of cassava, molasses, sugarcane and palm oil after accounting their future demand for food, feed and biofuels.
- *Phase IV:* To assess the number, characteristics and socio-economic implications of employment impacts caused by biofuels production in Thailand.
- *Phase V:* To conclude the methodologies and indicators used for assessing sustainability of biofuels in Thailand and to discuss on the sustainability of biofuels for transport in Thailand and recommendations for further improving biofuel systems in Thailand towards more environmental, economic and social sustainability.

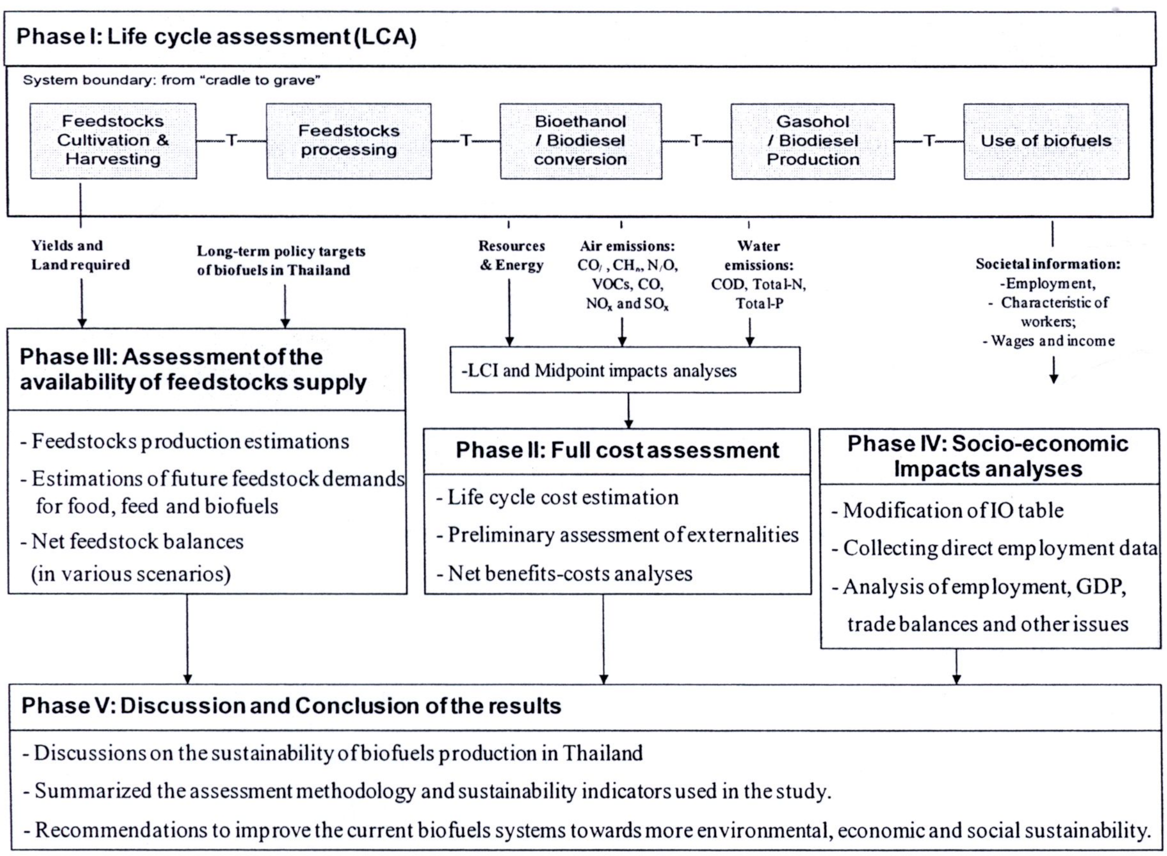

Figure 1.1 Research framework