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Local Production and Use of bio-ethanol for Transport in Ethiopia

Status, challenges and lessons

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Lund, September 2008

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Abstract

This thesis describes bio-ethanol production and use for transport fuel in Ethiopia, focusing on current status and potential, barriers, implications and recommendations for a sustainable market. The need for such research is justified as it paves the way for bio-ethanol development in Ethiopia towards a more sustainable path as challenges are surmounted.

Bio-ethanol from molasses is identified in Ethiopia to substitute gasoline in as much quantity as possible as an attempt to reduce the burden of foreign currency requirement for importation of petroleum products. Despite the availability of bio-ethanol and the potential to produce more, as well as repetitive efforts to use bio-ethanol for transport fuel, it has not materialized yet. The following research questions are addressed to investigate the problem and put forward recommendations. (1) What is the current status and future potential of bio-ethanol from molasses in Ethiopia? (2) What are the barriers to and implications of the production and use of bio-ethanol? (3) What lessons can be taken from Brazil to stimulate sustainable bio-ethanol development in Ethiopia?

Different approaches were utilized to investigate these questions. The theoretical background on main issues of bio-ethanol that include barriers and implications associated with the development of bio-ethanol at an international level were investigated from literature. Experience of Brazil on the successful bio-ethanol development was studied. A detailed contextual assessment was investigated to determine the status and future potential of bio-ethanol production and use, the main players in the supply chain (actors, networks and institutions), the barriers and implications. The result indicates that technical and economic as well as issues related to policies and regulations are main factors for hindering the progress of the bio-ethanol use and production expansion in Ethiopia. Based on Brazil's experience, recommendations were forwarded to overcome the barriers and minimize the negative implications to speed-up the development of a sustainable bio-ethanol market in Ethiopia.

Executive Summary

Background and purpose

This thesis concentrates on bio-ethanol production and use as a transport fuel in Ethiopia. Petroleum importing poor countries, like Ethiopia, are compelled to find ways to reduce such import mainly because oil imports consume the major share of their foreign currency earnings. Ethiopia meets its petroleum requirement entirely through imports. This drains its foreign earnings heavily and has become a major burden on the society and government. As an attempt to secure increasing energy demands and reduce the foreign currency burden, the government has been undertaking measures to use biofuels; namely using jatropha as a main feedstock for biodiesel and sugarcane for bio-ethanol.

There have been repetitive attempts in the past to introduce bio-ethanol into the transport fuel market. Despite these efforts and the availability of the product and even the potential to produce more, the use of bio-ethanol as a blend with petrol has not materialized. The purpose of this research work is therefore to explore the production and use of bio-ethanol as transport fuel in Ethiopia focusing on the current status and potential, barriers to and implications of production and use, and lessons from Brazil to overcome the barriers and negative implications of expanded use of bio-ethanol

Methodology

The thesis work is conducted using a combination of research methods. The author conducted a literature review, interviews, informal discussions, site visits and applied observations. A literature review was conducted to investigate background information on the main issues surrounding bio-ethanol in an international context including barriers for diffusion and implications on production. The main Ethiopian sectoral assessment and the experience of Brazil were also investigated through this literature review. Informal discussions were important to explore issues of relevance at various occasions with individuals and representatives of organizations. Interviews were conducted to analyse detailed contextual assessment on status, future potential, barriers and implications with respect to bio-ethanol development in Ethiopia. Site visits were paid to physically see the feedstock cultivation, sugar extraction and bio-ethanol production systems.

Status and potential

The first objective of this research is to identify and analyze the current status of the supply chain and future potential of bio-ethanol production and use in Ethiopia. The main findings are as follows.

Feedstock production: The feedstock for production of bio-ethanol is molasses from sugarcane. Sugarcane grows in Ethiopia for production of sugar, and the by-product (molasses) is used for bio-ethanol production. Currently, sugarcane is predominantly cultivated by the state owned sugar factories. There are three factories: Wonji-Shoa, Metehara and Fincha, which are in operation and the fourth, Tendaho, is under the construction phase. Though private sugarcane developers are entering into the sector, they are at a very early stage. The state owned factory dominancy will remain so in sugarcane cultivation for the near future. These state owned factories currently occupy about 26 500 hectares of land for cultivation of sugarcane and produce around 12 500 tones of cane per day. Within 5 years, the cultivation area and the production are expected to increase about 100 000 hectares and 61 000 tones of cane per day respectively. Given the large area identified for sugarcane plantation, which stands at 700 000 hectares and its ability to yield around 108 million tones of cane per annum, there is significant room to accommodate additional developers.

Sugar extraction: As the feedstock for bio-ethanol is a by-product from sugar extraction, sugarcane undergoes sugar extraction before it goes to bio-ethanol plant. Currently the three state owned sugar factories are the only facilities to extract sugar and deliver the molasses. The current combined sugar production capacities reach around 300 000 tones and deliver about 100 000 tones of molasses. With the inclusion of the fourth factory and expansion work in the respective factories, the combined sugar and molasses production will reach about 1 600 000 tones and 600 000 tones respectively in 7 years time. The molasses produced has also other local purposes for cattle feed and distilleries, though the requirement is low.

Fermentation and distillation: There is only one plant, Fincha Sugar Factory, currently engaged in fermentation and distillation for the production of bio-ethanol. It has a capacity of producing 8 million litres of bio-ethanol that comply the requirement to be used as transport fuel in a blend. A ton of molasses can produce about 260 litres of bio-ethanol. Due to recent government commitment to increase the production volume of bio-ethanol, new bio-ethanol plants are going to be annexed with the sugar factories, including the sugar factory being constructed. As a result, the quantity of bio-ethanol from the state owned sugar factories will reach about 135 million litres per annum in 5 years time. This amount would be 40% of the gasoline requirement at that time. The country has a potential to produce more than 1 billion litres of bio-ethanol per annum from the area identified to sugar cane.

Blending and distributing: Petroleum import and distribution is under the control of the state which also regulates the price. There are 6 oil distributing companies, local, regional and international ones. Currently, none of them carry out blending operation. A contract has been concluded with one of these oil distributing companies to provide the blending service on the basis of a service fee (Birr 40/m^3). The construction of this blending unit is underway. When completed, the blending system employs automatic in-line blending mechanisms, and will have a capacity of 1500m^3/day, more than the country daily gasoline consumption, which is less than 400m^3/day.

Barriers and implications

The second research objective for this thesis is to identify and discuss the key barriers blocking the bio-ethanol development, and the implications of production and use of bio-ethanol. The main findings are as follows.

Key barriers: A number of barriers were identified in the literature for the international context. These include: economic, technical, policy and regulation, infrastructure, causality dilemma, knowledge and information, and political. The following are the main findings in the Ethiopian context.

Economic: Lack of economic incentives to the oil distributing companies is one notable blocking factor identified for the progress of bio-ethanol use. Oil distributors incur additional expense for upgrading their fuel stations to deal with blending and distributing of gasoline. Absences of low interest loan systems or setting better margins to compensate for the additional expense to the oil distributors are major problems. This lack of economic motivation therefore hinders the progress since the oil distributors are situated at a very important stage of the supply chain.

Technical: The assurance of the quality of the blend and the two main components is a concern especially for the oil distributing companies since they are the ones who face the customer directly at the end. As the bio-ethanol blend requires extra care along the supply chain than the conventional gasoline, it remains an unanswered concern. In addition, the lack of adequate local testing on the performance of the bio-ethanol-gasoline blend causes skepticism on the product and hinders the full cooperation of the oil distributors. Therefore, the quality control aspect of the blend and the concern on the performance remain an obstacle for bio-ethanol progress in Ethiopia.

Policy and regulation: Policies and regulations are important tools to support bio-ethanol development by creating markets and future certainties. Their absence on the other hand, is a major hindrance and provides little incentives to potential investors. Policies and regulation can create demand and future predictability for the sector in Ethiopia so they are the pre-requisite for developers and investors. The absence of policies and regulation in the area of bio-ethanol in Ethiopia is stagnating progress towards the use of bio-ethanol and expansion of production

Knowledge and information: Lack of knowledge and adequate information on bio-ethanol in the country also contribute to the slow progress. In addition, bio-ethanol development has a weak link with research institutes and there is a lack of research work. Greater research work is needed to generate information that can be used as in put to formulate policies and regulations that can in turn support the bio-ethanol market.

Implications: Benefits and concerns are associated with the production of bio-ethanol. Scholars in the field of biofuels indicate 3 main benefits- economic, environmental and social. They also indicated, on the other hand, that there are environmental and social concerns. Based on the information collected through interviews and the discussions as well as through observations, this thesis work attempts to analyze the key implications. The following are the outcomes.

Economic: Bio-ethanol production and use in Ethiopia creates a market for excess molasses generated as a by product from sugar factories. It also improves trade balances by providing foreign currency savings. Since the production cost of bio-ethanol is much less than the gasoline price, the savings potential by using bio-ethanol is rather high. Moreover, it provides energy diversification and supports the effort to improve the energy security of the country.

Environmental: The main environmental implications of bio-ethanol production include water consumption, water pollution, land use and biodiversity loss, and energy balances and greenhouse gas emissions. The feedstock cultivation and production of bio-ethanol are found consume considerable amounts of water. Not only the consumption, but also the effluent release system threatens the aquatic life of the near-by river. Effluent containing high BOD and low pH value are just diluted with water and released to the river. Furthermore, land requirements for the expansion of sugarcane cultivation can cause deforestation, and the use of agrochemicals can cause habitat loss and impact on biodiversity. Energy balances and net greenhouse gas emission are found to be areas, which require further research due to the lack of prior study and data availability in Ethiopia.

Social: Social implications related to bio-ethanol production and use in Ethiopia includes impact on food security, land rights and employment creation. With respect to the impact on food security, theoretically the land and water requirements for bio-ethanol production does not seem threaten or aggravate the food security in Ethiopia, given the huge land and water availability. The land tenure system is tight to protect the poor from being displaced, as the land ownership remains with the state. The land holders can rent their holdings to investors without the danger of being displaced. The other social implication is employment creation. Bio-ethanol production creates both direct and indirect employment. For example, the state owned sugar factories alone will create direct job opportunities for more than 102 000 workers, most of them unskilled including rural women. In connection to job creation, the working conditions and health of the workers remains an issue that requires extensive study.

Lessons

The third and last objective of this thesis is to outline lessons to overcome the barriers, and potential negative implications in order to develop a sustainable market using the experience of Brazil. Due to the similarity in feedstock type and suitable climatic condition for sugarcane cultivation of both Ethiopia and Brazil, the measures Brazil implemented to create a successful bio-ethanol market offer important lessons. The following are key lessons for Ethiopia.

State intervention: Bio-ethanol development in Brazil succeeded due to state control of the industry at the beginning, and later the industry was liberalized to operate under the market principles. In a similar account, currently bio-ethanol development in Ethiopia is under the control of the state. Even more intervention is needed now to kick-start bio-ethanol use and production expansion. It should be, however, last for only a certain period of time. A level playing field for private developers should be facilitated in order to work on competition and improve efficiency. The industry should eventually be led by market force and competition with minimum state intervention. State interventions should not continue indefinitely (should only be till the market development), improvement in productivity, technology and infrastructure will be achieved through competition. The positive role of the government in the long run will be indispensable in setting up the legal system and competitive mechanism.

Institutional framework: The establishment of appropriate implementing institutions with defined tasks was one of the measures Brazil took to advance the bio-ethanol program. In Ethiopia, the bio-ethanol development program is led by a forum, without defined tasks and what to expect from members of the forum. This weak institutional set up is one of the causes of the current delay in action. A target and defined tasks that can help to achieve the target needs to be identified. On the basis of these pre-defined tasks, appropriate institutional arrangement for implementing the strategy needs to be created.

Supportive policy: Supportive policies played a crucial role in the bio-ethanol development of Brazil. Likewise, Ethiopia needs to enact policies to support bio-ethanol production and use sustainably on the basis of its unique context. Policies for a blending mandate, economic incentives, and strategic direction on research and development are, in the opinion of the author, very important.

- Enacting a blending mandate will have the capacity to create long term market demand and to attract private sector investment in technology and infrastructure advancement. Any blending mandate should respond to social and environmental concerns to create sustainable bio-ethanol development.

- Providing soft loans to private investors and tax incentives for imported vehicles are two incentive mechanisms suggested. Provision of low interest loans solves the capital shortage of private investors wishing to enter into the industry. Provision of tax incentives for vehicles that can use more percentage of bio-ethanol blends will enable higher consumption of bio-ethanol.

- Another important lesson that Ethiopia should learn and apply is the strategic guidance on the state level on long term research and development. Policy that directs both public and private institutes to focus on long term research needs to be enacted. Continuous research and development is the basis for finding answers to questions raised and information needed as input for policy formulation, and it is a key to find the many social and environmental issues that are not yet answered.

Contributions:

This thesis work contributes to knowledge on the Ethiopian bio-ethanol market, and thereby provides inputs to policy-makers, researchers, business and industrial actors. For policy-makers, it suggests some key policy options that can be of support to the development of bio-ethanol, not only from a theoretical perspective but also from practical discourse as well as proven and tested experience based on interviews. For researchers, it can serve the basis for further study for which potential areas are pin-pointed. For business, it provides the available information on the bio-ethanol area, which can serve as input to evaluate business plans. In addition, it equips business to open a dialogue with the government and relevant agencies on the type of policies that need to be put in place to expand the bio-ethanol market in Ethiopia. For industrial actors, it provides the important aspects of bio-ethanol production, and thereby enables them to become aware of opportunities and potentially take appropriate action.

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1 Introduction

1.1 Research problem

Biofuels[1] for transport fuel have recently attracted significant attention worldwide. This is mainly due to the escalation of oil prices coupled with a shortage of forecasted reserves and their reduced carbon emissions compared with fossil fuels. These factors and the increasing energy demand for transportation to keep the pace of economic development are alerting many countries to find alternative energy sources for their security of energy supply. The growing energy demand in China and other rapidly developing countries for example has reached 1 million barrels per day, which exacerbates the oil price to reach an all time record of more than $144 per barrel, and without bio-ethanol the price is estimated to soar even by more than 15% (Biofuel Review ,2008)[2].

Oil imports consume the major share of poor countries foreign earnings. Several times in the past oil dependent developing countries suffered as a result of unpredictable oil price hikes. The recent record hike has resulted in disturbing effects on many of these countries, some of which now spend as much as six times on fuel as they do on health, or twice the money on fuels as on poverty reduction (UN-Energy, 2007). Many of these countries are in Africa. In Kenya, for example, oil imports balance the value of its annual trade deficit. Countries like Namibia, Ghana, and Zambia are also in a similar situation (world politics review, 2006)[3]. This oil import dependency puts high risks on the economy of these countries both from unpredictability of the market and soaring prices. Thus many countries are compelled to find ways to diversify their energy source from biofuels.

There are also environmental reasons for countries to diversify their energy mix from biofuels. As a result a number of countries have introduced or are planning to introduce targets to raise the proportion of biofuels within their energy portfolio (Dufey, 2006, p1). For instance, the target set by EU to achieve 5.75 percent biofuels content in transport fuels by 2010 will require five times more production in EU[4]. In addition the Kyoto obligation and the various national steps towards biofuels could propel global biofuel production to raise four fold in the next 20 years (Dufey, 2006).

Both developed countries (Canada and Australia) and developing countries (Argentina, India and South Africa) are also among countries that have enacted new pro-biofuel policies (UN-Energy, 2007). As a result of this global demand, biodiesel is growing at the rate of more than 30% from the year 2006, and its production is likely to reach 12 billion liters by the end of

[1] Biofuels are transport fuels derived from biological sources. Bio-ethanol and biodisel are the two primary biofuels currently used in existing vehicles

2 http://www.biofuelreview.com/content/view/1544/1/

3 http://www.worldpoliticsreview.com/Article.aspx?id=354

4 Biofuel Directive (2003/30/EC): stipulates member states to replace 5.75% of all transport fuels (petrol and diesel) with biofuels by 2010. the directive also stated for an intermidiate target of 2% by 31 December 2005. The target of 5.75% is to be met by 31 December 2010. the percentage is calculated on the basis of energy content of the fuel and apply to petrol and diesel fuel for transport purposes placed on the markets of member states. (Available at: http://ec.europa.eu/energy/res/legislation/doc/biofuels/en_final.pdf)

2010, and global bio-ethanol is growing at a rate of 6.5% from 2006 and its market is expected to exceed 120,000 million liters by the end of the year 2020 (Biofuel Market, 2007)[5].

The growing demand for biofuels is believed to benefit poor countries mainly due to vast uncultivated land and low cost labor, particularly in the Sub-Saharan African countries, among which Ethiopia is one. Energy in Ethiopia affects many aspects of development and is a key instrument to meet the UN millennium development goals. It has implications on social, economic and environmental as well as on accessing water, agricultural productivity, health, education and gender related issues. Improvements in all areas require improvements in energy supply: both in quantity and quality (MME, 2007).

The majority of the people have not been able to use modern energy sources like electricity, kerosene, or gas. Most people living in rural areas (about 83% of the 78 million populations)[6] use only biomass (wood dung and agricultural waste) for household energy requirements (cooking and baking). Biomass energy consumption is estimated to be about 95% of the total (MME, 2007). Energy requirements from biomass have been increasing as a result of mainly population growth. This increased requirement has driven more trees to be cut thereby aggravated deforestation, erosion and desertification. These phenomena have become a threat to the remaining biomass stock thereby exposing the soil to erosion which in turn has undermined people's ability to feed themselves (MME, 2007). In addition, women and children often have to travel long distances for fuel wood collection. Moreover, people using biomass as fuel are adversely affected by indoor air pollution.

Petroleum products, which entirely come from import, on the other hand are mainly used by urban households. Due to shortages of biomass and changes of lifestyle, accompanied by economic development the demand for petroleum products has been increasing (MME, 2007). This rise of demand results in faster growth of petroleum import thereby increasing the import bill both from growing quantity and rising price. Importation of petroleum products is actually draining the country's foreign currency that is hard to earn. A decade ago, expenditures on petroleum products was 1.5 billion Ethiopian Birr[7]; in 2007 this figure soared to 9 billion Birr (EPE, 2007). The same source estimated the value to reach 11billon birr in 2008. The annual consumption of petroleum appears to be more than 1.1 million tones which is equivalent to 5.4% of total final energy consumption, which accounts also 40% of total imports and absorbs more than 60% of exports earnings (MME, 2007).

Security of petroleum supply or other sources of energy which can substitute petroleum is crucial for sustained economic growth. If security is achieved by reducing the quantity of petroleum and thereby reducing the import bill, the savings could be diverted to other development investments on the energy sector.

As an attempt to secure this energy requirement and reduce the foreign currency burden, the government has been undertaking measures to use biofuels. The anticipated additional benefits through the use of biofuels in the country include: diversifying energy sources, expanding rural development through job creation in feedstock production, transport and distribution; reduce harmful substances from vehicle exhaust; reduce green house gas emission; contribution to soil and water conservation; and building local industries (MME,

5 http://www.rncos.com/Report/IM508.htm

6 Central Statistics Authority of Ethiopia (CSA, 2008)

7 Currently 1Euro is exchanged with 13 Ethiopian Birr

2007). The government focuses to use bio-ethanol from molasses (by-product from sugar factories using sugar cane as a feedstock) and biodiesel from plants such as jatropha.

Gross available potential land for production of feedstock for biodiesel in Ethiopia is estimated as 24 million hectares and the total irrigable land for sugarcane production for bio-ethanol production is about 700 000 hectares, which offers a potential to produce 1 billion liters of ethanol (MME, 2007). Currently there are three factories producing sugar from sugar cane. These three sugar factories dominating the main supply line in the domestic market are called Fincha, Wonji-Shoa and Metehara. The combination of their annual production capacity reached 2.8 million quintals of sugar. While Fincha produces eight million liters of ethanol, Wonji-Shoa and Metehara together yield 64 000 tons of molasses per year which are also expected to start producing ethanol in 2008 and 2009 respectively to raise the total quantity to about 60 million liters by mid of 2009 (Reporter, 2007 and Tesfaye, 2007, p9). Ethanol produced from Fincha reaches to the international market through an Italian company Silcompa. Molasses has also been exported to overseas markets. The fourth state-owned sugar factory project, Tendaho, whose construction is underway at a cost of about 1 billion USD, is expected to develop over 64 000hectares of land and expected to increases the capacity to produce the bio-fuel energy. With the completion of the four sugar factories in 2012/2013, 128.1 million liters of ethanol per year will be produced (Reporter, 2007).

In order to transform this potential into reality, there have been repetitive efforts to start using bio-ethanol for local consumption and as a continuation of this endeavor the government developed a strategic plan in 2007 considering jatopha as a principal feedstock for biodiesel production followed by castor bean, and sugarcane as a principal feedstock for bio-ethanol production (MME, 2007). Among other things the strategy focused on stimulating feedstock enhancement, stimulating demand, enhancing environmental sustainability, awareness creation and promotion of biofuels, updating energy policy and establishing biofuel program (MME, 2007). Particularly, blending 5% of ethanol with gasoline in the year 2007 and followed by 10% in the years to come was the plan set out. With these of course the plan encompasses expansion of sugar factories.

However, despite continuous efforts and envisaged benefits that can be obtained through the use of biofuels, local usage has not materialized. Particularly, the intention to blend bio-ethanol with gasoline for transport fuel has been attempted since many years as there has been eight million liters of bio-ethanol product since 1999. This thesis aims to assess the prevailing situation and come up with recommendations to stimulate and realize this long awaited aspiration. It essentially assesses the current situation, future potential and barriers for bio-ethanol production and use from molasses. It also attempts to provide some recommendations that Ethiopia could take measures based on the country specific situation augmented by other successful countries experiences, mainly from Brazil.

1.2 Research objectives

The objectives of this research are as follows:

- To identify and analyze the current situation of the value chain for bio-ethanol production and use.

- To identify key barriers blocking the development of production and use of bio-ethanol in Ethiopia, and the implications of extended production and use from an economic, environment and social point of view.

- To outline lessons to overcome the barriers and potential negative implications in order to develop a sustainable market using the experience of Brazil.

1.3 Research questions

In order to fulfill the aforementioned objectives, there are three research questions this research poses. These include:

- What is the current status and future potential of bio-ethanol from molasses in Ethiopia?

- What are the barriers to and implications of the production and use of bio-ethanol?

- What lessons can be taken from Brazil to stimulate sustainable bio-ethanol development in Ethiopia?

1.4 Research methodology

1.4.1 Data collection

Different techniques have been utilized for collecting data and relevant information. Both primary and secondary sources have been investigated using the following techniques:

1.4.1.1 Primary data

Primary data was collected through interviews, as well as observations and informal discussions.

Interviews

Primary data was collected through formal interviews of various actors and experts who involve directly or indirectly in bio-ethanol production and use. The interviewees were mainly selected by contacting first the national bio-fuel forum coordinator, Ministry of Mines and Energy and then from respondents. In order to get an opportunity to supplement questions, if necessary, and allow the author to adjust questions, semi-structured open ended interview was conducted. This method allowed having a good interpersonal interaction, supplementary questions to be added in instances where the author needed more information. Moreover, it allowed clarifying confusing questions.

The interview with the various stakeholders allowed the author to obtain their viewpoints on the study topics. At times different views were presented on the topic and thus the same questions were discussed with various informants applying triangulation to reveal facts. Before each interview, the author designed a goal and in most of the interviews asked the informants to describe their role and the interaction with other actors in the development of bio-ethanol. The following are the key informants with whom the interview has been conducted. The names of people, organizations they work for and the date interviewed are shown in the bibliography section.

a) Ministry of Mines and Energy (MME)
b) Ministry of Trade and Industry (MOTI)
c) Ministry of Agriculture and Rural Development (MOARD)
d) Ethiopian Sugar Development Agency (ESDA)
e) Ethiopian Environmental Protection Authority (EPA)
f) Ethiopian Quality and Standard Authority (EQSA)
g) Forum for Environment
h) Ethiopian Investment Authority (EIA)
i) Ethiopian Agricultural Research Organization (EARO)
j) Ethiopian Petroleum Enterprise (EPE)
k) Ethiopian Transport and Communication Authority (ETCA)
l) Nile Petroleum
m) Yetebaberut petroleum
n) National Oil Company (NOC)
o) Kobil Ethiopia

Observations and discussions

Data was also collected using direct observation. In order to get the real picture of sugarcane plantation and sugar and bio-ethanol production, site visit was paid by the author and stayed two days at the Fincha Sugar Factory. The site visit was important to observe the farm as well as the industrial activities. The cutting of sugar cane, sugarcane transport to the sugar factory, sugar extraction and bio-ethanol production were observed by the author.

Informal discussion was also held with different individuals. This was intended to get the view points of individual as well as to collect more information. Discussion with Fincha Sugar factory was held to know more about the effluent treatment practice. Discussion with individual car owners was held in order to test the positions with regard to using blended fuel. Informal discussion was also held with departments of Ministry of agriculture and rural development to clarify the status of policies and their implications to bio-ethanol production

1.4.1.2 Secondary data

Secondary data was mainly conducted through literature review. Literature review has been undertaken during the formulation of the problem. Similarly it has been undertaken during the various phases: presentation of the theoretical background information, during the case study of the Brazilian bio-ethanol experience, analysis of the current and future potential of bio-ethanol production and use, analysis of the barriers and implication of production and use of bio-ethanol etc. Both printed and electronic sources have been utilized. These include: reports, strategic documents, journals, newspaper articles relevant to the study, books, workshop papers, committee proposals, various web pages and research papers. Moreover policy documents and proclamations were reviewed. Since the area of study for Ethiopia is new, the literature review was used to build the study on existing experience.

1.4.2 Data analysis

The contextual assessment and the information and data gathered were analyzed using an analytical framework for the diffusion of renewable energy technology developed by Jacobsson & Johnson (2000). As the framework has been developed to clarify obstacles in diffusing renewable energy, its application for the case under study was believed to have high relevancy.

1.4.3 Analytical framework

A framework helps to guide data collection and analysis for the study under consideration. The identification of the framework has been done through literature review on issues pertinent to the case. The diffusion of new renewable energy systems faces complex obstacles that need to be understood and identified in a systematic way to support its development with appropriate tools. Thus this new technology diffusion and improvement in society needs to be studied from a number of perspectives that influence its improvement and diffusion. Institutional set-up and structure of production, influence of the technology choice made by individual firms, cultural variables, industrial networks, and technological systems and systems built around specific technologies or products are factors considered by different authors (Jacobsson & Johnson, 2000 p.5).

Based on the technological system approach meaning that when there are many technology systems in a country and that some actors are involved in several of them and also when the focus of the enquiry is competition between various technologies to perform a certain function (energy supply), the bare bone framework is a tool developed to study the characteristics of the emerging technology (Jacobsson & Johnson, 2000). Bio-ethanol production and use in Ethiopia that aim to answer the questions posed under the research question in part 1.3 is an appropriate case to utilize this suggested framework. There are at least technology systems of the incumbent and technology system of the bio-ethanol system where they compete to fuel transport vehicles and actors could involve in both systems. The framework adopted for the analysis is shown in fig1-1 below.

As the framework requires specifying the unit of analysis, breadth and depth as well as spatial domain (Jacobsson & Johnson, 2000), the bio-ethanol product as a precise unit of analysis is taken and the supply chain (production, supply and use) as aggregate for the breadth and depth seems appropriate as the production and use of bio-ethanol are influenced by all involved in the chain. More focus is given to the local market as regards to spatial domain though the domain entails some reflections of global market as local market has always been a component of a global set-up.

Having decided on the focus of the study, the next step was identifying and assessing the structural components of the system: actors, networks and institutions.

- Actors: these include firms along the value chain, universities and research institutes, public bodies, influential interest organizations and organizations deciding on standards.

- Networks: these include both formal and informal networks that could be for instance user supplier networks, public-private partnership, university-industry links, supplier groups, etc.

- Institutions: these include culture, norms, laws, regulations and routines of the system.

During the analysis of these structural components, the socio-political, market and technical issues are embodied in the discussion. Socio-political issues are reflected when the institutions are described and mainly indicates how the existing institutional set-up, legislation, and people's perception are functioning with respect to bio-ethanol production and use in

Ethiopia thereby attempt has been done to identify the blocking mechanisms. Market issues has touched in the identification of actors and cover how demand of bio-ethanol is perceived by actors, the market potential of bio-ethanol, existing experiences of actors, situation of incentive systems, infrastructure and local market control of gasoline. Technical issues incorporated to show the competence and knowledge of actors along the supply chain, and cover established technology characteristics, and investment incentives.

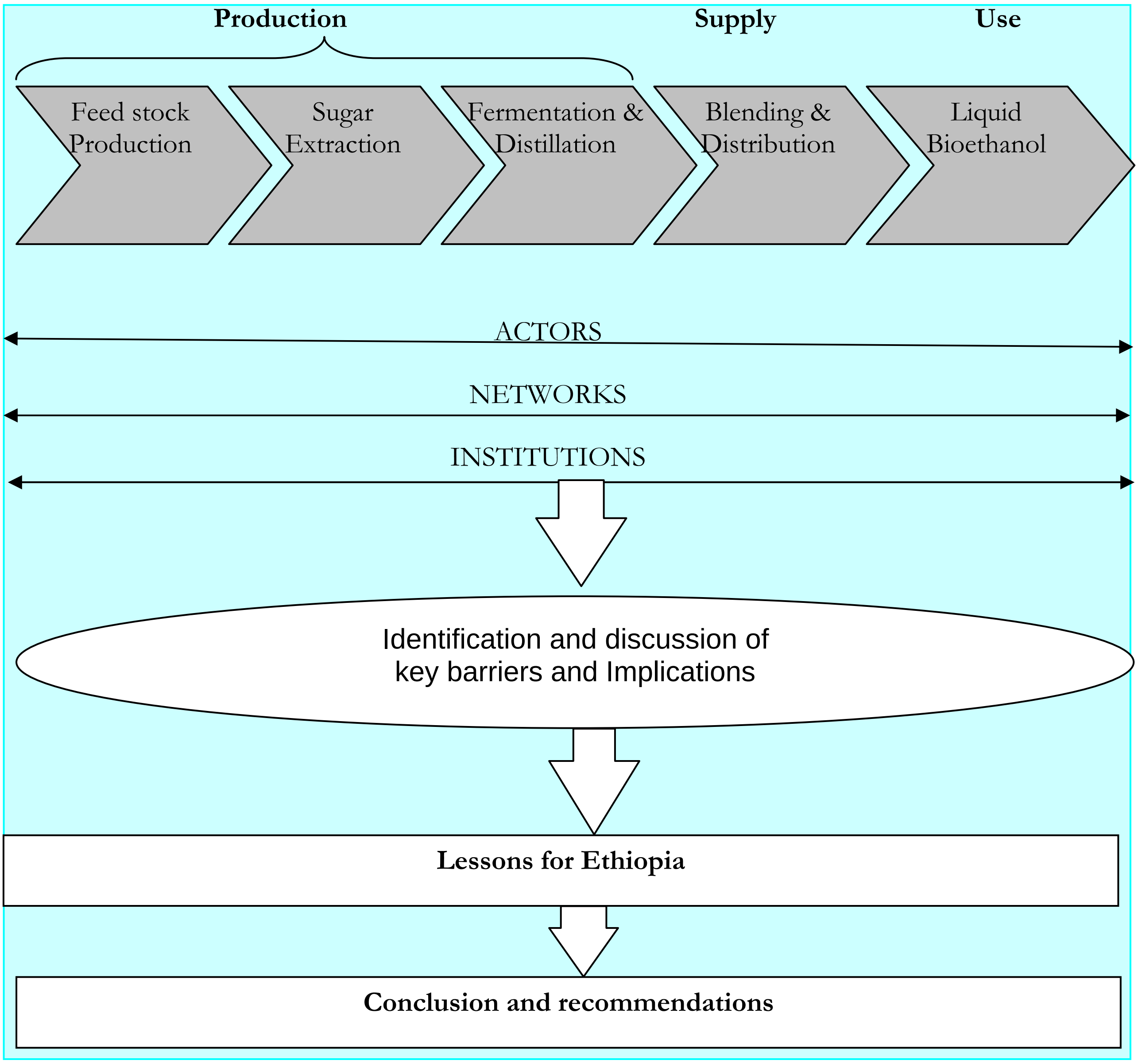

Figure 1-1 Analytical Framework

Source: Adopted from Jacobsson and Johanson, 2000, Palmer, 2008 and Etal.

Finally there is the identification and discussion on the key barriers and the implications. The identification is done in a two stage processes: on the basis of the background information from international context, the Ethiopian context is classified through interview, discussion and observation. This identification and the successful experience of Brazil in the bio-ethanol development provide lessons to be applied to Ethiopia. In order to take the appropriate message for Ethiopia, the Brazilian case has been studied and described from literature. The case of Brazil mainly contain only important issues the author believes relevant to overcoming the barriers and minimizing negative implications in developing sustainable bio-ethanol market in Ethiopia.

1.5 Scope and limitations

This thesis covers a wide perspective on bio-ethanol that goes across several sectors and includes many actors involved in the system. The author believes such coverage provides greater understanding of the bio-ethanol development status and the connection with the relevant sectors and actors. Particularly with the absence of related study in the past, the information presented in this thesis will be a starting point to explore more on issues of high relevance.

The geographical scope of the study is bound to bio-ethanol production and use in Ethiopia. Key stakeholders involved in the supply chain in the production and use of bio-ethanol are the main focus. As the goal of the thesis is to help the country to develop a sustainable bio-ethanol market, the scope is narrowed down to identification of key barriers to and major implications of production and use of bio-ethanol. The emphasis on barriers and implications reveals the major factors affecting the bio-ethanol progress and sustainability respectively.

The temporal scope foresees on short to medium term (next 5-10 years) and thus many of the analysis are relevant for these periods. Because bio-ethanol can be produced from a number of feedstocks and with the change in feedstock the whole supply chain will change. It may be possible other technologies could be developed in Ethiopia that can use second generation feedstocks. Also, the current direction of producing bio-ethanol using only molasses may change. There are intentions by private developers to use *sugarcane*[8] and food crops. In that case, the existing set-up, barriers and implications will take another form. In some cases however, some suggestion and indications for long time perspective are mentioned to some extent.

This thesis is not without limitation that the author would like to acknowledge. The first limitation is the wide scope of the study. Analyzing the whole value chain of bio-ethanol development, its barriers and implications are broad. It needs multidisciplinary approach that requires inputs from different disciplines. As a result, the study may have limitations to encompass some important issues at depth and to satisfy experts in the specific discipline.

Another limitation is the information contained in the study may not as detailed and exhaustive as it should be. Due to lack of prior study on the area, the data collection, and analysis was challenging. Absence of knowledgeable experts in the bio-ethanol energy was also one of the causes for lacking detailed information Data on various aspects was incomplete and information needed for analysis was missing and thus the analysis made on the basis of such insufficient and incomplete data would be less vivid, unsatisfactory and shallow. Background information in the various sectors on the Ethiopian context was extremely poor, difficult to trace the original source and not updated.

[8] Under the current direction, the by-product of sugar extraction from Sugarcane (Mollasses) is the feedstock for bio-ethanol production in Ethiopia. Private developers, however, have the intention to produce bio-ethanol using sugarcane, sugarcane that has not been undergone through sugar extraction.

1.6 Structure of the thesis

The structure of this thesis begins with an introduction where among other things the research problem, the objective, the research questions, the methodology and the framework for analysis are addressed. Then chapter 2 deals with the theoretical background. It serves the main basis for discussion of the key barriers and implications associated with the Ethiopian bio-ethanol development. In order to facilitate the identification, analysis and discussion in the process of the research, this second chapter provides background information consisting of two sections.

The first section indicates general description about bio-ethanol that includes why it has been chosen to be used for transport fuel, what feedstocks are available for it, how it can be produced from these different feedstocks, what looks the yield from the different feedstocks, what seem the trend of production and demand for bio-ethanol at global level, what are the barriers and sustainability issues at global level as well as policies enacted by different countries to promote bio-ethanol. This section is believed to give background information to the paper describing what are known in the field. It shares the known facts of other studies that are closely related to this thesis study. Moreover, local production and use of bio-ethanol is strongly linked with what is happening at the global level and indicating the trend in the global level would give what direction and requirement should the local development take and fulfill respectively.

The second section of the background chapter will describe about three sectors in Ethiopia on the basis of the first section. They are main sectors that would have influence or be influenced by the bio-ethanol program that include: agriculture, energy and transport. There are of course other sectors that could be influenced as sectors are interlinked. But these three sectors are directly linked to the bio-ethanol development and are important examining them in the country in order to determine to what extent the bio-ethanol development would affect (positively or negatively) the present configuration. The focus in the sectors lies in the current set-up (main actors, production and use) and institutional and legal framework.

Following the background information, the case of Brazil in bio-ethanol development is described in chapter three. It presents the bio-ethanol experience of Brazil that has successfully developed in the production, local use and export of bio-ethanol for transport sector. Its main focus is on measures that have been taken to overcome the barriers at the early development of the bio-ethanol program and environmental aspects Its purpose to include here is that it provides practical insights into the different approaches used, identifies the success and then uses the experience as a lesson to forward appropriate recommendation at a later stage (in part 6). Particularly the feedstock type Brazil has been using and the intention of Ethiopia to use similar type of feedstock (Molasses from Sugarcane) will give relevant lessons to the Ethiopian bio-ethanol endeavour.

For the analysis of the Ethiopian bio-ethanol setting, which is presented in chapter 4, the two sections of the background information are jointly used as input. For the analysis, an innovation system approach framework for technology development and diffusion as described in 1.3.3 is utilized. The framework is used to identify the structural component (actors, networks and institutions) of the bio-ethanol development in Ethiopia and to assess the interest, current status and future potential of actors.

Following the analysis, key barriers and implications are discussed in Chapter 5. They are derived from the analysis. The identification of barriers and implications are done in two steps. First the theoretical explanations are formulated in the background part. Then they are checked through interview and observation. The discussion is followed by a recommendation for overcoming the barriers and develops sustainable domestic market. The part is derived from the discussion and lesson taken from the experience of Brazil. In general the thesis takes the following structure.

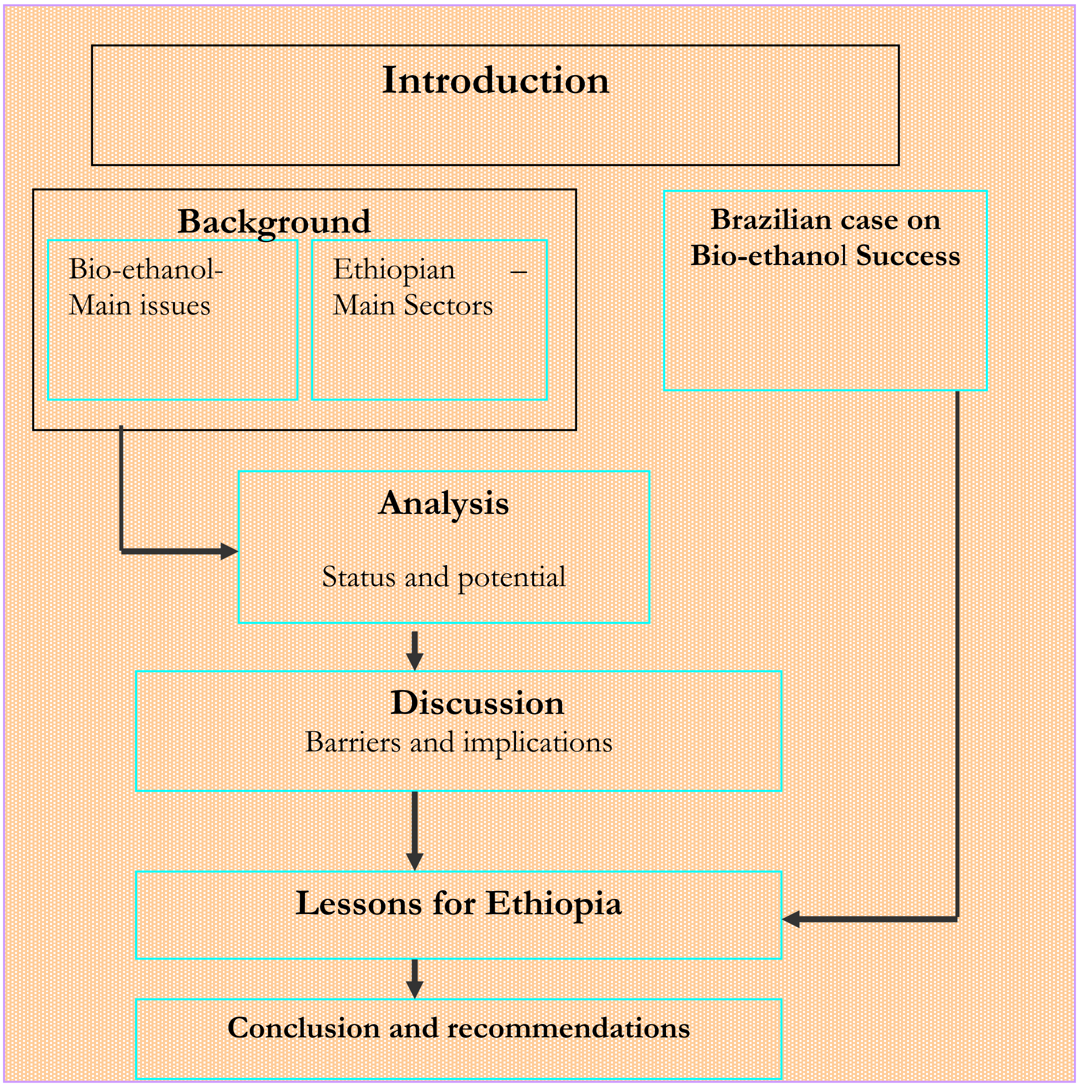

Figure 1-2: Structure of the research

1.7 Relevancy of the thesis

The research contributes to developing knowledge on the bio-ethanol market in Ethiopia thereby providing an important value to policy makers, academic researchers, business society, industry actors and interested groups.

For policy makers: it provides a range of available policy options that could be considered to adopt in Ethiopia context to support the bio-ethanol development. The barriers and the means to overcome them and the social and environmental concerns highlighted in the study could also provide important inputs for policy makers to make interventions for sustainable domestic bio-ethanol market. The inclusion of tested and proven policy tools sketched from Brazil would reinforce the choice for priority.

For business society: Bio-ethanol development in the country is at an early stage. The information contained in the study provides important understanding about bio-ethanol in general and the status in Ethiopia in particular. Knowing the status in Ethiopia could be important to businesses to have a basic data and the opportunities thereon. In addition, the policy options presented will equip them with essential background information to open dialogue with the government to introduce stimulating condition.

For academic researchers: The study can also serve as a platform to provide basic information on the bio-ethanol development to make further research on areas of data insufficiency. The indication of areas lacking sufficient data and potential areas for further study would guide researchers to select priority areas and undertake further study.

For industry actors: The implication of bio-ethanol is not well understood in Ethiopia. This study tries to indicate implications associated with bio-ethanol expanded production. Knowing these issues would enable industry actors to consider them in their action and when they set up new facilities thereby available data could be captured, analyzed and improvement achieved.

2 Background on bio-ethanol and Ethiopia

This theoretical part consists of two parts. The first part indicates general description about bio-ethanol. The second section will give information about Ethiopian main sectors that could potentially be influenced by the bio-ethanol program. The information displays the current situation of the sectors focusing on points related to the bio-ethanol development.

2.1 Bio-ethanol-main issues

Biofuels have attracted global attention due to concerns on climate change, energy security and dependency and import burden of petroleum products. They are increasingly considered by many countries as much as feasible to substitute the fossil fuel source in the transport sector. Currently bio-ethanol and biodiesel, sometimes referred them as first generation biofuels, are the most important ones as both can be used blended or in neat form although neat usage requires engine modification (IAE, 2004). Biodiesel is blended with petroleum based diesel whereas bio-ethanol is blended with gasoline. Biodiesel is derived from oil crops like rapeseed, palm-oil, jatropha, sunflower, and soy while bio-ethanol is based on starch crops like sugarcane, sugar-beats, corn, wheat and sorghum (Dufey, 2006). Since the focus of the thesis is on bio-ethanol the following section presents background information exclusively on bio-ethanol.

2.1.1 Why bio-ethanol use for transport?

Bio-ethanol is a liquid obtained by distillation of fermented sugar. It has become preferential because of its potential of matching the convenient features of petroleum at competitive price (Wyman, 1996). It can also be produced from various resources available domestically: agriculture and forestry residue, organic portion of municipal solid waste, woody and herbaceous crops and dedicated starchy crops (Rutz D. and Jansse R.. 2008). It offers a number of benefits that includes: high *octane*[9] and high heat of vaporization that allow it to achieve higher engine efficiency. Its use reduces ozone and smog formation compared with the conventional gasoline due to its low volatility and photochemical reactivity (Dufey, 2006). Its blended use reduce fossil fuel consumption and provide oxygen to promote more complete combustion that results less exhaust emission of carbon monoxide and unburned hydrocarbon (Wyman, 1996). In addition to using the existing petroleum infrastructure, bio-ethanol can be blended with gasoline in any proportion up to 10 per cent without the need for engine modification (IAE, 2004). Blends of 5 percent or 10 percent of bio-ethanol in gasoline are denominated B5 and B10, respectively (Dufey, 2006, P 7). In some cases they are denominated as E5 for 5% bio-ethanol blend (Bio-ethanol 5% and 95% gasoline) and E10 for 10% (Dufey, 2006).

Bio-ethanol greatest benefit lies in its potential to reduce greenhouse gas emissions by partial replacement of oil as a transport fuel (IAE, 2004). This could help developed countries meet their commitments under the Kyoto Protocol and mitigate the effects of climate change. In economic terms, today's high gasoline price makes bio-ethanol from the most efficient producer countries competitive (Dufey, 2007). These are largely developing nations. It also reduces the burden of foreign currency expenditure for poor countries that are net importer of petroleum products and have potential to produce and use bio-ethanol (WWI, 2006).

Other considerations behind bio-ethanol market development include the promotion of greater energy security, rural development, and poverty reduction (Dufey, 2007).

[9] Octane number is a figure indicating theantiknock properties of a fuel

2.1.2 Feedstock and production

Different feedstock are available for producing bio-ethanol as it can be derived from any biological raw-materials that contain sugar or materials that can be converted into sugar from starch or cellulose(Dufey, 2006). For instance, sugarcane and beats are feedstock types that contain sugar whereas corn, wheat, and other cereals contain starch (Rutz D. and Jansse R. 2008). Below in figure 2-1 shows the different feed stocks that can be used to produce bio-ethanol.

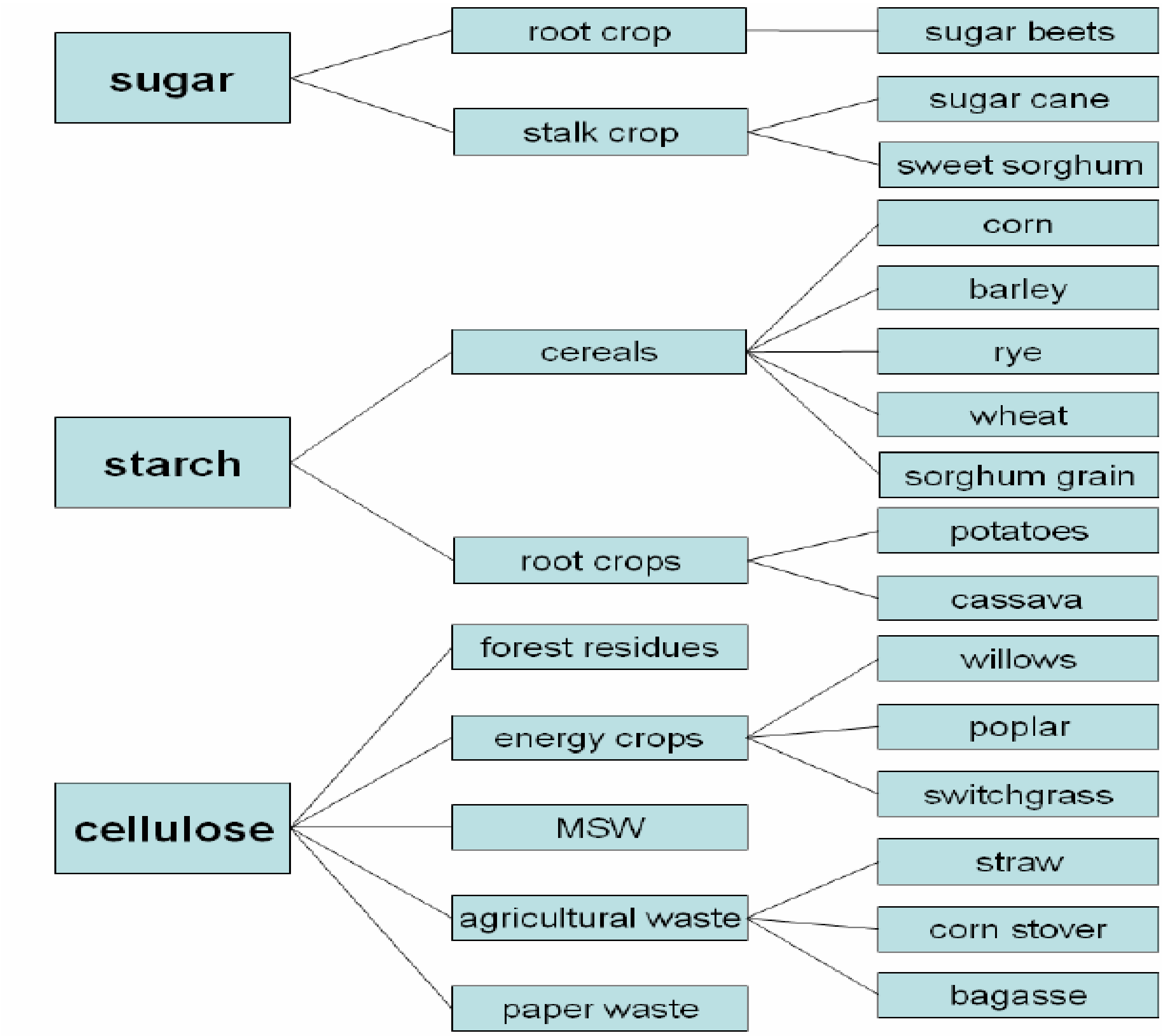

Figure 2-1 Types of Feeedstocks for Bio-ethanol Production[10]

Source: Rutz D. and Jansse,R. 2008

Bio-ethanol from sugar and starch bearing plants is readily available and the feedstocks of such plants are called first generation. They are characterized by only parts of the plants (sugar or starch) are used for bio-ethanol production (WWI, 2006, P 20). On the other hand, next generation feedstocks types are used wholly for bio-ethanol production (stalks, grains, tubes).

[10] MSW means Municipal Solid Waste

These different feedstocks demand various processing steps to deliver bio-ethanol depending on their embedded sugar type. This is depicted in table 2-1

Table 2-1: Bio-ethanol production steps by feedstocks and conversion technique

Feedstock type	Feedstock	Harvest technique	Feedstock conversion to sugar	Process heat	Sugar conversion to Alcohol	Co-products
Sugar crops	cane	Cane stalk cut, mostly taken from field	Sugars extracted through bagasse crushing, soaking, chemical treatment	Primarily from crushed cane (bagasse)	Fermentation and distillation of alcohol	Heat, electricity, molasses
	sugar beet	Beets harvested, foliage left on the field	Sugar extraction	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed, fertilizer
Starch crops	wheat	Starchy parts of plants harvested; stalks mostly left in the field	Starch separation, milling, conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed (e.g. distillers dried grains)
	corn	Starchy parts of plants harvested; stalks mostly left in the field	Starch separation, milling, conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed (e.g. distillers dried grains), sweetener
	potatoes	Potatoes harvested, foliage left on the field	Washing, mashing, cooking, starch separation, conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed, industrial use
Cellulosic crops	trees	Full plant harvested (above ground)	Cellulose conversion to sugar via saccarification (enzymatic hydrolysis)	Lignin and excess cellulose	Fermentation and distillation of alcohol	Heat, electricity, animal feed, bioplastics, etc.
	grasses	Grasses cut with regrowth	Cellulose conversion to sugar via saccarification (enzymatic hydrolysis)	Lignin and excess cellulose	Fermentation and distillation of alcohol	Heat, electricity, animal feed, bioplastics, etc.
Waste biomass	Crop residues, forestry waste, municipal waste, mill waste	Collected, separated, cleaned to extract material high in cellulose	Cellulose conversion to sugar via saccarification (enzymatic hydrolysis)	Lignin and excess cellulose	Fermentation and distillation of alcohol	Heat, electricity, animal feed, bioplastics, etc.

Source: Rutz D. and Jansse,R. 2008

Generally, the feedstocks are converted to bio-ethanol by acid or enzyme based approach[11]. In both cases, the feedstock first treated in order to facilitate the next steps. These may be size reduction, separation and cleaning as has been shown under harvesting technique in table 2-1. The next step is feedstock conversion to sugar where acids and enzymes are used to break apart to form their component sugar (WWI, 2006). Then the sugars are fermented to bio-ethanol by adding yeasts, bacteria or other suitable organisms and then the bio-ethanol is separated by distillation.

The next generation feedstocks comprise cellulose rich organic materials that include biomass such as wood, tall grasses and crop residues (IEA, 2004), which are harvested for their total biomass. These feedstocks can be converted into bio-ethanol by advanced technical processes. The organic parts of the municipal solid waste (MSW) are also one of the feedstock under the next generation.

The yields of the feedstocks is also varies. For instance the yields of the first generation feed-stocks are shown in Fig.2-2. It shows that bio-ethanol production from sugarcane is the highest per hectare.

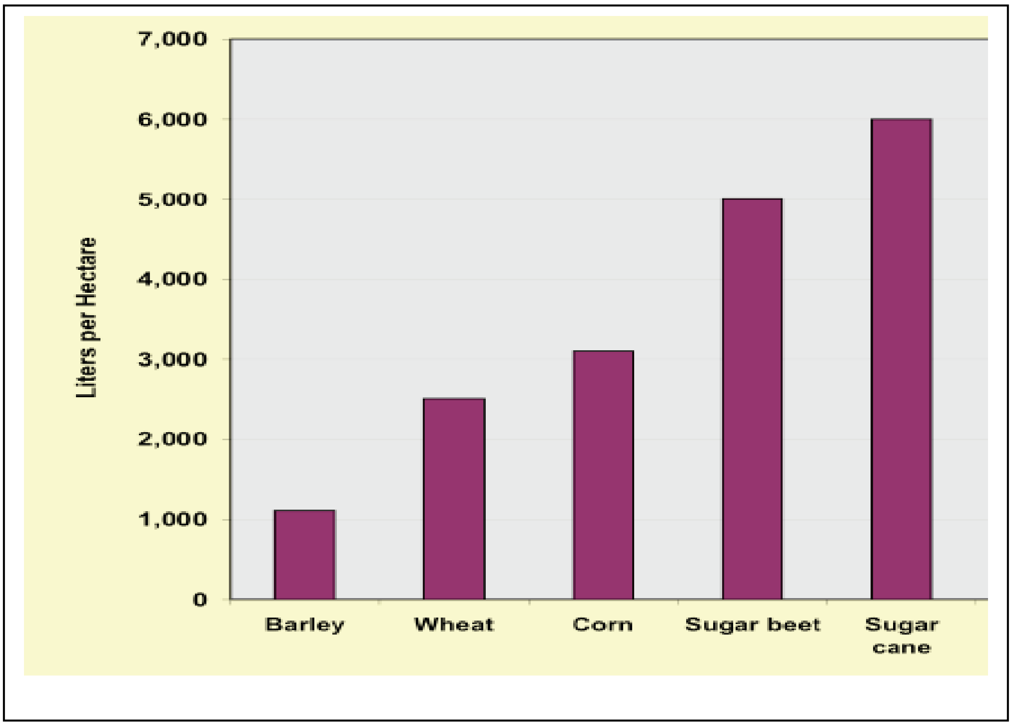

Figure 2-2 Bio-ethanol yield from first generation feedstock

Source: World Watch Institute, 2006

[11] Detailed production steps for each feedstock type can be obtained at Biofuel for Transport, IAE,2004 P34-41

2.1.3 Current status and future trends of bio-ethanol

The production and use of bio-ethanol is rising worldwide as a result of various driving factors as described in 2.1.1

The production in 2000 was around 20 billion liters and the quantity doubled to around 40 billion liters in 2005 (WWI, 2006). Predictions indicate that the production would reach 80 and 120 billion liters by the year 2010 and 2020 respectively (Bio-Fuel Market, 2007 and Dufey, 2006). Figure 2-3 shows the current status and future trends of bio-ethanol

Of the total quantity produced globally in 2005, Brazil's share was about 38% followed by USA with 32%. 60 % of the global supply in 2005 came from sugarcane and the remaining 40% from different feed-stocks (Dufey, 2006).

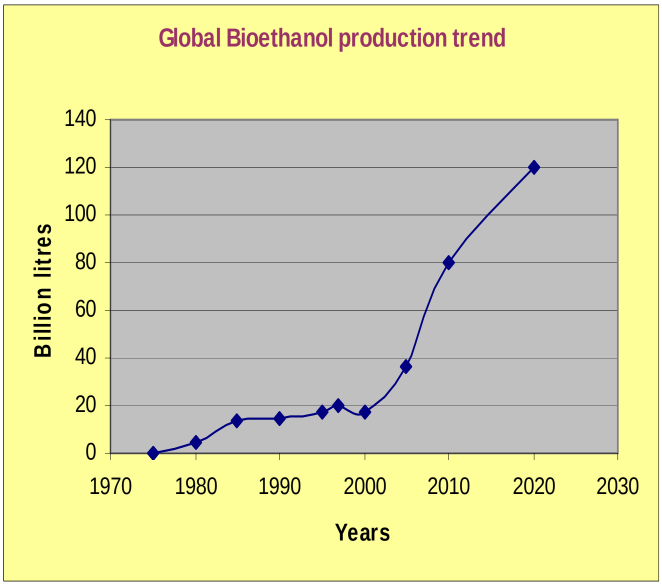

Figure 2-3: Current status and future trends of bio-ethanol production

Source: Adapted from World watch Institute, 2006 and Bio-fuel market, 2007

The future demand of bio-ethanol is expected to exceed the supply which implies that there will be opportunities for low-cost producer developing countries, especially for tropical countries with low labor and land costs (Dufey, 2007).

2.1.4 Bio-ethanol and vehicle compatibility

In most cases countries use less percentage of blended gasoline for transport fuel such as 5% and 10%. This is due to the fact that less percentage blend doesn't require engine modification (WWI, 2006). More recently research and road test on higher percentages and even on neat bio-ethanol has focused on engine modification in order to use either in higher proportion or entirely run by bio-ethanol (IAE, 2004). In most literature, it is indicated that bio-ethanol blend with gasoline up to 10% doesn't have any problems with the conventional gasoline engine and car manufacturers themselves provide guarantee for this except for old models (IAE, 2004). Many car owners, however, do not know this compatibility and it is on the contrary a concern.

IEA stated the potential problem caused by bio-ethanol-gasoline blend when used on the conventional gasoline operated engine as (IEA, 2004): ' … *alcohols tend to degrade some types of plastic, rubber and other elastomer components, and, since alcohol is more conductive than gasoline, it accelerates corrosion of certain metals such as aluminum, brass, zinc and lead (Pb). The resulting degradation can damage ignition and fuel system components like fuel injectors and fuel pressure regulators (Otte et al., 2000). As the ethanol concentration of a fuel increases, so does its corrosive effect. When a vehicle is operated on higher concentrations of ethanol, materials that would not normally be affected by gasoline or E10 may degrade in the presence of the more concentrated alcohol. In particular, the swelling and embrittlement of rubber fuel lines and o-rings can, over time, lead to component failure. These problems can be eliminated by using compatible materials,* *such as Teflon or highly fluorinated elastomers (Vitorns) (EU-DGRD, 2001). Corrosion can be avoided by using some stainless steel components, such as fuel filters…'*

2.1.5 Key barriers

A host of barriers could limit introduction and diffusion of renewable energy (bio-ethanol) technologies. The following are barriers mentioned by different authors to develop bio-ethanol energy systems (Geller, 2003, Reddy and Painuly, 2003, Rutz and Janssen, 2008, McCormik, 2007 and etal).

Economic barriers: The production of bio-ethanol, depending on the feedstock of course, is mostly expensive and market is immature and the full benefits of externalities are not accounted. Given that the bio-ethanol technology system may have a relatively long pay back period, it is not easy to secure long term financing at low interest rates. Traditional lenders are reluctant to provide such loans because of many reasons.

Technical barriers: bio-ethanol system lacks standardization and quality control. In addition, technical barriers pertain to the technical performance of individual technologies and the unreliability about its performance.

Policy and regulation barriers: absence of regulation and policy blocks the creation of market and at the same time limit the involvement of developers due to market uncertainties.

Infrastructure barriers: depending on the percentage of the blend and the technology employed, modified infrastructure may be required.

Causality dilemma: oil distributors claim that before they sell blended gasoline they require vehicles to comply to use this fuel without any problem. On the other hand the automotive industry claims that the infrastructure has to be developed first.

Ethical barriers: the feedstock for bio-ethanol system may compete with food supply.

Knowledge and information barriers: the general public and decision makers may lack knowledge and information. Consumers may lack credible information on the performance, reliability or economic merit of the new system. Developers may also lack accurate data to enter into the business.

Political barriers: lobbying groups may influence politicians to create or conserve an unaffordable political framework for the bio-ethanol system.

2.1.6 Implications of bio-ethanol production and use

The development of bio-ethanol is associated with economic, environmental and social implications. Bio-ethanol is perceived as it would render economic, environmental and social benefits and hence many countries are in the process of increasing its production and use (WWI, 2006). However, there are also some concerns with regard to the environmental and social aspects associated with its development. The following are main implications cited in different literatures.

2.1.6.1 Economic

Economic implications of bio-ethanol include: higher costs of bio-ethanol than conventional fuel, improved trade balance, energy diversification and security, foregone government revenue, and production diversification and value adding (Dufey, 2006 and WWI, 2006).

Higher costs than conventional fuel: one of the economic concerns regarding domestic bio-ethanol development may be higher costs than conventional fuel though economic costs differ from country to country depending on feedstock and technology (Dufey, 2006, IAE, 2004, WWI, 2006 and etal).For instance, Brazil being the most cost efficient producer, its bio-ethanol product can be competitive with gasoline as low as USD 25 a barrel (Duffey, 2006). Other similar low bio-ethanol producing countries include Pakistan and Zimbabwe Duffey, 2006). The economic benefit on bio-ethanol development for tropical countries is larger than temperate zone countries due to higher crop yields and lower costs for land and labour in the former (WWI, 2006). When petroleum prices were above USD 50 per barrel during 2005 to 2006, bio-ethanol from sugarcane was significantly less expensive than gasoline from these countries (WWI, 2006).

Feedstock variety for bio-ethanol has also an impact on the economic benefit. For instance bio-ethanol from corn is expensive than from sugarcane (IAE, 2004, Dufey, 2006 and etal). Because bio-ethanol yield per hectare from corn is less than from tropically grown sugarcane (Dufey, 2006).

Improved trade balance: reliance on imported oil means heavy foreign expenditure that could otherwise be used for other urgent needs for developing countries (Dufey, 2006, WWI, 2006, etal). In this context, developing domestic bio-ethanol means an opportunity to replace oil imports and improve trade balance (Dufey, 2006). In Brazil for instance, replacement of gasoline by bio-ethanol saved some USD 43.5 billion between 1976 and 2000 (Dufey, 2006).

Energy diversification and security: bio-ethanol development is a key strategy to achieve greater energy security by diversifying the portfolio (Dufey, 2006, WWI, 2006, Dominik R. and Rainer J, 2008). The world oil price volatility, uneven oil distribution in the globe, and heavy dependence on imported fuels can be a factor that leave many countries volunerable to disruption of supplies (Dufey, 2006, WWI, 2006). This could clearly impose high risk in energy security, particularly to those countries which are dependent on imports. As a result, domestic bio-ethanol development may have positive implication in reducing the energy insecurity risk.

2.1.6.2 Environmental

The main environmental concerns in the production and use of bio-ethanol are water consumption and water pollution, land competition for food crops and biodiversity and energy balance (Dufey, 2006, DSD, 2005, WWI, 2006, Rutz and Janssen, 2008 and etal)

Water consumption: bio-ethanol production, both on feedstock cultivation and conversion, consumes considerable quantity of water. Apart from the quantity, water contamination impacts of released ethanol are important environmental issues (WWI, 2006 and Rutz and Janssen, 2008).

Land use and biodiversity: land use practices influence habitat and biodiversity aspects. For instance, feedstock production can cause severe environmental problems which can be disruptive stage of total bio-ethanol production. Improper and massive use of pesticides and fertilizer could also be the cause for negative environmental impact of bio-ethanol production (DSD, 2005, WWI, 2006, UN, 2007, Dufey 2006, Rutz and Janssen, 2008, IAE, 2006 and etal)

Energy balance: energy balance refers to the point at which the energy required to produce one unit of bio-ethanol is greater than the energy that comes out, and production in this case is not viable (Rutz and Janssen, 2008). There exist a debate about whether bio-ethanol have a better negative energy balance from all feed-stocks than conventional fossil fuel from the perspective of the whole life cycle (Dufey, 2006). For example the production system of Brazil has an energy balance of between 8.3-10.2 as shown in the following table and thus considered beneficial (IEA, 2004).

Table 2-2 Energy balance of Sugarcane to Bio-ethanol in Brazil

	Energy requirement (MJ / tonne of processed cane)	
	Average	**Best values**
Sugar cane production	202	192
Agricultural operations	38	38
Cane transportation	43	36
Fertilisers	66	63
Lime, herbicides, etc.	19	19
Seeds	6	6
Equipment	29	29
Ethanol production	49	40
Electricity	0	0
Chemicals and Lubricants	6	6
Buildings	12	9
Equipment	31	24
Total energy input	251	232
Energy output	2 089	2 367
Ethanol	1 921	2 051
Bagasse surplus	169	316
Net energy balance (out/in)	8.3	10.2

Source: IEA, 2004

Other feedstocks energy balance has been also stated by Rutz D. & Janssen R., 2008 as shown in table 2-3

Table 2-3 Different feedstock energy balance

Fuel Type (feedstock)	Estimate of fossil energy balance
Bio-ethanol (cellulose)	2-36
Bio-Ethanol (Wheat)	2
Bio-Ethanol (Corn)	1.5
Bio-Ethanol (Sugar beats)	2
Bio-Ethanol (Sweet sorghum)	1
Petrol (Crude oil)	0.8

Source: Rutz D. & Janssen R, 2008

2.1.6.3 Social concerns

Main social impacts in connection to bio-ethanol development include implication for food, land right and creation of job (UN, 2007, IAE, 2004, WWI, 2006, Dufey 2006 and etal)

Implication for food security: as the production and use of bio-ethanol expand, the availability of adequate food supply could be threatened by bio-ethanol production to the extent that land, water and other productive resources could be diverted away from food production (UN, 2007, IAE, 2004 and etal).

Land right: expansion of agricultural land for production of feed-stock could contribute conflicts over land rights and landlessness issue, which could force rural dwellers to migrate and cause to lose their access to key forest resources and ecosystem services (DSD, 2005, Dufey, 2006, Rutz & Janssen, 2008).

Employment creation: one aspect of social benefits linked with domestic bio-ethanol development is the creation of job and rural revitalization (WWI, 2006). Job creation is an external social benefit which normally not considered as direct advantage during domestic bio-ethanol development (Rutz & Janssen, 2008). Sugarcane in Brazil for instance, which is directly related to bio-ethanol production, employees more than 1 million workers, in most case unskilled. Large category of the workers are also women and from rural areas (Dufy, 2006). In addition to income generation by creating job, bio-ethanol domestic production offers opportunities for better livelihoods (Rutz D. & Janssen R., 2008).

2.1.7 Policies to promote bio-ethanol programs

Experience shows that supportive government policies have been essential to the development of bio-ethanol programs. These policies are usually developed to respond to domestic goals associated with the bio-ethanol production and use (Dufey, 2006). For instance, Brazil was motivated to develop policies that have supported the Bio-ethanol program by pressure to reduce the import bill and increase energy security (Dufey, 2006). Additional motivation exists today driven by the potential to mitigate global warming (WWI, 2006).

Given the complex barriers that block the early development of the bio-ethanol program on the one hand and the benefits one can obtain on the other, the use of some form of pubic policy is reasonable to make bio-ethanol production grow in the earliest stages of the industry development (WWI, 2006). The common policy tools that have been successful in fostering the bio-ethanol program are: blending mandates, tax incentives, government purchasing policies and support for bio-ethanol infrastructure and technologies (World Watch Institute, 2006)

The 1975 PROALCOOL program of Brazil, for instance, (presented in detail in part 3), was emerged as a reaction to the oil crisis and aimed to substitute gasoline with blends of bio-ethanol produced from sugarcane. In order to achieve this several policy measures were introduced: production quotas and a fixed purchasing price for bio-ethanol; control of domestic bio-ethanol sales and distribution by a monopolistic agent; subsidies to bio-ethanol blend gasoline producers; tax incentives to car owners using bio-ethanol blend gasoline; and soft loans to implement the necessary technical changes for vehicles (Dufey, 2006). In addition, several other countries (both developed and developing) have either implemented or are implementing policy tools to support bio-ethanol market development. The following table shows some of these experiences (Dufey, 2006).

Table 2-4 Example of policy tools implemented by different countries to promote use of bio-ethanol

country	Target/mandate	Production support	Consumption support	Other requirements
Brazil	1975 Proalcool program mandated blend of 20-30% (E20-E30 %)	Credit to cover 60% of sugar storage costs; tax exemption on vehicles using bio-ethanol or Flexible Fuel Vehicle (FFV)	Credit to cover 60% of sugar storage costs; tax exemption on vehicles using bio-ethanol or Flexible Fuel Vehicle (FFV); mandate to use on government vehicles.	Mandate to use on government fleet vehicles
US	The 2005 energy bill requires increase in ethanol use from 4 billion gallons in 2006 to 7.5 billion gallons by 2012 (a 2.78 % increase target for the 2006)	Volumetric Ethanol Excise Tax Credit (VEETC): a US$ 0.51/gallon to gasoline refiners. Small producers get US$0.10/gallon tax credit for the first 15,000 gallons. Grant and loan programs: Imports protection: US$0.54/gallon secondary duty to the normal tariff to imports based on cheaper biomass and more efficient technology	Tax credits. Fuel tax exemptions. Federal and states incentives to acquire FFV. Mandate to use ethanol on Government vehicles. Loan assistance	All cars built after 1980s will operate on E10. FFVs on sale
Canada	3.5 % of ethanol in transport fuel by 2010	Some provinces exempt bio-ethanol from road taxes	Exceptions from Euro 0.07 per liter excise tax	All cars built after 1980s will operate on E10. FFVs on sale
EU(in general)	Directive 2003/30/EC set target for their consumption in the transport fuel mix: 2% by 2005 and 5.75 by 2010		The Directive 2003/96/EC grant partial or total exemption from excise tax on bio-fuels	
Sweden	3% in 2005 (in energy content)	Tax incentive for new plant construction. Capital grants. Quotas	For bio-ethanol a total tax exemption of Euro 530 per cubic meter- to be revised annually	
India	5% blend	Subsidies for input, tax credits and loans	Fuel tax exemption Guaranteed prices	

Source: Dufey, 2006

2.2 Ethiopia- main sectors

The main sectors that have influence or be influenced by the bio-ethanol program will be agriculture, energy and transport. There are of course other sectors that could be influenced as sectors are interlinked. But these three sectors are directly linked to the program and worth examining them in order to determine to what extent the bio-ethanol development in the country can affect (positively or negatively) the present configuration. Besides, looking into the sectors gives background information for the analysis in part five. Thus the following part describes briefly the current situation of these sectors.

2.2.1 The Agricultural Sector

Ethiopia is an agrarian economy based country. Its total area is 1 127 127 square kilometre, of which 7444 square kilometres is covered by water. About 66% of the total land area is considered to be potentially suitable for agriculture, whereas only 15% of this land area is cultivated (ONAR 1, 2002)[12]. In terms of the area that can be developed by surface water irrigation, it is estimated at about 3-4 million hectares, of which not more than 5% or 200 000 hectares of land developed. Only about 10-15% of the total land is presently covered by forest as a result of rapid deforestation during the last 30 years (Country profile, 2005)[13]. The main causes for this rapid deforestation are extensive farming activities, overgrazing and uncontrolled exploitation for fuel wood (ONAR 1, 2002). Of the remainder, the majority part of the land is utilized by pastoralists. Some land is dry and infertile for agriculture or any other use (ONAR 1, 2002).

Agriculture in Ethiopia is the main sector in the economy, accounting for an average of 45% of the GDP, about 85% of employment generation, and 85 % of export earnings. Crops are the major contributors of the GDP with in the agriculture sector and account about 64%, followed by livestock accounting 23% and forestry with 13% (Agricultural and Rural Development, 2002). Within the agricultural farming, the commercial farming is limited, whereas the mixed farming of the smallholder agriculture and the pastoral livestock system are the leading one. The smallholder agriculture accounts for over 95% of the cultivated land and production (Birehanu, 2006). Production system is largely characterized by subsistence farming, low levels of external inputs, dependency in rainfall and limited integration into the market (Birehanu, 2006). The highlands (above 1500m above sea level) which amount to be about 44% of the highland mass are the greatest economic asset of the country. They shelter about 88 % of the total population and account for over 90% of the economic activity, including about 95% of the cultivated lands and 67% of the livestock population. About 60% of the highlands exhibits slopes in excess of 30% (MOARD, 2002).

2.2.1.1 Land ownership

The existing constitution of the Federal Democratic Republic of Ethiopia with regard to land ownership states that the right to ownership of land is exclusively vested in the State and in the People of Ethiopia. In order to implement this provision, further a rural land administration law is enacted having the following salient features as Ethiopia is divided into 9 regional administrative states (Agricultural and Rural development Department, 2002, p 42):

- Land is a common property of the Nations, Nationalities and Peoples of Ethiopia and it shall not be subject to sale or to other means of exchange.
- Regions shall administer rural land in accordance with the general provision of this proclamation and each Regional Council shall enact a law on land administration of its region

Many debate presents on the issue of the existing land tenure. Experts rather recommend the ownership to be decided based on the socio-economic situation of the country, preferably

[12] http://www.afdb.org/pls/portal/docs/PAGE/ADB_ADMIN_PG/DOCUMENTS/OPERATIONSINFORMATION/AGRICULTURE%20SECTOR%20REVIEW_ETHIOPIA.PDF [last accessed 2008, August 20]

[13] http://lcweb2.loc.gov/frd/cs/profiles/Ethiopia.pdf [last visited 2008, August 20]

substantiated by research (EEA, 2002). However, to close any policy dialogue on the issue, the government inserted the key feature of the existing land tenure system (public ownership of land) as one of the articles of the constitution (EEA, 2002). In connection to land tenure, a study made by the Ethiopian Economic Policy Research Institute indicates that the national average holding is 1.02 ha per household where 37.6% of the households have less than 0.5 hectare per household and 63% of the households own less than or equal to 1 hectare per household. The average landholding per active farm labor force (land-labor ratio) is only 0.38 hectare and about 11% of the households are landless (EEA, 2002)[14]. The land-holding size significantly determines the level of farm income; and the low level of income of farm households in Ethiopia is largely a result of both the small size of holding and the low level of productivity (EEA, 2002).

2.2.1.2 Crop production

About 744 000 square kilometer of the land area (66% of the total land) is considered to be potentially suitable for agricultural production while only close to 15% (112 000 square kilometers) is actually cultivated; almost all are dependent on rainfall. Farming in Ethiopia is mostly in the hands of peasants, who cultivate individual small size plots-all land belongs to the state. Given the suitability of the climate, Ethiopia cultivates a variety of crops. In the highlands, grains (barley, corn, teff, and wheat) as well as pulses and oilseeds are the major crops; whereas at lower elevations, sorghum and sugarcane are favored.

According to the 2007 Ethiopian Statistics Authority report, of the private holding cultivated area, which accounts 95 % of the total cultivated land, cereals occupied 8 471 920 ha, oilseeds occupied 741 791 ha, pulses occupied 1 379 046 and Sugarcane occupied 42 995 ha (CSA, 2008). The types of crops, the area covered and the yield per ha of these private holdings are shown in table 2-5 below.

Around 83 % 0f the population in Ethiopia lives in rural area and they depend on agriculture for their survival. Poverty is rampant by low level of agricultural technology. Rainfall has often been irregular and as a result the majority of these rural dwellers are vulnerable to food insecurity and famine. Domestic production can only cover about 70% of the food requirement and each year about 4-6 million people need food assistance although the potential to be self sufficiency and even surplus exists (Agricultural and Rural development Department, 2002, p 2).

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[14] http://www.eeaecon.org/miscellaneous/newsfolder/polbrser1.html [last visited 28/06/08]

Table 2-5Area under cultivation, production and yield of major crops for 2005/6 main crop season of Ethiopia

S/n	Crop type	Cultivated land (ha)	Production (ton)	Yield (ton/ha)
1	**Cereals**	**8 471 920**		
1.1	Barely	1 019314	1 352 140.	1.33
1.2	Maize	1 694 522	3 776 440	2.23
1.3	Sorghum	1 464 318	2 316 041	1.58
1.4	Finger Millet	374 072	484 409	1.30
1.5	Teff	2 404 674	2 437 749	1.01
1.6	Wheat	1 473 917	2 463 064	1.67
1.7	Oats	32 798	36 243	1.10
2	**Oil Seeds**	**741 791**		
2.1	Linseed (Flax)	174 108	108 224	0.62
2.2	*Neug*[15]	274 720	147759	0.54
2.3	Sesame	211 312	149 3867	0.71
2.4	Ground Nuts	37 126	51 080	1.38
2.5	Sunflower	13 019	11 176	0.86
2.6	Rapeseed	30 637	29 206	0.95
3	**Pulses**	**1 379 046**		
3.1	Chick-Peas	200 066	253 871	1.27
3.2	Field Peas	221 715	210 095	0.95
3.3	Haricot Beans	223 357	222 701	1.00
3.4	Faba Beans	459 202	576 156	1.26
3.5	Lentils	97 110	81 049	0.84
3.6	Grass Pea	124 954	183 784	1.47
3.7	Soya Beans	6 352	5 849	0.92
3.8	Fenugreek	20 762	16 398	0.79
3.9	Gibto	25 526	28 717	1.13
4	**Other crop**			
4.1	*Sugarcane*[16]	42 995	1 374 712	31.97

Source: Central Statistics Authority of Ethiopia, 2008

2.2.1.3 Agricultural Policy

The government of Ethiopia enacted in 1993 the Agricultural Development Led-Industrialization (ADLI) strategy establishing a link between agriculture and industry. What it means is that the economic activities in general and industrial development in particular is led by agriculture, the direction of the economic development is determined by agriculture. Furthermore, it means that agricultural development plays the leading role, determining the pace and direction of industrial development.

[15] Neug is sunflower

[16] Sugar cultivation area is taken those of the state sugar factories. The area currently being developed by the new sugar factory area is taken into account. Since harvesting is not started , the yield shown is much less than the assumed average

ADLI being the general strategic direction that gives emphasis on agriculture, there are specific policies and strategies put in place that support implementation of this grand strategy. Among the different policies, the land use and forest conservation and utilization proclamation are briefly reviewed here as they have important connection with the bio-ethanol development in order to show the status and extent of these policies in taking care of the concerns being raised with regard to land competition and deforestation.

Rural land administration and land use proclamation

The main objective of the rural land administration and land use proclamation (proclamation no 456/2005) are the following:-

- To establish an information database that enables to identify the size, direction and use rights of the different types of land holdings in the country such as individual, and federal and regional states holdings

- To resolve problems that arise in connection with encouraging individual farmers, pastoralists and agricultural investors and establish a conducive system of rural land administration

- To sustainably conserve and develop natural resources and pass over to the coming generation through the development of a sustainable rural land use planning based on the different agro-ecological zones of the country

To implement the objectives the proclamation states as a guiding land use master plan to be developed and implemented by an authority which will be established in accordance with the constitution of a *region*[17] to ensure the proclamation is realized. Though there are responsible departments at the federal as well as in the region to take care of the proclamation, no study on land classification and land use planning are yet done (Kifelu, 2008, July 6, personal discussion). They are expected to be accomplished in the future. As a result there is no effective control to prohibit access to and use of food crop agricultural lands and high nature-value sites to energy feedstocks. Besides, due to absence of updated land information there is skeptic on the claim that 66% of the total land area is suitable for agriculture.

Policy on forest development, conservation and utilization

There are policy, strategy and proclamation on forest development, conservation and utilization developed as a package in 2007. The policy and strategies are legally proclaimed under the proclamation number 542/2007 and is called a proclamation to provide for the development, conservation and utilization of forests.

This package entails detailed issues on forest development, conservation and utilization. It addresses both private and state forests. As most of the time is public properties vulnerable to distraction, the proclamation indicates the following with regard to conservation, development and administration of state forests.

- State forests will be designated, demarcated and registered

[17] In Ethiopia, there are 9 autonomous adminstrative regions which have their own regional constitution.

- State forest will be properly developed, conserved and utilized
- State forest will be utilized in accordance with the management plan to be prepared and approved
- Protected natural forests and forest lands will be demarcated and conserved for the purpose of environmental protection and conservation of history, culture and biodiversity
- Unless in possession of written permit from the Ministry of Agriculture and Rural Development or the appropriate regional body, no person will, with in the state forest, (a) cut trees (b) settle temporarily or permanently (c) graze domestic animals (d) carry out hunting activity (e) carry cutting saws and any other tools used for cutting trees (f) keep beehives or extract honey.

The responsibility to implement the proclamation is given to the ministry of agriculture and rural development. It is expected to ensure the implementation by coordinating the appropriate federal and regional bodies and providing technical support. However, the implementation of this proclamation is yet to be started (Kifelu, 2008, July 6, personal discussion).

2.2.2 Energy sector

Ethiopia's Energy consumption is predominantly based on biomass energy sources. The lion proportion (95.1%) of the country's energy demand is met by traditional energy sources such as fuel wood, charcoal, branches, dung cakes and agricultural residues (Energy Policy, 1994). The balance is met by commercial energy sources such as electricity and petroleum. Petroleum accounts 4.3% and electricity 0.6% (EMSA, 2001)[18]. The most important issue in the energy sector is the supply of household fuels, which is associated with massive deforestation and the resultant land degradation (EEA, 2004). The increasing scarcity of fuel wood is compounded by Ethiopia's high population growth rate.

The energy sector in Ethiopia remains heavily dependent on biomass despite the country's huge potential of various energy production resources. However, the exploitation rate is very small, except for biomass. Table 2-6 below indicates the resource potential and the exploited status of the various energy sources.

Even though per capita energy consumption of Ethiopia is among the lowest in the world, which is 28KW[19], the gap between sustainable biomass supplies and demand is constantly widening. The current (2008) fuel wood deficit is estimated to be about 65 million m^3 per day[20] (EEA, 2004).The demand of households for forest products in many areas exceeds by far the annual incremental yield from the existing forest. As a result, the price of fuel wood has roared to a record high that people living in cities are forced to switch to fossil fuel use. The current price for one metric tones of fuel wood reaches as high as Birr 200.

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[18] http://www.fao.org/docrep/004/AB582E/AB582E00.HTM [last viewd 2008, August 20]

[19] http//: www.eppco.gov.et, accessed on July01, 2008

[20] Basic density of wood is assumed as 500kg/m^3, energy content of fuel wood is equivalent to 7250MJ/m^3 (Ethiopian Journa; of Economics, 2004)

Table 2-6 Energy resource potential and exploited rate in Ethiopia

Overview of energy status			
Resource	Unit	Potential	Exploited (%)
Hydropower	MW	>45,000	<3
Solar/day	KWh/m2	4-6	0
Wind Speed	m/s	3.5-8	0
Geothermal	MW	1070	0
wood	Million tons	1120	50
Agricultural waste	Million tons	15-20	30
Natural Gas	Billion m3	113	0
coal	Million tons	96.3	0

Source: Meskir, 2007

The major use of energy, about 89% of the overall energy consumption in the country, is the households. The second most important sector in terms of energy consumption is industry (4.5%) followed by services and others (3.6%) while agriculture and transport were attributed to the remaining 2.3% (EEPCO, 2005)[21]. The consumption of energy is directly related to the availability of energy source, the size of the population and the price. Table 2.7 shows the sector-wise percentage usage distribution of energy source type in Ethiopia.

Table 2-7: Sector wise energy source utilization percentage distribution

	Energy source		
Sectors	Biomass (%)	Petroleum (%)	Electricity (%)
Households	98.6	1.1	0.3
Industry	75.7	17.3	7
Services	94.3	1.3	4.4
Transport	-	100	-
Agriculture	-	100	-

Source: Meskir, 2007

Transport and agriculture sectors are entirely dependent on imported fossil fuel as Ethiopia doesn't have at the moment vehicles run by electricity and biofuel. Petroleum import quantity is shown in part 2.3.3. With regard to electricity use, currently the country is able to generate 831MW of electricity per hour from hydro dams, which accounts 98% of all electric production, the rest comes from fossil fuel and only about 14% of the population has access to electricity (NBE, 2007 and EEPCO, 2005)

The current holdings of the power sector is entirely controlled by the state, no private power supplier exists in the country though provisions are given to private investors (see next part on energy policy).

[21] http//: www.eppco.gov.et, accessed on July01, 2008

Generally the dependency of the hydro-power plants on rain, depletion of forests for biomass source and price escalation of petroleum products bear heavy burden to fulfill the country's energy requirement and it is mandatory to expand the energy mix from available resources, giving priority on the basis of social-economic and environmental benefits.

Energy Policy

A comprehensive national energy policy which aims to ensure least-cost development consistent with the country's energy resource endowment and socio economic policies has been prepared in 1994. According to this policy document, the government general energy sector direction is:

- To enhance and expand the development and utilization of hydrological resources for power generation with emphasis on mini-hydropower development.
- To promote and strengthen the development and exploration for natural gas and oil;
- To greatly expand and strengthen agro-forestry programs;
- To provide alternative energy sources for the household, industry, agriculture, transport and other sectors;
- To introduce energy conservation and energy saving measures in all sectors;
- To ensure the compatibility of energy resources development and utilization with ecologically and environmentally sound practices;
- To promote self-reliance in the fields of technological and scientific development of energy resources;
- To ensure community participation, especially the participation of women, in all aspects of energy resources development and encourage the participation of the private sector in the development of the energy sector.
- To stage popularization campaign through mass media using various national languages to create awareness among the general public and decision makers regarding energy issues; and,
- To create appropriate institutional and legal frameworks to handle all energy issues.

With regard to modern type of energy source, the policy document emphasizes the development of rich energy sources of the country from hydro, geothermal, natural gas and coal. It has also mentioned finding non-fossil fuel source as alternative source of transport energy in a bid to reduce the use of petroleum. But specific target as to how much and to what extent as well as with what incentive the bio-ethanol fuel source the country should develop has not been mentioned in concrete terms. It is only recently a concerted effort has been undertaken to blend with gasoline and use as a transport fuel.

The government has taken steps to address the power sector issues. One notable specific change that has been put in place is to delineate operation and regulatory functions, and liberalize the sector to promote private investment. In this regard, Proclamation No. 86/1997 has been enacted to regulate the activities of electricity suppliers and thereby operation and regulatory functions. It also provides for the establishment of a regulatory authority, The Ethiopian Electricity Agency (EEA), responsible, among other things, for recommending tariffs; and establishes the principle of third party access to the grid for facilitating private investment in the future (EEPCO 2005)[22]. The currently tariff rate being operational by this agency in the country is shown in appendix III.

With regard to liberalizing the sector to promote private investors Proclamation No. 37/1997 is enacted. This enactment allows the participation of domestic private investors in the production and supply of electrical energy with an installed capacity of up to 25 mega-watts and, production and supply of electrical energy with an installed capacity of above 25 mega-watts is open to foreign investors. The provision entails the development of small and medium scale capacity plants from diesel, coal, gas, hydro and other sources. As incentives to private investors, Council of Ministers Regulations No. 7/1996 and as amended in No. 36/1998 extends attractive package in the form of duty and profit tax exemptions (EEPCO, 2005)[23].

2.2.3 Transport sector

The transport sector contributes only about 6% of the total GDP in Ethiopia albeit it's crucial role in supporting agricultural development, facilitation of trade and domestic competitiveness (NMSA, 2001)[24]. Road transport, single railway, airline and ships are the conventional transport means. The dominant mode of transport in Ethiopia, however, is road transport, having share of 90% in transporting passenger and cargo across the country. The road density is among the lowest in Africa estimated to be about 30km per 1000 square kilometer (NMSA, 2001). The development of surface transport service has been limited due to wide topographical variations, extremely rugged terrain, sever climatic conditions, and a widely dispersed population (NMSA, 2001). These factors make construction of transport infrastructure not only physically difficult but also extremely costly.

As mentioned, the road transport plays important role in the movement of goods and passengers as compared to other modes of transport. According to the Ethiopian Road Authority of the Ministry of Transport and Communications, totally 166,309 vehicles found registered in the year 2004/05 (MME, 2007) and this number has increased to 240,000 in 2007 (RTA, 2008). These vehicles consume either gasoline or gas oil fuel type.

The transport sector consumes more than 50% of the total petroleum products the country is importing every year (MME, 2007). The volume of the fuel consumed by road transport vehicles has the greater share and currently become a challenge due to increasing quantity and price escalation of the products. Stated below in table2-8 is the country's petroleum consumption, excluding kerosene which is used for household cooking fuel, in quantity and value respectively for the last 7 years.

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[22] Ibid

[23] Ibid

[24] http://www.fao.org/docrep/004/AB582E/AB582E00.HTM [last viewd 2008, August 20]

Table 2-8: Petroleum import data (In quantity)

	Importation (quantity in metric tones)					
	Gasoline	**Jet Fuel**	**Diesel oil**	**LFO**[25]	**HFO**[26]	**TOTAL**
2000/01	129,588	224,536	620,186	51,852	69,410	1,095,572
2001/02	132,808	248,711	622,094	38,412	80,087	1,122,112
2002/03	148,354	269,210	679,747	41,698	93,370	1,232,379
2003/04	130,370	292,766	687,991	47,121	89,844	1,248,092
2004/05	147,149	333,079	771,807	45,109	109,755	1,406,899
2005/06	137,222	368,670	811,013	41,385	116,822	1,475,112
2006/07	148,368	411,357	925,389	42,406	116,435	1,643,955

Source: EPE, 2008

Table 2-9: Petroleum import data (In Value)

	Importation in value ('000' Birr)					
	Gasoline	**Jet Fuel**	**Diesel oil**	**LFO**	**HFO**	**TOTAL**
2000/01	346,536	532,685	1,307,334	79,006	101,726	2,367,287
2001/02	291,310	498,491	1,109,177	56,666	109,076	2,064,720
2002/03	369,329	629,545	1,454,320	74,248	156,451	2,683,893
2003/04	411,304	825,219	1,737,682	86,589	156,234	3,217,028
2004/05	603,547	1,437,764	2,928,585	96,342	222,594	5,288,832
2005/06	753,382	2,108,241	4,076,947	131,130	360,701	7,430,401
2006/07	835,671	2,455,345	5,006,395	135,497	362,058	8,794,966

Source: EPE, 2008

The share of gasoline of the total consumption declined from 13 % in 2000/01 to 9% in 2006/7. This is due to the fact that vehicle importers have been inclined more to diesel driven vehicles as a result of gasoline cost (Negessu, 2008, July 18, personal discussion). In terms of quantity, gasoline showed 14.5 % increment from 2000/01 to 2006/7. Price wise the increment has been 141%. As can be seen from table 2-9, the total value spent during the year 2006/7 increased by 272% from 2000/01. On average the money being spent for petroleum products has been increasing by 45% annually.

As a result of the increment and huge expenditure of money for petroleum products, the government regularly adjusts the local selling price of the products including the subsidies to transfer some of the increment happening in the world market to consumers. The existing price structures looks like as stated below in table 2-10.

[25] LFO means light feul oil

[26] HFO means heavy fuel oil

Table 2-10: Current Price structure of petroleum products

S/No	Description	Gasoline	KEROSENE	Diesel oil	LFO	HFO	JET Fuel
1	Ex-Djibouti price	6.5657	6.8165	6.7179	4.7196	4.6149	6.8197
2	Djibouti/Dewele/ Galafi Transport	0.0804	0.0804	0.0804	0.0876	0.0876	0.0804
3	Total Border Price (1+2)	6.6461	6.8969	6.7983	4.8072	4.7025	6.9001
4	EPE's Margin	0.0598	0.0350	0.0584	0.0500	0.0500	0.0600
5	**Product Cost(1+4)**	**6.6255**	**6.8515**	**6.7763**	**4.7696**	**4.6649**	**6.8797**
6	Excise Tax [30% on(1+2)	1.9939					
7	VAT [15% on 1+2+6]	1.2960		1.0197	0.7211	0.7054	
8	Road Fund	0.0950		0.0800			
9	Municipality Tax	0.0200		0.0200			
10	Stabilization Fund	(0.8866)	(1.5888)	(1.4637)	0.0118	0.0119	(0.0020)
11	**Total Duty (6 to 10)**	**2.5183**	(1.5888)	**(0.3440)**	**0.7329**	**0.7173**	**(0.0020)**
12	**Invoice Price(5+11)**	**9.1438**	**5.2627**	**6.4323**	**5.5025**	**5.3822**	**6.8777**
13	Distributors Margin	0.2562	0.4573	0.4677	0.4475	0.4478	0.5123
14	**A.A Retail price (12+13)**	**9.4000**	**5.7200**	**6.9000**	**5.9500**	**5.8300**	**7.3900**

Source: EPE, 2008

Except for the stabilization fund (0.8866 Birr/ liter), gasoline gets no subsidies. Compared to other petroleum products on the other hand, its price build up entails all taxes (Excise, VAT, and Municipality), that was not the case in the past. In the past heavy subsidy was given to keep the price at minimum. As can be seen from the table, the price build-up of gasoline that tries to incorporate all taxes and avoid subsidy as well as the price value itself is in favor of bio-ethanol.

3 Experience in Brazil

The use of bio-ethanol in Brazil as fuel goes back to the beginning of the 20th century, although the 1930s was marked as a time when ethanol-gasoline blending took place in a significant scale (Calle and Luis, 1997, P1). In 1923 for instance, the production quantity of bio-ethanol had reached to 150 million litres per year. In 1931, Federal decree passed mandating that bio-ethanol was to be added to gasoline to the extent of 5% of the mixture (by volume) and establishing guidelines for its transportation and commercialization, by 1941, bio-ethanol production had grown to 650 million litres (Moreira and Goldemberg, 1999, p 3).

The production of bio-ethanol reached 17.7 billion litres by the year 2006, of which 13.3 billion litres consumed as transport fuel representing around 40% of the fuel used in motor vehicles with spark ignition engines that year .Around 80% of the total production was used as transport fuel, whereas 5 percent went to local industrial use for food industry, perfumes and ethanol derived chemicals, and 15% was exported (UNICA, 2007, p 14- 16). In addition, the sector generated 11.3 TWh of electricity, most of which was consumed by the sector itself, that is equivalent to 3% of the country overall electricity power consumption. Overall, the sugar cane industry contributed 14.6 % of the domestic energy offer in 2006 by replacing 420 000 barrels of oil equivalent per day worth of fuels (gasoline, fuel oil or natural gas) for the transportation and industrial sectors (UNICA, 2007).

3.1 Important millstones

The government of Brazil took a number of measures at different times to overcome the challenges posed to sugar industries and back the development of the sugar cane agribusiness. The following interventions were important steps in developing the bio-ethanol program.

When the government found that the national sugar production was in excess of the consumption needs and considering that there was a world trend towards limitation on sugar production, the Sugar and Alcohol Institute (IAA) was created. Its main purpose was to ensure the balance in the sugar market, and that producing ethanol would be a feasible alternative for the sugar industry. Accordingly, policies were designed subsequently to sustain and keep the activities of the sector organized and profitable (UNICA, 2007, p 21).

The production and use of bio-ethanol for transport fuel represent the most important step in Brazil for fossil fuel substitution and commercial fuel program successfully implemented since the creation of the National Alcohol Program in 1975, commonly called “ProAlcool”. The Brazilian Alcohol Program (ProAlcool), aimed at gasoline substitution by ethanol obtained from bio-mass, e.g. sugarcane, cassava and sorghum (Sugarcane became the sole source of ethanol production), was established in late 1975 as a consequence of oil crises. The purpose was to reduce oil imports, as well as to solve the problem of fluctuating sugar prices in the international market (Goldemberg and et al, 2003).

The first stage of ProAlcool was set up in November 1975 and determined that the program was to be implemented by the executive power (UNICA, 2007, p 22). At the same time the National Alcohol Executive Commission (CENAL) was created to accomplish the following tasks (UNICA, 2007). (1) determine how different agencies directly or indirectly linked with the program would participate to support the expansion of ethanol production, (2) setting criteria to be followed for the implementation of new distillery projects, (3) setting up annual programs for the various types of ethanol by specifying their uses, including the blending mandate (4)deciding on suitability of proposals and/or projects for modernizing, expanding or implementing ethanol distilleries to the purposes of the program and (5) setting the location criteria to be followed for the implementation of storage units..

The program embraced also financial support in terms of providing loans at low interest rate than those prevailing at that time for investments and expenses related to the program. Besides, different agencies were given mandates to accomplish tasks related to the program. The National Oil Council (CNP) was responsible for assuring ethanol producers prices subject to premiums or discounts, depending on the technical specification of the type of ethanol purchased from them (UNICA, 2007 and et al). UNICA also indicates that "…*The exportation of molasses or any ethanol type or grade to export markets was compulsorily promoted either by the IAA or with private businesses acting as intermediaries, which would do so only when expressly authorized by the Institute nonetheless. It was also incumbent upon the IAA to set up the technical specifications for molasses and ethanol, whatever the types and origins. Furthermore, all ethanol distilleries, whether designed as annexes or independent units, were subject to registration with the IAA, whatever the raw material used".*

The first program created a full institutional framework to evaluate and finance new projects involving various ministers. The program used the existing productive structure at that time to install annexed distilleries to existing sugar mills to produce anhydrous bio-ethanol. As a result of this program, from 1975/76 to 1978/79, the country was able to rise its fuel ethanol production from 0.56 billion liters to 2.5 billion liters, 2.1 billion liters of which being the anhydrous grade which is basically meant for blending with gasoline (UNICA, 2007, Calle and Cortez, 2004). Notable problem mentioned during the first phase was the difficult relationship between the multinational auto manufacturers and the government.

To stimulate the production of hydrous bio-ethanol that could be used directly to the engines of passenger vehicles, the government redesigned the first Proalcool program in 1979, which was known as phase II of the Proalcool. In phase II the National Alcohol council (CNAL) was created with a task of setting the price of bio-ethanol and overseeing the bio-ethanol production target. Proposing price was the responsibility of the National Oil Council in addition to the duty of setting up bio-ethanol distribution program for consuming companies and oil distributors (UNICA, 2007). The redesign of the program was resulted the production of hydrous bio-ethanol to grow from 395 million litres in 1978/1979 to 1.7 billon litres in 1992/93 crop season. Likewise the annual sales of cars running exclusively on hydrous bio-ethanol increased from 240,638 units in 1980 to 698,564 in 1986 , representing 96 % of all new vehicles sold in the domestic market (UNICA, 2007)).

The success was not achieved in a simple way; it involved a complex economic and logistical challenge (refocus, 2006)[27]. '…*With the help of public subsidies and tax breaks, farmers planted more sugar cane, investors built distilleries to convert the sugar to ethanol and carmakers designed cars to run on 100% alcohol. The government financed a huge distribution network to get the fuel to gasoline stations and kept alcohol prices low to attract consumers…'* Especially at the beginning, the increase of production and use made possible by the following three government actions (Goldemberg and etal, 2003)

- The obligatory decision to purchase a guaranteed amount of ethanol by the monopolistic state owned oil company, Petrobras.

[27] http:// www.re-focus.net[last visited on 7, August 2008]

- The provision of economic incentives (offering loans with low interest rates from 1980 to 1985) for agro-industrial enterprises willing to produce ethanol.

- By making ethanol attractive to consumers, by selling it at the pump for 59% of the price of gasoline.

Besides, public and private R&D investments on agricultural as well as industrial productivity and on engine running with 100% or a higher blend of bio-ethanol supported the development at the beginning. (Elena, 2007)

Generally, the increase in production and use of bio-ethanol program as a fuel was made possible during the early stage by taking the following important steps (UNICA, 2007, IFPRI, 2006, ReFocus, 2006, Goldemberg and etal, 2003, Elna, 2007 and etal)

- Establishing appropriate institutional framework and tasks to be accomplished towards the implementation of the program
- The decision on blending quota of bio-ethanol
- The provision of economic incentives for agro-industrial companies willing to produce bio-ethanol by offering low interest rate loans
- Making bio-ethanol attractive to consumers by selling at the pump station at reduced price than gasoline.
- By public and private R&D investments.

Today, Sugar-cane, sugar and ethanol prices are free and determined by market rules. That means that the production and marketing of sugar-cane, sugar and ethanol is no longer subject to State control. The prices paid to producers are determined by the markets (UNICA, 2007 and et al). Also, there is no ethanol free gasoline on the market now. Gasoline is marketed with either E25 (25 % blend of bio-ethanol) or E100 (100 % bio-ethanol) .For these two types of fuels, there are three types of vehicles in the market (Schmitz and etal, 2005). '…*First, for the use of the so-called gasohol*[28] *ordinary gasoline engines need some minor modification. All automobiles on the market in Brazil experience no problems in the use of E25. On the contrary, the blending of bio-ethanol even improves the engine performance. Second, there are automobiles for the use of pure bio-ethanol (E100) which need more modification. Third, since 2003 so-called Flexible Fuel Vehicles (FFVs) are on the market. They can be run by E25 as well as by E100. This type turned out to be a major success. In 2004 FFVs already accounted for 30% of the newly registered vehicles and in 2010 the FFVs are expected to have a share of 25% of the entire Brazilian fleet…'*

3.2 Feedstock and production

The feedstock for bio-ethanol production in Brazil is sugarcane. The cultivation is based on a ratoon-system, which means that after the first cut the same plant is cut several times on a yearly basis (Smeets and etal, 2006). Yields decline with approximately 15 percent after the first harvest and 6-8 percent in the following years (Smeets, 2006). The simplified overview of the feedstock production is shown in Fig 3.1 below.

[28] Gasohol is the name given to 25% bio-ethanol and 75% gasoline or E25

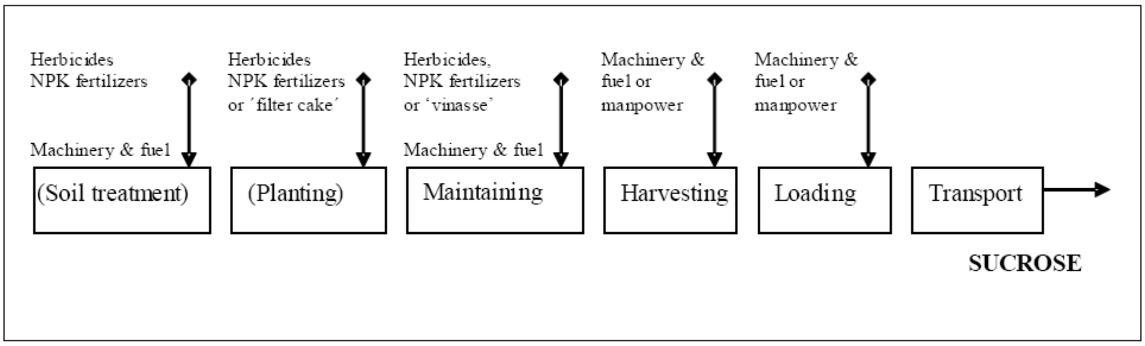


Figure 3-1: simplified overview of sugarcane production in Brazil

Source: Smeets, 2006

Sugar-cane can in Brazil is grown either by the industrial plants themselves (in owned or leased lands) or through farming companies related to the same business group or third parties, usually natural persons, who are referred to as sugar cane suppliers. These suppliers are more than sixty thousand in number and have utilized 5.3 million hectares of land out of the 6.3 million hectares of the total growing area, of which 50% of the sugar cane out put goes to sugar production and the remaining 50% to ethanol production (UNICA, 2007, P36). Mean ethanol out put reaches 6900 liters per hectare. The land used for all sugarcane crops (sugar and ethanol) represents only 7.5% of the area used for all crops or 0.6% of the Brazilian territory.

The suppliers usually sell their production to the plants located near to them because of quality deterioration if longer time is taken for delivery and transportation costs (UNICA, 2007). To prevent an unbalance income distribution between the suppliers and the processors due to these factors, the suppliers association and the association of sugar and ethanol industries jointly created a system that aims to set parameters for a fair and an appropriate remuneration for producers. The system created distributing the net income from sugar and ethanol sales among sugarcane suppliers and industries. To that end the system employs the following techniques UNICA, 2007):

- a technical method to assess the quality of the sugar-cane delivered by the supplier, in terms of the amount of sugars usable in the industrial process that it contains
- the means farming and industrial processing costs;
- the price for the end products, i.e. sugar and ethanol, either for the domestic market or exports, asked in the course of the crop year (May through April of the next year);
- the characteristics of each industrial plant's production and marketing activity for the crop year; these characteristics consist of the amount produced of each product (sugar and ethanol) and the end use after sale (use as fuel, export, etc.)

The system is said updated every five years and today the apportionment look like: in the case of sugar production 59.5% of the income goes to the sugarcane suppliers and 40.5% for the processor and for ethanol case 62.5% goes to the suppliers and the rest 37.5% to the processors (UNICA, 2007).

The simplified process for sugar extraction and bio-ethanol production from sugarcane is shown in fig 3-2 below. It shows the combined production ways for sugar and bio-ethanol. Both hydrous and anhydrous types of bio-ethanol are also produced. Cyclohexane is used in the final distillation of the anhydrous bio-ethanol (UNICA, 2007).

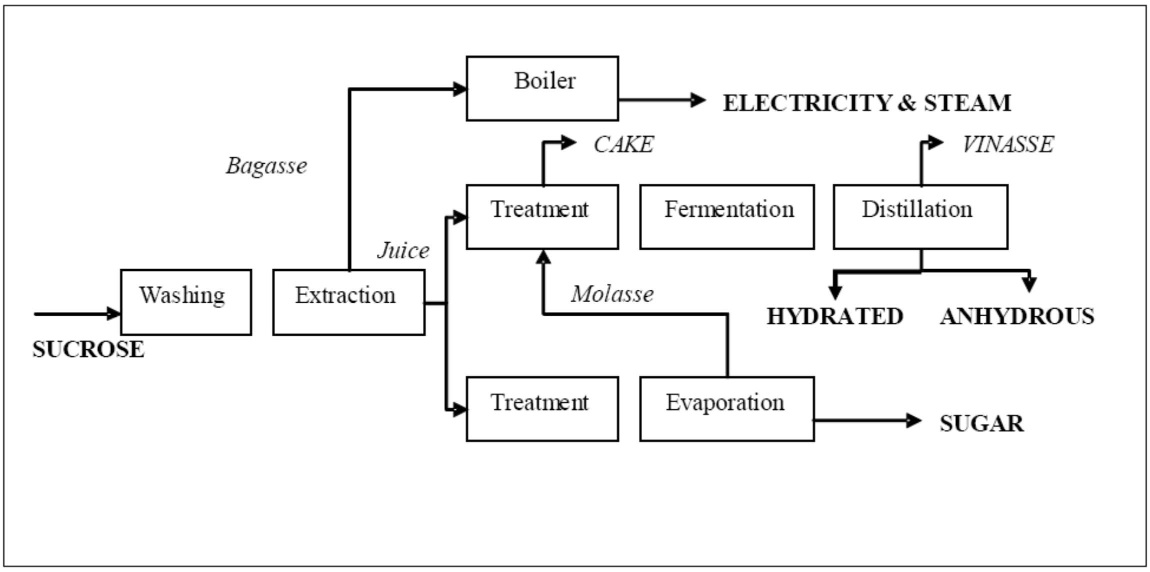


Figure 3-2: Simplified process flows for sugar and bio-ethanol production

Source: Smeets and etal, 2006

The blending with gasoline is done at the distributors' base when loading the tanker truck that will carry the product to the point of sale. The mixing is done both manually and in automatic in-line system (UNICA, 2007). In the manual mixing case, first the desired volume of bio-ethanol is filled and then the gasoline follows.

3.3 Environmental situation and impacts

The area covered by sugar cane crop in Brazil represents about 0.6% of the total 850 million hectares, of which only 0.3% land area is taken up for bio-ethanol. Farming area for all amounts to 60 million hectare, which is about 7% of the territory. With this land occupation for farming, Brazil is a net exporter of food (UNICA, 2007). Therefore, the sugar cane and bio-ethanol production doesn't have a conflict for food competition in terms of land use (UNICA, 2007). It is indicated also that future expansion will be based on degraded pasture lands and fields, and expansion to any forest areas and protected biomes is restricted by legislation (UNICA, 2007).

With regard to water consumption, sugarcane farming doesn't use irrigation; almost all the water used comes from rain. Generally the sugarcane industry consumes less water per ton of cane produced and processed. All industrial systems are closed, with high recycling rate (UNICA, 2007). There is also a billing system for collecting, consuming and releasing of effluent to water bodies to induce a reduction of collected and consumed volume as well as better use of water. Due to such a system for instance, the water collection and release levels have been substantially decreased over the past few years, from around 5 m3/ton of sugar-cane worth of collected water (in 1990 and 1997) to 1.83 m3/ton of sugar-cane in 2004 (UNICA, 2007).

In order to prevent and minimize possible environmental degradation due to expansion or new development in bio-ethanol production, environmental impact study will be conducted prior to the implementation of any such activities. The form of that study is set forth by law, and anyone interested is assured the right to know and monitor it. Regulated permit system assures projects that may have negative environmental consequence not to get licenses and hence refused to be approved and implemented. The permit system is organized in three steps (UNICA, 2007):-

- The first license approves the location and conception of the undertaking, certifying its environmental feasibility, and provides for requirements to be fulfilled for obtaining the subsequent permits;
- The next permit, the implementation permit, allows the undertaking to be implemented; and
- The third permit or the operation permit approves the start-up of the undertaking. This permit is valid for ethanol production plants only for three years and a renewal application before the expiry period must be filed. Renewal is issued when the undertaking is found to comply with the state and federal standards.

Along the course of the procedures, public hearings are the means to discuss the project activity with the community.

Other environmental issue that may attract interest with regard to Brazil bio-ethanol production and use is the energy balance. The ratio between the renewable energy produced and the fossil energy used was 8.9 (UNICA, 2007). This is due to the low need of mineral fertilizers in the cultivation of sugar cane and the surplus in the conversion process that results from the use of bagasse as an energy source (Schmitz and etal, 2005). This could attain greenhouse gas abatement of 2-2.8 kg CO_2-equivalent per liter of bio-ethanol. For example, the greenhouse gas emissions avoided by the sector in 2003 were stated as 27.5million tones of CO_2-equivalent by replacing gasoline with bio-ethanol and 5.7 million tones of CO_2-equivalent by using cane bagasse in sugar production (UNICA, 2007).

3.4 Technological improvement

One of the main successes the Brazilian bio-ethanol program has achieved is the reduction of bio-ethanol cost through technological breakthrough, improved management and investments in infrastructure (UNICA, 2007). The technological development taken at different periods include (UNICA, 2007):

- In the period 1980-90, development of new sugar cane variety, introduction of new grinding system, fermentation with greater capacity, use of waste product from the bio-ethanol plant (vinasse) as a fertilizer, introduction of biological control of the sugar cane beetle, optimization agricultural operations, and self sufficiency in energy
- In the period 1990-2000, start of surplus energy sale, improved management in technical agricultural and industrial, development of new sugar cane harvesting and transportation systems and development of advanced automation system.

By doing these advancements, production of sugar cane per hectare has increased by 33%, conversion of sugarcane into ethanol has increased by 14% and productivity in fermentation (M^3 ethanol/M^3 reactor/day) has increased by 130 % in the period.

4 Analysis- Conditions and potential

This part analyses the situation currently prevailing in Ethiopia on production and use of bio-ethanol. The framework depicted in fig 1-1 guided the analysis. The background information presented in part 2 is also used to address important issues on the development of bio-ethanol. Using the background information as input and the framework as guidance, the actors, networks and institution in the value chain along with the current condition and future potential are identified.

Currently the government of Ethiopia is undertaking various steps to use bio-ethanol as a transport fuel blended with gasoline. The feedstock chosen for the production of bio-ethanol is molasses from sugar-cane although corn Stover was considered as potentially useful. Thus the analysis is done on the current undertakings of the government.

4.1 Actors

There are different important actors (such as firms, public bodies etc…) along the value chain of bio-ethanol production and use from sugar cane molasses, which are technically and politically so powerful that they can initiate or strongly contribute to the development of bio-ethanol at the different stage. Due to the distinctive nature of operations at the different value chain (feedstock cultivation, sugar extraction, fermentation/distillation, blending and use level), different actors involve at each step and thus various actors dominate towards the final need of production and use of bio-ethanol at each level. Particularly firms involved in the value chain are the ones which play dominant role. Other actors are also involved despite their weak link in the value chain at the moment.

4.1.1 Firms and their status

Various firms involve in the production and supply phase of the bio-ethanol value chain. In order to understand them well and explore the current positions as well as the future intention and potential of these firms, the information is organized based on the classification on the value chain as Production, supply and use as shown in the framework of fig 1-1 on page 7.

4.1.1.1 Main firms in the production level

The production level of the value chain consists of feedstock production, sugar extraction and fermentation/distillation. This production stage of the value chain is dominated by the state owned sugar factories that are engaged mainly in sugar cane plantation and sugar extraction. Currently there are three sugar factories, Wonji-Shoa, Metehara and Fincha, which have been in operation at least for decades and the fourth, Tendaho, which will be the biggest in capacity is under the project phase (Shimeles and Aklilu, 2008, June 8, personal interview). All the factories cultivate sugarcane for extraction of sugar and they produce or intend to produce bio-ethanol from the by product obtained from the sugar extraction. Their role and current status as well as their future intention are elaborated below.

Feedstock production

The three factories cultivate feedstock for the production of sugar. The feedstock used for production of sugar by the sugar factories is solely sugar cane. Sugar cane plant is generally grown between the latitudes of 30^0 North and South mainly because it requires a warm climate coupled with adequate natural or artificial water (Shimeles, 2008, May 30, personal interview).

Due to this factor the farm areas of all the sugar factories are located in areas considered suitable for sugarcane cultivation in the country and the factories are also constructed close to these plantations. The following table shows general description of the sugar cane production area of these sugar factories.

Table 4-1 : Description of Sugar Factories sugarcane plantation areas

S/N	Description	**Name of the sugar factories**			
		Wonji-Shoa	Metehara	Fincha	Tendaho
1	Distance from the capital	110km to the east	210 km to the east	340 km north-west	600km north-east
2	Annual Rainfall	800mm	550mm	1250mm	234mm
3	Average Min. Temperature	15.3 ^{0}c	17.53 ^{0}c	15 ^{0}c	21.8 ^{0}c
4	Average Max. Temperature	26.9 ^{0}c	32.6 ^{0}c	31 ^{0}c	39.7 ^{0}c
5	Altitude	1540 a.s.l	950m a.s.l	1650 m a.s.l	340 m a.s.l
6	Source of water	Hydro dam on Awash river	Hydro dam on Awash river	Hydro dam on Fincha river	Dam on a river
7	Irrigation system	Furrow irrigation	Furrow	sprinkler	Irrigation

Source: Ethiopian Sugar Development Agency (ESDA)

From the interviews (Shimeles, Azemera and Afework, 2008) and observation from site visit the following information is obtained. Sugarcane cultivation in Ethiopia follows ratoon system similar to that of the Brazilian. Before planting at the first time, the soil is intensively prepared and necessary fertilizers are applied. During plantation the plants are treated with artificial fertilizers including filter cake from the bio-ethanol plant. After 12-18 months, the cane is ready to be cut. For cutting and harvesting, it is a common practice to burn down the cane in order to simplify manual harvesting and avoid possible attack by insects and animals with in the farm. After cutting, the cane is loaded on trailers and transported to the sugar factories. The same plantation continues to deliver cane for 7-8 years and when the yield declines another cycle will start.

The current satus and future expansion scheme of the plantation the sugar factories are able to cultivate and envisage to cultivate respectively are summarised in table 4-2 below.

Table 4-2 Current and future sugar cane plantation area and quantity

S/N	Description	**Name of the sugar factories**			
		Wonji-Shoa	Metehara	Fincha	Tendaho
1	Current sugar cane area (ha)	7022	10100	9500	-
2	Current sugar cane production (Tone Cane per Day)	3100	5000	4400	-
3	Expansion sugar cane area (Ha)	15978	10000	10500	50,000
4	Sugar cane production from the expansion area (tone cane per day)	9400	5000	8100	26000

Source: ESDA, 2008

The table shows the current areas cultivated and the production quantity of sugarcane from these areas as well as the future expansion plan both from the existing sugar factories and the project being constructed. The cultivation is mainly done by the factories themselves on the land they are allocated. Insignificant quantity is planted by out-growers living in the surrounding in the case of Metehara. The factory gives seeds and proper advice and later it buys the cane the out-growers cultivated. The price is based on the sugar content the cane would deliver during extraction. Otherwise, the practice of cultivation and harvesting are done entirely by the factories themselves by employing seasonal labourers. Wage is determined based on the area the labourers are able to cut sugarcane on a daily basis. On average they earn between USD 60-100 per month (Yersaw, 2008, June 20, Personal interview). Compared to the country minimum wage amount for low skilled worker which stands at Birr 235 per month (Ethiopian Investment Agency, 2007), the workers engaged in sugarcane cutting earn better. Besides, the factories provide medical service, insurance coverage, and residence free of charge to the labourers to maintain long time relationship so as to attract them season after season. Since cultivation and harvesting jobs are seasonal, the factories do not employ permanent workers for the labour works of plantation cutting and loading to trailers and hence do not retain the workers in the entire year. Cultivation is done from the beginning of December to the end of May of the year while harvesting is done from the beginning of November to the end of May (Yersaw, 2008, June 20, Personal interview). Such classification of periods is done due to mainly rain, which facilitates erosion if the cultivation is not covered by plants when it starts raining and makes harvesting impossible during the three month rain period. As a result, cultivation, and harvesting as well as plant operation will not be undertaken during the rainy season that extends from June to September.

All factories cultivate sugar-cane by irrigation. Wonji- Shoa and Metehara sugar factories employ furrow type irrigation as the topography is flat whereas Fincha, surrounded by hilly landscape, utilize sprinkler type to reduce erosion. These irrigation systems practiced by the factories waste considerable amount of water due to poor management and low level of awareness (Shimeles, 2008, May 30, personal interview). Proper account of water lacks as to what amount of water effectively utilized for the farm and that part of water being wasted. Water is normally considered by the farms as a free resource despite the fee the factories have to pay to the Ethiopian Water Works Authority, a government body which constructed and owns the irrigation facility (Shimeles, 2008). However, there is no explicit amount that goes only to the water quantity, the payment is as a lump-sum including for the construction.

Use of pesticides and fertilizers are also common to all farms. Since the locations of the farms differ, so does the type of pests on the farm. As a result, the type and quantities of pesticides the plantations apply differ. Generally, insecticides like Malathion and Dursban, herbicides like Glyphosate, Velpar, Paraqat, 2-4D Amine and fungicides like Benomyl, Lysol are being used by the farms. Urea and DAP are also the main fertilizers of the plantations (Shimeles, 2008 and Yersaw, 2008, personal interview).

The current cultivation areas as well as the production quantity of sugar cane are very small compared to the country's potential. The identified potential land area that suits for cultivation of sugar cane has been estimated as 700,000 hectares (MME, 2007). The average cane production per hectare is assumed to be 154 tones, which would deliver a potential sugar cane production of 107.8 million tones.

Realizing this potential and the investment opportunities in the sector, many private investors have shown interest and received investment license. According to the Ethiopian Investment Office (Aklilu, 2008, June 2, personal interview), 20 private (mainly foreign ones) investors have been licensed to develop sugar cane cultivation with a total land area of about 400 hectares. Most of these private actors are at the pre-implementation stage; only 4 of them have received the land they have requested. The exact status and future potential of all the private firms could not be fully captured as they are scattered in the different region and unable to reach them through phones. But at the current position, they don't seem influential and dominant firms in the value chain- though the interest of these private firms and their involvement indicate the bright prospects of the feedstock production and of bio-ethanol development in the country.

Sugar extraction

The main firms that play a role in the sugar extraction operation today are the existing three sugar factories which are already in operation. Others are in the process of entering into the field. Particularly, Tendaho project is believed to play dominant role when it is completed.

The entire sugar cane that is being cultivated and produced by the sugar factories will be consumed for production of sugar. At the moment, no sugar cane is cultivated solely to the production of bio-ethanol. All sugar cane produced goes to sugar production and the by-product from the sugar factories, molasses, is utilized for bio-ethanol production. This is because sugar is a high value product in Ethiopia and still there exists a gap between locally produced supply and demand. The general process flow how the sugar factories convert sugar cane into sugar is shown in fig 4-1 below.

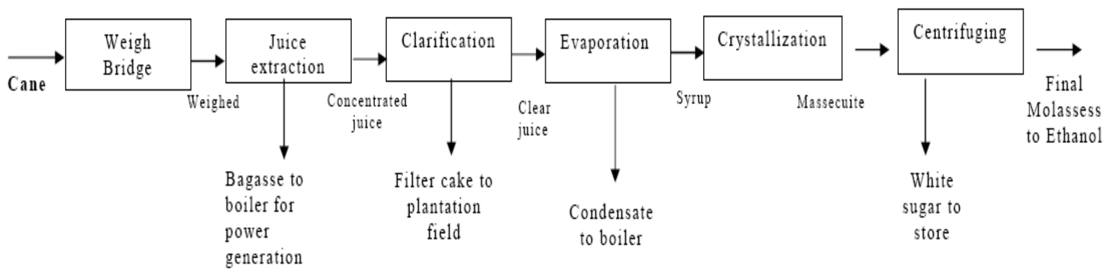


Figure 4-1- General process flow of Sugar production in Ethiopia

Source: Fincha Sugar factory

Sugar cane coming from the field is weighed first and passed to the juice extraction stage where separation of juice from bagasse is made. Bagasse is the fibrous residue of the cane stalk after crushing and extraction of the juice. This bagasse goes to boiler for steam generation to be used for the sugar factories own consumption. The steam generated is enough to cover the sugar factories thermal energy requirement. They however take additional energy from the national grid (generated 100% from hydro) to fulfil the electricity requirement except Fincha, which is self sufficient that require additional electricity only in the winter season for maintenance work as it doesn't have production in the winter and thus doesn't generate energy as the rain makes virtually impossible to cut and transport sugarcane. All factories have short term plan to generate electricity and sell the excess power to the national grid, which was not that attractive in the past due to low electricity rate.

Then the production process continues with clarification step wherein impurities (scums) are separated from the juice. These impurities contain generally about 1% in weight of phosphate, counted in P_2O_5, coming from cane and sometimes also from clarification aids. They also contain nitrogen (1% in N) and a great part of proteins existing in cane juice. They have therefore fertilizing properties and are used on the sugarcane plantation field (Muleta, Yiersaw and etal, 2008, personal interview).The clear juice obtained at this stage is further concentrated by evaporation where the condensate is returned to boiler to increase thermal energy efficiency. Then crystallization (formation of sugar crystals) followed by centrifugation (separation of sugar and molasses) complete the process. The molasses obtained at this final stage then goes to the production of bio-ethanol. It is residual syrup from which no crystalline sucrose can be obtained following evaporation, crystallization and centrifuging of the massecuite (mixture of sugar crystal and molasses). It is a by-product of sugar manufacturing and the cheapest source of feedstock for ethanol production.

The existing three sugar factories employ the same kind of production step as depicted here-above and together currently produce 295,063 tones of sugar annually (Shimeles, 2008, May 30, Personal interview). The new project which has been launched already with an investment capital of $600 million is expected to boost the production by 600,000 tonnes, which is expected to start in 2009 (ESDA, 2008). With the expansion work being undertaken by the other three factories together, the four state owned factories alone are expected to produce 1, 560,981 tons of sugar by the year 2013/14.

During the 2007/08 period local demand for sugar was set at 350,000 tonnes, which is about 4.5 kg per person per annum-which is considered low even by African standard that is estimated to be 20. The shortage was fulfilled by importing 36,000 tonnes of sugar worth of more than $13 million. In 2008/9 it is projected to reach 420,000 tonnes (Shimeles, 2008, May 30, personal interview). Besides trying to satisfy the local demand, Ethiopia is exporting raw sugar to the European market to utilize the *Everything But Arms (EBA)*[29] initiative. Since the benefit obtained under this initiative is attractive, more sugar is exported than imported (DSD, 2005).

The shortage of sugar supply and the attractiveness of the EU market coupled with the annual rising need for sugar certainly call more expansion work and new investment in the sector to come in. This in turn will benefit the production of bio-ethanol by supplying increasing amount of molasses generated from the sugar factories.

Fermentation and distillation

There is only one plant, Fincha Sugar Factory, engaged in fermentation and distillation for the production of bio-ethanol to date in Ethiopia. The other state owned factories are in the process of installing an ethanol production unit from molasses following the government direction to introduce a mandatory regime to blend bio-ethanol with gasoline for vehicles fuel. This can render a good option for the factories as they generate huge amount of molasses and be a means to convert into useful products easily.

Metehara Sugar factory is in the process of evaluating bids submitted by various foreign companies to erect and commission a bio-ethanol plant (Bekele, 2008, June 8, personal interview). It is planned that the whole work will be completed in less than a year and production will be started around July, 2009.

[29] On an international level it has been reache to consensus between the developed countries to reduce world-wide poverty by 50% in 2015, among other things by means of an open and honest trading system. In response to this, the EU has formulated the Everything But Arms (EBA) initiative. Through this initiative, Least Developed Countries (LDC) can export certain commodities tax and duty free to the EU in order to increase the amount of trade with the LDC's, enhancing their export earnings and encouraging the diversification of their economies (DSD, 2005). As a consequence, Ethiopia being one of LDC's, exports raw sugar under this initiative.

Wonji-Shoa sugar factory has completed the feasibility study and now in the bid preparation phase to invite companies to participate in the supply of equipment and erection as well as commissioning of a bio-ethanol plant (Bekele and Shimeles, 2008, personal interview). It is expected as the envisaged plant would start producing bio-ethanol in 2010.

Likewise, Tendaho sugar Factory project (the biggest in capacity) has awarded a contract to possess a turnkey plant comprised of sugar extraction and bio-ethanol producing plant to an Indian company. The project is in the civil construction and equipment manufacturing phase and the plants are expected to be operational in 2011 (Bekele and Shimeles, 2008).

The Fincha bio-ethanol plant is the only plant now producing bio-ethanol, both technical (hydrous) and anhydrous which can be used for power alcohol. The current annual production capacity of Fincha Sugar factory is limited only to about 8 million litres. Due to market problem, this capacity has never been utilized fully. Whereas the potential ethanol production from the 700,000 hectares of suitable irrigable land for sugar cane plantation is estimated as 1 billion litres. The assumptions taken to arrive to this figure are: (1) total net irrigable areas identified for sugar cane is 7000, 000ha (2) average cane production per hectare as 154 tons (3)percentage of molasses from the total sugar cane produced is 3.8% and (5) Ethanol production per ton of molasses as 250 litres (MME, 2007).

In the next 5 years till 2013, the state owned four sugar factories have planned to reach a production volume of 135 million litres (ESDA, 2008). Of which 21.5 million will come from Fincha Sugar Factory, 22.7 million litres from Wonji-Shoa, 35.5 million from Metahara and 55.4 million litres from Tendaho. Though additional quantities are also expected from private firms, reaching those who requested an investment licence to enter into the sector was not possible. But it can be assumed as the quantity will be more than the number shown if not reached 1 billion in the short and medium term.

The existing bio-ethanol production plant employs a combination of biological and physical processes in the production. It is produced by fermentation of sugars with yeast and then concentrated to fuel grade by distillation. The flow chart, shown in Fig 4-2 below, is a schematic representation of the principal steps in fuel bio-ethanol production in Ethiopia.

There are three sub units namely Molasses treatment, fermentation and distillation that are carried out in the bio-ethanol production process. These are briefly described below as explained and understood in the site visit.

The first process step in fuel bio-ethanol production is molasses treatment. This stage envisages a reduction in the level of impurities, notably Calcium salts to facilitate the next operations, i.e., fermentation and distillation. This guarantees better performance with regard to distillation where the reduction in scaling will be significant, thus permitting better yields and lower steam consumption (Azemera, 2008, June 20, personal interview).

Molasses at a concentration of 86^0 Brix[30] comes from the sugar factory, undergoes heating to a temperature of 95-100 ^{0}c and dilution to 50^0 Brix using process water and steam condensate in order to reduce molasses viscosity. While heating, acidification is undertaken using sulphuric acid to a pHof 4.7-4.9 and then sent to decanters to remove solid materials by sedimentation. The diluted juice in decanters will be further diluted to a final concentration of 20-22^0 Brix

[30] Brix means percentage(in weight) of soluble solids present in sugar solution

and cooled to a temperature of 55-60^{0}c, which is now called as *Mash*[31]. This Mash is now free of large part of the impurities and suitable for obtaining a good fermentation.

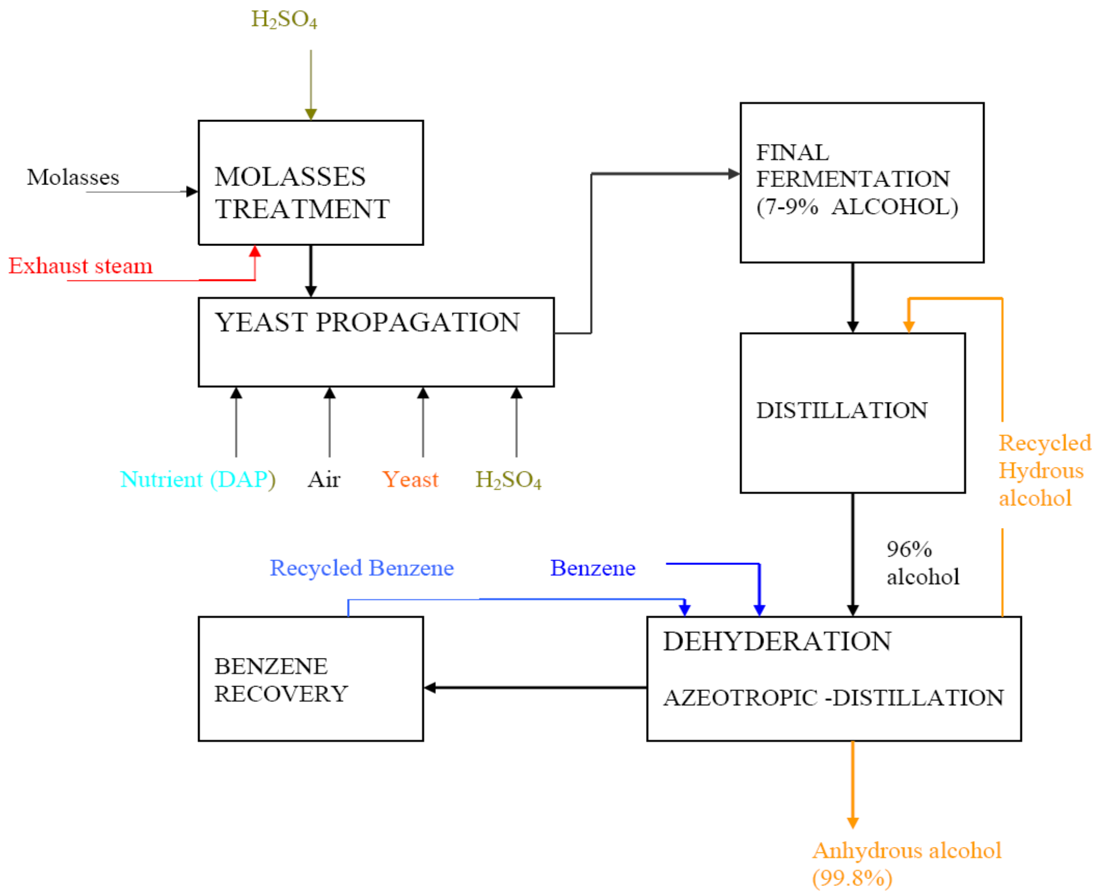


Figure 4-2 Bio-ethanol production process

Source: From Site visit at Fincha Sugar Factory, 2008

Yeast[32] propagation is a pre-fermentation step in the fermentation process aiming to achieve optimum yeast cell concentration required for fermentation. The stage is supplied with nutrients and air and thus the process is referred as aerobic fermentation. The nutrients to be added are nitrogen and phosphorous, due to the fact that the raw material (molasses) is poor in these components for the yeast to multiply and be active. Nitrogen is important both for the phases of cell multiplication and fermentation, mainly because of protein and nucleic acid synthesis. When Nitrogen deficiency occurs, cell growth is reduced and the speed and the productivity of fermentation also decrease. Nitrogen is added in the form of ammonia sulphate. Final fermentation is a process where alcohol and carbon dioxide is produced. The whole fermentation process takes about 24-30 hrs, with resulting beer (fermented mash) containing 7-9% ethanol by volume.

[31] Mash means sugary liquid (cane juice/molasses raw material) in the right condition for the fermentation process

[32] Yeast is the micro-organism that transforms sugar into alcohol by fermentation

The third step is distillation, in which the fermented beer is distilled to draw off ethanol. By conventional distillation processes ethanol can be concentrated to about 96% ethanol by volume, which is called hydrous ethanol or technical ethanol that is utilized by pharmaceuticals, beverage industries and others. The anhydrous bio-ethanol or bio-ethanol to be used for fuel with gasoline blend should be concentrated and further distillation cannot increase this percentage, as the composition form azoetrope, or a constant boiling. The remaining water can be removed by dehydration, a step that follows conventional distillation. Therefore, aromatic benzene is added to commercial grade bio-ethanol in the dehydration step so that anhydrous bio-ethanol is obtained. Benzene is chosen due to its less cost compared to other solvents and its consumption is about 1-2 liter per 1000 liter of bio-ethanol. Since the bio-ethanol that has been produced in the past was the hydrous type, benzene consumption was almost none.

The bio-ethanol production of the past shows as the plant was operating at low capacity. As there was no market for anhydrous bio-ethanol both at local and export level, the entire production has been the hydrous type. This figure together with background data is detailed in table 4-3 below. As the conversion of molasses is estimated as 250 liters of bio-ethanol could be obtained from a ton of molasses, there has been excess of it in the past, which the factory was selling for beverage industries and for private cattle farmers to be used as feeds (Azemera, 2008, June 20 personal interview).

Table 4-3 Past bio-ethanol production quantity

Description	**Years**			
	2003/4	2004/5	2005/6	2006/7
Hectares cut (ha)	5017.01	5439.52	5913.66	5668.41
Cane crushed (ton)	694271	758474	815028	780764
Cane production (ton/ha)	138.4	139.44	137.82	137.74
Sugar produced (ton/ha)	16	15.89	15.72	15.37
Sugar yield (%)	11.59	11.39	11.41	11.16
Molasses produced (ton)	24608	22225	21607	24376
Bio-ethanol production (liters)	911431	1636047	6847816	6066860

Source: Fincha Sugar Factory

Since 2005 the production quantity reached to 6 million liters as a result of sales contract agreement entered with foreign company. According to the contract, Fincha Sugar Factory shall supply 6 million liters of the hydrous bio-ethanol to the company yearly, which is based in Italy, with an ex-factory price of $0.202 per liter up until the recent government decision that has banned the export in order to accumulate for local gasoline blending that is expected to start with in few months (Shimeles, 2008, May 30, personal interview). The remaining quantity is consumed by different local industries- mainly for beverage sectors.

The current selling price indicated above is said to have adequate margin for the Factory and hence any value greater than that value would be an incentive to act in favor of the blending. Besides, the ownership of the factory is under the state and state priority to use the local bio-ethanol for local blending use will be well implemented by the Factory/ies (Shimeles, 2008).

Production of bio-ethanol is associated with by-products. The by-products from Fincha bio-ethanol production are carbon dioxide, spent wash (stillage) and fusel oil. Carbon dioxide evolves during fermentation and is released to the environment. The amount of it is almost as great as the production of alcohol. Fusel oil on the other hand can be separated during distillation. It is however not the case now as no market has been identified yet. It used to be separated and stored in a dedicated storage tank, but then no application has been found and hence it is left to be in the final product.

The other important by-product that will affect the water body if it is released directly is spent wash produced during fermentation due to its high BOD content and acidity. The spent wash from the bio-ethanol plant has been taken care of by a pre-treatment (comprised of neutralization and clarification) followed by an effluent treatment system when the plant started production. However, during the site visit it was understood that both the pre-treatment and the effluent treatment system were not functioning due to maintenance problem, as a result, the option it has been applied was to dilute with water and discharge to nearby river.

The design condition the Fincha Sugar Factory effluent treatment system envisaged to generate and treat wastewater from the bio-ethanol plant before discharge into the Fincha River were as shown in table 4-4 below. But due to absence of proper functioning of equipment and instrumentation, the quantity of effluent conditions is worse today. Many staffs whom the author held discussion with during the site visit expressed their fear in that the current blind operation certainly makes the factory to loose resources and at the same time threatens the aquatic life in the river. They quoted that the maintenance of the equipment and instrumentation as well as making the pre-treatment and the effluent treatment system functional to operate with in the design parameter would not be beyond the capability of the technical staff there, it is only a matter of lack of focus from the management as the bio-ethanol plant has not been given due attention due to unavailability of adequate market for bio-ethanol in the past.

Table 4-4: Design effluent condition of the Fincha bio-ethanol plant

S/N	Description	Flow rate (m^3/day)	BOD_5 (kg/day)	BOD_5 (mg/l)
1	Spent Wash	640	22400	35000
2	Washout water	14	21	1500
3	Floor washing	7	4	600
4	Regenerating column	23	0	0
5	Cooling	3880	8	2
	Inlet effluent condition	4564	22433	450-600
	Outlet effluent condition	4564	2242	45-60

Source: Fincha Sugar Factory

In summing up, generally the firms that are dominant actors in the production level, i.e., feedstock production, sugar extraction and fermentation/distillation, currently and the near future are the state owned sugar factories. The current status and the upcoming year plan in terms of production (size of land for sugar cane, cane production, sugar and bio-ethanol production) are detailed in table 4-5 below.

Table 4-5: summary of current status and future plan

Description	**Years**							
	2007/8	2008/9	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Total Sugarcane areas (effective)(ha)	23 657	28 025	43 172	64 677	89 814	107 704	115 196	117 275
Total sugar-cane production (million tons)	2.625	2.732	4.259	6.625	9.659	12.066	14.007	14.319
Total Sugar Production (ton)	299 145	311 039	47 667	723 755	1 050 355	1 305 749	1 520 716	1 558 203
Total molasses production (ton)	103 249	107 460	165 963	256 534	37 850	466 852	542 559	554 679
Total bio-ethanol production (m^3)	8000	8000	20 690	55 962	83 452	112 815	132 886	13 855
Total power generation for national grid (MWH)	-	-	53 072	166 667	363 908	521 658	583 117	593 624
Employment (job opportunity) (number)	28 500	34 600	57 400	78 819	91 455	101 933	102 117	102 227

Source: MME, 2007

4.1.1.2 Main firms in the blending and distribution

There are six oil distributing companies working in the country that could play crucial role in the blending and distribution of bio-ethanol. These companies are local, regional, and international ones and they are: Shell, Total, Kobil, Yetebaberut Petroleum, National Oil Corporation (NOC), and Nile Petroleum. Recently Agip and Mobil withdrew from the business. These companies currently are responsible for the marketing and distribution of petroleum products. In accordance with the Distribution Agreement with the Ministry of Trade and Industry, the companies distribute the petroleum products supplied to them by Ethiopian Petroleum Enterprise. All fuels come either through the port of Djibouti or recently from Sudan. The import and distribution is fully under the control of the government and prices are regulated to avoid dramatic changes

The oil industry in general is a mature industry characterized by moderate growth rates, high barriers to entry and few multinationals engaged. The government introduced the Ethiopian Petroleum Enterprise (EPE) as the regulating body to import oil through the harbor of Djibouti or from new facilities in Sudan. Companies wishing to participate in the oil industry have to apply for a license with EPE (Worku, 2008, personal interview).

The blending and distribution of blended gasoline has not yet started. Preparation work is being undertaken by the firms involved in the line. The current direction indicates that blending will be done by Nile petroleum in its facility located 20 km outside of Addis Ababa. The task is given to Nile Petroleum as its facility is positioned well from the others in terms of place, capacity and cost for upgrading to blending operation (Mengistu, 2008, Alemayehu, 2008 and etal, personal interview). If everything goes as planned the facility will start blending with in three months (Babkir S.E, 2008, June 8, personal interview).

Nile Petroleum with the support of the steering committee established by the government from different organizations to assess and recommend the best blending option among the possible alternatives has now decided to commission the facility to apply the 'In-Line Blending' mechanism (see fig 4-3 below) (Babkir, 2008). In the In-line blending mechanism, ethanol and gasoline are blended in-stream prior to/at the blender and a single finished product is loaded. The volumetric flow rate of gasoline and ethanol are pre-set and automatically controlled depending on the fuel grade required. In this blending method, an accurate blending level and a homogenous blend can be achieved by pressure mixing.

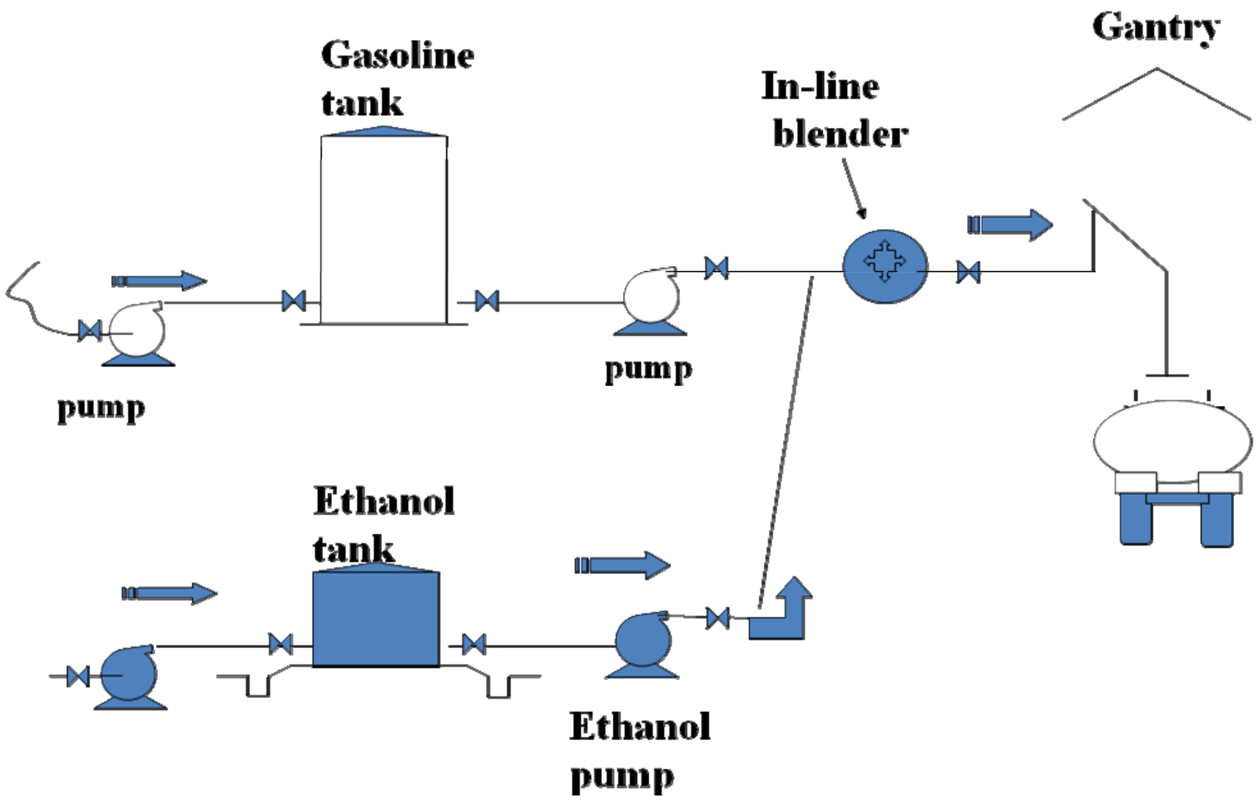


Figure 4-3 Schematic diagram of in-line blending

Source: ESDA, 2008

The blending capacity is said to reach up to 1500 M^3 of ethanol per day while the current consumption of gasoline has been equated as 400 M^3 (Babkir, 2008). The advantage mentioned this option would offer include: (1) elimination of the potential for blending errors (2) Providing better quality control (3) Providing greater ease for program compliance (4) Complying with the industry safety standards and good practices (5) Widely used in countries using gasoline-ethanol blend fuel and (6) Relatively cost effective. The limitation identified was the need to have stand-by set up to ensure continuity of operation.

At the moment while making the facility ready for operation, contract negotiations are progressed with different parties: with the Bio-ethanol producer, the oil distribution companies and Ministry of Trade and Industry.

The contract with bio-ethanol producer encompasses the quality criteria the bio-ethanol has to comply, quantity and delivery scheme. Negotiations with oil companies covers supply and delivery issues of gasoline to the point of the blending site and then receiving the blend to transport to their respective distribution outlet. Ministry of Trade and Industry is responsible to set prices of petroleum products based on world oil price and thus the contract with the ministry covers how the price adjustment will be done in cases of fluctuations (Babkir, 2008, June 8, personal interview).

According to the information gathered from these oil distributing companies through interview (Alemayehu, Getahun, Ahemed, and Birehanu, 2008, personal interview), though they support the blending, all seem unhappy to distribute blended gasoline due to the fact that distributing blended gasoline need additional investment for renovating storage tanks and pipes to avoid ingression of water through old tanks and seals. Besides, additional safety measures and operation in checking the quality of the blended product as well as fee for the service charge they are going to pay would increase their operation cost. According to them, the current margin proposed to them is not adequate to regain within five years the additional cost they incur and hence their motivation is low to work in full cooperative spirit in favour of bio-ethanol blend. Some of them even mentioned that sooner or later they would withdraw from the business as the benefit has been continuously deteriorating. Nonetheless they identified the materials they need to upgrade their fuel stations and submitted foreign currency request to the government for items they should buy from abroad in order to upgrade the stations and fulfil the mandate of selling the gasoline blend within the country.

4.1.1.3 Firms in the use phase

Vehicles that are operated by petrol will use blended gasoline when the blending starts. Therefore, all firms' owning petrol vehicles will buy blended gasoline when they utilize fuel stations located in Addis Ababa at the initial phase, then subsequently throughout the country. Under the current direction, both private and company vehicles in Addis Ababa will get only blended gasoline in all fuel stations when the product is ready. Thus firms will not have choice either creating or falling the demand. The blending capacity has taken into account the demands of all vehicles running by petrol (Babkir, 2008, June 8, personal interview). Hence, despite their potential role affecting the demand, the government direction that all fuel stations should have to sell only blended gasoline lessens their significance.

4.1.2 Public Bodies

There are various public bodies that have roles in the bio-ethanol production and use. The current status as explained by the different organization through interview is summarized below.

Ministry of Mines and Energy (MME): It is responsible for upstream (exploration and development) licensing, general policy issues for the development of mines and energy in the country. In connection to bio-ethanol, the ministry prepared the national biofuel strategy and made to be approved by the council of Ministers in September 2007. The strategy encompasses important points that need to be fulfilled in the development process. Among these points the following are worth to be mentioned:

- The implementation of the biofuel program should be a key in supporting the food security effort
- The biofuel program implementation will be conducted in such a way that it should not deteriorate the economic, environmental and cultural values. It would instead be

implemented with out competing with land, water and other resources requirements of farmers and pastoralists for farming and grazing respectively.

- The implementation of the biofuel program will be designed in such a way that farmers and pastoralists will be beneficial through involvement and participation.
- The biofuel program will be implemented in a way that ensures sustainable development. In this regard, the development will be realized by protecting or improving the soil, water and biodiversity resources.
- The biofuel products will be produced in compatible to international agreements for reducing greenhouse gasses.

Except indicating the strategic direction the bio-fuel development aims to comply, there is no guideline as to how the objectives would be achieved. In order to develop such guideline, a national biofuel forum has been established recently. The ministry currently coordinates the bio-ethanol fuel program by chairing this National Biofuel Forum (Melis, 2008, May 26, personal interview), which is established at national level with the membership of the different government organization in the development and utilization of bio-fuel.

Environmental Protection Authority of Ethiopia: the task of the authority with regard to bio-ethanol production and use or any project for that matter will be to demand firms or investors wishing to develop new project to undertake initial environmental impact assessment and get an approval before implementation (Ali, 2008, May 27th, personal interview). The law stipulates that any project that is envisaged to be developed or expanded its operation should prepare environmental impact assessment statement and submit to the authority before commencing the project work and being issued a license. Only when the project gets permission (approval) that the envisaged project commences its implementation (EIA Proclamation, 2002). The main aim being to assess the possible impacts on the environment prior to the approval of a public instrument and to provide an effective means of harmonizing and integrating environmental, economic, cultural and social considerations into a decision making process in a manner that promotes sustainable development. However, in reality this doesn't happen always due to mainly uncoordinated work among the public organizations involved in the issuance of land and trade licenses (Ali, 2008). As a result all firms and owners of project that have built or are in the process of building bio-ethanol production facility have not necessarily fulfilled the authority's procedure.

To compensate this gap, the pollution prevention and control department of the authority has been included in the national bio-fuel forum to follow-up and influence developers to comply the standards of the country. Again here except for the sugar industries which have to fulfil a certain standards when extracting sugar, there is no parameters developed for ethanol producing plants as it was not a priority (Ali, 2008). As a result, the authority is considering now to develop standard for bio-ethanol production units based on international experience. At the moment the authority doesn't have industry standards both for fermentation/distillation plant and blending unit. Even the new blending unit which is being constructed has not undertaken environmental impact assessment. Once the standards are developed and if any operation is found to violate the standard, depending on the severity of the violation a 5 year period will be given to adjust the operation to fulfil with the requirements (Ali, 2008).

Ministry of Trade and Industry: The role of the ministry with regard to bio-ethanol production is issuing a trade license when proponents fulfil requirements set by the ministry (Chemeda, 2008, May 29th, personal interview). In addition, the state owned sugar factories agency, the Ethiopian Sugar Development Agency (ESDA), is accountable to the ministry. New government owned sugar factory development and expansion on the existing factories are proposed by the agency and approval is given by the ministry. Fund for the implementation is availed by the ministry from the sugar fund established under the ministry. The ministry plays important role through approval of projects prepared by the state sugar agency, allocate finance and supervises timely implementation of the projects. On another account it also sets the price of gasoline at each level and will have also a role in fixing the price of bio-ethanol (Chemeda, 2008, May 29th, personal interview).

Investment Authority of Ethiopia: the role of the authority in general is to issue investment license for proponents wishing to invest in the country. Since the bio-ethanol program is one of the priorities of the government, the authority further facilitates to the issuance of land with regions. It is focusing on land provision because it has become an issue particularly when it comes to regions in that investors may not get the plot of land they requested or the issuance takes years (Aklilu, 2008, May 29th, personal interview). This is due to the fact that the data on availability of land at the federal level and practically at the region differs. Land demarcation study and allocation according to the need the region would like to develop on have not been done, in cases where there are data, those data are based on old studies and may not reflect the existing actual situation at the site (Aklilu, 2008). At times the study indicates a certain land to be used for growing a certain crop but actually the land may be issued for another crop.

The authority issued 20 licences for investors requiring engaging in Sugar and Ethanol production. Of which only four are entering into operation and the rest are in the preliminary stage which means that they have not yet secured the land they have requested (Aklilu, 2008).

Ministry of Transport and communication Authority: the role this ministry plays with regard to bio-ethanol is to establish legal framework and guidelines that will help to enforce the use of blended gasoline incorporating incentives to promote further the bio-ethanol share (Bazezew, 2008, June 2, personal interview). Currently draft document is being prepared as to which vehicles are supposed to use the blended gasoline and the possible incentives the government can offer to promote the use. Consultation with the different stakeholders (vehicle importers, private car owners, ministry of inland revenue) has been conducted and reached to the common understanding towards the use of blended gasolin. Depending on the available quantity of bio-ethanol and the number of vehicles, whether the commencement to use blended gasoline should start only with the public vehicles or should it include the private ones, and which age groups of vehicles should be mandated to use are some of the discussion being held further in the draft regulation (Bazezew, 2008). Due to the inadequate quantity of the bio-ethanol currently being produced, 5% blend with in the capital will be started. As experience is gained and the projected production of bio-ethanol will be realized, the percentage will be raised to 10% while at the same time covering all the regions distribution outlets.

Ethiopian Petroleum Enterprise: Currently, the full demand of petroleum products of the country is met through imports handled exclusively by the Ethiopian Petroleum Enterprise (EPE). EPE, a state-owned enterprise, is entrusted with the purpose- as enumerated in the Council of Ministers Regulation No 210/1995- to import and sale refined petroleum and other petroleum products.

With the exception of Liquid Petroleum Gas, bitumen products and lubricants (which are not under the direct control of the enterprise), EPE carries out the procurement of all other petroleum products through competitive international tenders on a need basis. With regard to the blended gasoline that will be in use very soon, EPE doesn't have clear understanding whether it should buy the bio-ethanol and own the blend so that sell to the oil distributors operating in the country as it does now for petroleum or not (Worku, 2008, June 2, personal interview). The regulation, however, assigns importation of gasoline exclusively to the enterprise.

Quality and Standard Authority (QSA): is the national standards body among other activities responsible for developing of standards, certification and testing. Its central role in the development of standards is to coordinate the development and serve as a secretariat for the standard developing technical committee (Aregahegne, 2008, May 30th, personal interview). Technical committee is expert group made up from government, industry, user group and sectors.

The development of standard has eight steps and commences when the authority receives request from a source. The source could be government body, public or private industrial firm, professional association or individual. For the case of bio-ethanol and blended product, the Ethiopian Petroleum Enterprise requested the quality standard for the bio-ethanol that can suit for power alcohol and the 5% blended product. After receiving the request, the authority involving all stakeholders started up-grading the working draft standards which have been developed earlier. These working standards are shown in appendix I.

Implementation of or compliance with Ethiopian Standards is normally voluntary, but for standards that have direct influence on health, safety and related considerations, compliance is often made compulsory. In general, implementation of standards is done by regulatory bodies, consumers, and most importantly, by industry. It is also enforced by QSA through certification of selected products and services for which QSA has the competence and mandate to carry out. With regard to ensuring the quality of the components and the bio-ethanol blend, firm decision has not yet been taken whether the standards are voluntary or mandatory. The standard for gasoline has been a voluntarily one up to now.

4.1.3 Other actors

There are potentially other actors which could strongly contribute towards the bio-ethanol production and use in their speciality. Universities and research institute, for instance, are well positioned to generate new knowledge through research and development and demonstration works. But the current link of these institutions is very weak and some of the relevant departments don't even know the status of the blending program which was once actively participated in demonstration and promotional work (Nurelegne, 2008, June 2, personal interview).

The Agricultural Research Institute could contribute in producing improved sugar cane varieties that can enhance production and help to introduce better crop management for maintaining the biodiversity. There has not been any input till this date only very recently incorporated as member of a committee in the national biofuel forum realizing the importance of its input in the future. Even in this forum, specific tasks the forum would like to get from are not specified that would create gaps for what it can be able to contribute and what the forum expects it to contribute (Alemu, June 8, personal interview).

Addis Ababa University, department of Chemical Engineering, was one of the earlier promoters of ethanol use both for transport fuel and cooking fuel by partial substitution of gasoline and kerosene respectively. Laboratory test, demonstration work supported by workshops and discussion forums were some of the works undertaken in order to aware stakeholders and then start using bio-ethanol in the early times (Nurelegne, 2008).

For a number of reasons the effort did not result the desired target. Now renewed effort is being undertaken with the participation of different stakeholders without incorporating the department. This would undermine sharing of valuable information and experience that would help to take off from the previous level.

4.2 Networks

Many networks seem to be non existence at this stage in the bio-ethanol value chain except the formally established sugar development agency (ESDA). Earlier the informal joint opposition by the oil companies was considered to be one of the big bottleneck in promoting bio-ethanol (Shimeles and Melis, 2008, personal interview). Since then some of the influential international companies left the country and new local and regional companies engaged in the distribution business have emerged. The stance of these new companies somehow positive except the concern they raise on the economic benefit. Besides, all distributing companies working in the country do not have legal right to buy and import petroleum on their own which was not the case in the past. This right is mandated to the Ethiopian Petroleum Enterprise, which imports and sells to the distributing companies. This situation rectified the legal rights of the companies to refuse distributing blended gasoline. However, there seems still invisible systematic resistance if not refusal to delay the commencement.

The most important network visible now in the value chain is the Ethiopian Sugar Development Agency. This agency has been established to avoid competition among the sugar industries when they supply their products. As the capacity and production costs of the factories differ, the existence of the agency will make a uniform sugar price in the market. The benefit obtained from the sell goes partly to the sugar fund established under the ministry of trade and industry, which is being outlaid for expansion on the existing sugar factories and implementing new projects. The agency is also responsible in supporting and monitoring of the sugar industries activities.

Both Sugar and bio-ethanol price is determined by the agency now and thus currently bio-ethanol product is monopolized under this state agency. It is, however, the prime promoter of bio-ethanol to be used for transport fuel. This is due to in the one hand the lack of adequate market for bio-ethanol in the past, and on the other hand the perceived attractiveness of the benefit the agency (the sugar factories) could get if it is blended with gasoline. One of the early works conducted by the agency with regard to promoting bio-ethanol was testing the performance of vehicles running with gasoline blend. The test performed and the result documented by the agency is shown in table 4-6.

Table 4-6: Mileage test performed on 10% bio-ethanol using Mitsubishi Lancer GL and Mazda

Speed Km/h	Vehicles used					
	Mitsubishi			**Mazda**		
	E10 (Km/l)	Gasoline (Km/l)	Mil. gain, %	E10 (Km/l)	Gasoline (Km/l)	Mil. gain, %
30	17.53	14.27	22.85	14.43	11.10	30.00
40	19.70	17.44	12.96	17.60	16.43	7.12
60	20.01	18.35	9.05	16.30	14.33	13.75
80	16.17	14.83	9.04	14.85	13.66	8.71
100	12.25	11.73	4.43	12.45	12.25	1.63

Source: ESDA

4.3 Institutions

Institutions that include laws, regulations, norms, routines and culture on the bio-ethanol technology system have not been well developed as the system itself is in the development stage. The absence or the lacks of some of these institutions contribute to hinder the realization of the bio-ethanol technology system.

4.3.1 Laws and Regulations

Currently there are no official laws and regulations put up in the country to drive the development and diffusion of the bio-ethanol use. The only workable document which is serving as a basis for developing guideline, laws and regulation is the strategic document the council of ministers approved in September 2007[33] (Melis, 2008, May 26th, personal interview). The strategic document in itself doesn't have a legal value; it only indicates the government long term objectives and direction for implementation in the development of the bio-fuel program. In order to develop guideline thereby implement the objectives enshrined in the strategic document, the National Biofuel Forum, made up of different stakeholders and chaired by Ministry of Mines and Energy, has been established. The members of this forum include: Ministry of Mines and Energy, Ministry of Trade and Industry, Ministry of Transport and Communication, Ministry of Inland Revenue, Environmental Authority of Ethiopia, Quality and Standards of Ethiopia, Ministry of Agriculture and Rural Development, Ethiopian Petroleum Enterprise, Ethiopian Sugar Development Agency, Yetebaberut Petroleum, and National Oil Corporation.

All the members have tasks to accomplish towards the use of blended bio-ethanol. One of the purposes of the forum is to coordinate and oversee the work at national level and review the works of the members. Since its establishment a year ago, the forum conducted two meetings (Melis, 2008, personal interview). According to many members of the forum the author interviewed for this analysis, they expressed the situation as- though all of them support the bio-fuel program due to mainly escalating prices of petroleum products and the need to have secured energy system, the forum progress is very low as opposed to expectation of the government. Two reasons outweigh for these low progress: one is lack of day to day follow up on the part of the forum. As most described, at one time the work is labelled as very urgent and members instructed to give ut-most priority to accomplish tasks expected of them. On another time, it will be out of the agenda. This inconsistent attention given to the program could convey wrong message to members that the program would not be that serious and hence members stick only to their organizational tasks. The second reason most members forwarded is lack of knowledge, appropriate information and internalizing own responsibility by members in that the tasks expected from each member is not taken seriously. As a result of these situations the deadline of planned tasks are always missed.

4.3.2 Norms or standards

Working documents serving as draft standard for bio-ethanol, blended gasoline and guide for handling, storing and dispensing of blended fuel for automotive spark ignition engine have been produced by the Ethiopian Quality and Standard Authority. The concern here is that all of these standards are voluntary and no one can be sure that these standards would be met. Particularly when blending starts, ensuring the quality along the supply chain will become a major concern (Aregahegne, 2008). Many fear that with the absence of quality checking and legally accountable for inferior quality product, the consumer would suffer the consequence

[33] See part 4. for the strategic document

and thus might be a cause to lead failure of the attempt (Birehanu, Getahun, Ahemed and Alemayehu, 2008).

4.3.3 Routines and Culture

The current routines are built on the gasoline system and support this system very well. Therefore, the existing configuration of actors, networks and institutions tend to hinder the process of developing the new system knowingly and unknowingly. They seem to be in a lock-in system with the established technologies and seem not to look for opportunities to the pace the country should move. It is only because of the government commitment and push that little progress has been achieved so far to change to the new system. The petroleum price escalation and the foreign currency requirement burden in this case played impotent role to find alternative solutions.

With regard to the culture, though difficult to conclude, Ethiopian people normally tend to be very resistant to change and very speculative to new systems. Even for better systems, people don't simply jump in; they tend to see the system work for long period of time without problem. Generally most people are risk averters and not easily captivated with new systems. In this case however, people seem positive to align themselves with new system. The author interviewed 11 people who posse's petrol vehicles and the majority stance were towards using blended petrol (see Appendix II for detail). The daily news broadcasted in a state media regarding the price of petrol make people cautious and aware that import of petroleum has been already a burden to the country. Some said that they would expect ration system to be introduced like there was in earlier periods due to anticipated gasoline shortage. Instead of that they prefer to use blended gasoline and even felt happy on the existence of local substitute. Most of them, nonetheless, commented proper experiment to be conducted before materializing the product and suggested also the supply system to be sustainable once started.

5 Discussion-Barriers and implications

Ethiopia has currently bio-ethanol producing capacity of eight million litres per year at the Fincha Sugar Factory. Development projects to expand the production capacity is underway by other three state owned sugar factories as well in order to make use of the country's envisaged suitable potential for bio-ethanol production from sugarcane. Despite the availability of the product, though small in quantity and the potential to produce more, use of bio-ethanol as transport fuel has not materialized. Even the bio-ethanol plant that is installed to produce power alcohol has not been operating at full capacity due to lack of developed local market.

Given the day to day price escalation of petroleum where its import value has become a heavy burden, use of bio-ethanol has been envisaged to have positive implications, mainly by substituting petrol and facilitating to the country's effort to energy security. The development of bio-ethanol, however, could have long term impacts along with the perceived benefit. Undesirable consequences that may not be identified at the early stage may bring up at a later stage if proper development path is not followed. By taking precautionary measures at early stage to minimize the potential impacts at a later stage, use of development of bio-ethanol could sustainably benefit the country.

This part, therefore, identifies and discusses the key barriers to expand production and use of bio-ethanol and the implications of bio-ethanol extended production.

5.1 Key barriers

There has been uncoordinated effort in the past to introduce blend of bio-ethanol with gasoline mainly by Fincha Factory. In recent times renewed work involving different actors has been intensified following the approval of a strategic document on the development of bio-fuel by the council of Ministries in September 2007. It is coordinated by the Ministry of Mines and Energy and mainly looking ways to foster the implementation of the strategy. In this new effort, two deadlines had been missed that were set to be the starting date to use blend of bio-ethanol. The first was October, 2007 and the last was June, 2008. This indicates that the desire for using bio-ethanol and the actual development stage do not match. Though progress is seen in recent days in terms of revising the quality specification of bio-ethanol, gasoline and their blend, where to start the blend and in what blending ratio as well as drafting guidelines on the use of bio-ethanol, little is known when exactly the blend is going to start. There are certain barriers responsible for this delay and mismatching of plan and actual implementation.

There are a host of barriers contributing to the hindrance to develop local market and use of bio-ethanol as a transport fuel. The barriers lie with in economic, technical and some relate to public policies and institutions. As indicated earlier, the list of barriers outlined in the background chapter in chapter 2 guided the identification. All interviewees were asked under the framework of the background information to describe what the existing blocking mechanisms for the progress of bio-ethanol use in Ethiopia, and responses sufficiently supported are taken here and discussed. In some cases observation was also used in the identification. The following part presents the main barriers hindering the progress to use bio-ethanol and expand production in Ethiopia.

5.1.1 Economic barriers

The realization of bio-ethanol use in Ethiopia needs at least the cooperation of the producer, blender and the distributor. If one of these stages fails to stand on its feet, the bio-ethanol development faces a problem.

The supply of bio-ethanol seems at the current set up monopolized by the state owned Ethiopian Sugar Development Agency under which all the state sugar factories operate. Since the production cost of bio-ethanol is much less than the price of gasoline (see part 5.2.1.3), there will certainly be an economic incentive to the sugar factories to promote the use of bio-ethanol as a transport fuel. Given the supply structure, it is very likely that the use of bio-ethanol would benefit the sugar industries and thus they are pushing hard and act as prime promoters.

The blending service is going to be provided by Nile Petroleum, Sudanese based company recently entered the Ethiopian market to distribute petroleum products. According to the contract, Nile Petroleum receives birr 0.04 for every liter of bio-ethanol/gasoline blended and has entered three years contract with the Ethiopian Government (Babkir, 2008, June 8, personal interview). This fee entails adequate margin to give incentive to Nile Petroleum to move forward and start the blending as soon as possible (Babkir, 2008, personal interview). But due to slow service delivery system by some government agencies to utilize the tax free equipment importation right, the importation of some equipment has been delayed as a result of which the operation to start blending service has also delayed from the original planned time (Babkir, 2008, personal interview). Anyhow, as the manager of the company stated the rate fixed for the blending service is adequate to induce the necessary incentive to put all necessary effort from the Nile Petroleum side.

The distribution side on the other hand is constrained by lack of economic incentive. As has been indicated elsewhere, the multinational oil distributing companies like Mobil, Agip, Shell and Total which used to have monopolized the oil industry till 2003 are withdrawing from the business and are being replaced by local and other international companies. Since there is no refinery in Ethiopia, the industry participants act as distributors selling the several kinds of fuel through their own networks of over 500 stations with in the country. Their profit is determined by a distributor margin, which covers the costs of picking up the fuel, transportation and selling and a certain rather small profit per liter sold (Worku, 2008, June 17, personal interview). With in the given framework, the industry is not competitive and should be rather described as cooperative among the companies distributing the fuel.

Though the oil distributing companies operating in the country now theoretically accept to distribute the blend and the use of bio-ethanol in the country, as the direction of the government is to introduce a mandatory blended fuel distribution system, they are very much reluctant towards the progress as there is no definite incentive mechanism induced to them. They try to work towards the bio-ethanol development just to avoid finger-pointing from the part of the government and systematically hinder the progress. The main reason they give is that they need to be allowed to get some extra margin, more than what they are getting now in distributing gasoline, due to the additional investment and operational expense they are going to incur when they deal with the blend (Getahun, 2008, Alemayehu, 2008 and etal). For example, the additional capital expense for upgrading and operational cost the five oil distributing companies they are going to incur only in the capital when they start distributing blended gasoline is shown in the table below.

Table 5-1 Additional capital and operational expense of the oil companies (Only in Addis Ababa)

I/N	Type of expense	Distributing companies and their expenses in '000' birr				
		Shell	Total	NOC	YBP	Kobil
1	Depot upgrading	2904	4741	8316	5786	2288
2	Addis Ababa fuel stations upgrading	6616	5174	795	191	785
3	Additional operational expense (birr/year)	2025	2197	1407	137	1244

Source: EPE, 2007

In the author's opinion also it is clear that without settling the question of the additional expense coverage and changing the attitude of the oil distributing companies, the progress will be very slow and this lack of economic incentive is a noticeable barrier.

Due to absence of low interest borrowing facility on the other hand, the oil distributing companies went on as far as claiming the investment cost needed for up-grading their system to be covered by the government (Worku, 2008, June17, personal interview). In addition, due to the requirement of heavy investment for which the need to have big capital, private investors involvement on development of bio-ethanol (from feedstock to bio-ethanol production) has been limited (Shimeles, 2008, May 30, personal interview). There is no economic incentive put in place to date despite the priority given to the sector. Focus is given to the state owned sugar factories.

5.1.2 Technical

The concern raised here is that investment in developing bio-ethanol may be risky as it involves a number of uncertainties. Particularly the oil distributing companies are very concerned about it and they express the uncertainty as expanding the line of business to bio-ethanol represent a higher technical as well as financial risk than distributing the conventional petroleum products (Getahun, Alemayehu, Birehanu and etal, 2008, personal interview). Two key concerns are outweighed here considered hindering the promotion of bio-ethanol: quality problem and performance of the product

5.1.2.1 Quality problem

Nearly no water can dissolve in gasoline whereas bio-ethanol-gasoline blend containing a certain percent of water can induce a separation into two phases, which can cause vehicles to stall. For this reason, blend of bio-ethanol-gasoline requires anhydrous ethanol and storage and transport tanks must be kept free of moisture. In order to ensure the blend quality from water pollution, the following are to be met (Alemayehu, Shimeles, Worku and etal, 2008, personal interview).

a) Production of anhydrous bio-ethanol with pure ethanol content. Bio-ethanol considered suitable for blend when it contains only up to 0.5% water.
b) Bio-ethanol storage tanks that can prevent moisture in the distillery (in the factory)
c) Moisture preventing tankers bringing the ethanol from the distillery to the blending station
d) Moisture preventing gasoline and bio-ethanol storage tanks in the blending station
e) Moisture preventing tankers bringing the blend from the blending station to the fuel distribution stations and
f) Moisture preventing storage tanks receiving the blend in the fuel distribution stations.

Due to the necessity of keeping the quality at all stages on the one hand and the absence of current quality control system on the other, this quality issue has been one of the barriers in promoting bio-ethanol. This quality issue has also been one of the concerns to establish the blending station (Bekele, Aregahegne, 2008, personal interview). In the past, both the oil distributing companies and the factory producing bio-ethanol did not want to establish and operate the blending service giving a false pretext as blending is out of the line of their business (Getahun, 2008, July 23, personal interview). Especially the oil distributing companies were strongly resisting joining the force in promoting bio-ethanol demanding at one time a quality assurance system and on another claiming blending is not in their line of business.

Recently government has bridged this gap by hiring a foreign company to provide the blending service which the latter receives service fee on the basis of the volume of blend it prepares, currently it stands at birr 0.04/liter (Babkir, 2008, June 8, personal interview). Since the blending station is under construction, it is expected as it will incorporate all the necessary precaution in order to carry out the blending in accordance to the quality requirements fulfilling the point mentioned under d here above (Babkir, 2008, personal interview).

Points under a, b and c mentioned here-above are responsibilities that are to be fulfilled by the factories producing the bio-ethanol. Currently Fincha Sugar Factory complies with all the requirements to deliver to the blending station anhydrous bio-ethanol with a concentration of 99.9% (Shimeles, 2008, June 30, personal interview)), this means that there will be no water pollution problem from the existing factory, and *others*[34] are also expected to follow the same standard.

The points indicated under e and f are responsibilities that need to be fulfilled by the oil distributing companies. Some of these companies posses old fuel stations that do not satisfy the required standard needed to store blended gasoline. As a result they are undertaking upgrading work for which they have to incur additional cost and expect additional margin to cover this expense. Not only do incur cost for rehabilitating the fuel stations, they claim they also will have additional operating cost to transport the gasoline from border to the blending station and then from the blending station to their fuel stations, currently they transport from the border directly to their fuel stations. At the moment no clear information is available with regard to the additional margin as a result these oil distributing companies lack interest on accelerating the implementation. Moreover, the quality control system along the supply chain is still an issue that has not firmly decided as to who is going to control and where to base the quality checking. It is important to note here that the Quality and Standard Authority of Ethiopia has already developed a voluntary standard for the blend as well as for the main components which are being revised under the request of the Ethiopian Petroleum Enterprise. Thus these unresolved quality control problem and its associated expense are still hindering the progress.

5.1.2.2 Concern on the performance of the product

There are also concern regarding the performance of the product which is given as a reason not to expedite resources to the bio-ethanol production and use. Almost all actors know that blend of bio-ethanol (at least up to 10%) has been in use in many countries without the need to engine modification. However, some actors (few oil distributing companies) are still

[34] The state owned sugar factories which are in the process of building bio-ethanol plant

unconvinced on the direct entrance on using the product based on other countries experience without site and product specific demonstration on the performance of the product. The variation in altitude, the fear that blended fuel may be incompatible to old vehicles as most of the vehicles in Ethiopia are old, and mileage coverage are the issues raised by some respondents to limit their engagement (Alemayehu, Birehanu, and etal, 2008, Personal interview).

In the opinion of the author, actually these concerns relate more to the research and demonstration as well as awareness creation part of the promotion and had there been local test made, the results would have given confidence and demonstrated that the use of blended gasoline would outweigh the benefit so that those actors that have such dilemma could easily be aliened towards the need. But on the other hand absence of tests in the local condition should not limit the engagement and hinder the promotion as the concerns are scientifically unsubstantiated.

The author, recognizing these points as hindrance to the promotion of bio-ethanol, made literature surveys on the three points and found no ground to delay the use of the blend till local test demonstrates that these concerns are unwarranted. The author understanding from the survey on the points are presented in appendix IV.

5.1.3 Policy and regulation

Ethiopia's Energy policy of the 1994 EC[35] (2002) indicates only the intention to decrease the use of petroleum products in the transport sector by substituting, wherever possible, to new non-petroleum fuels. It addresses the question of how to enhance supplies and how to use energy more efficiently. However, the issue of bio-ethanol was not addressed properly and it can be said that there is no policy supporting bio-ethanol that can stimulate demand and create favorable condition for the development.

The absence of such policy is clearly a factor to hinder the development of bio-ethanol since investment decisions are very unlikely unless government policy that ensures investment on the sector is worthwhile is formulated. The current bio-ethanol production monopoly structure may not last forever. Private producers are already showing interest to enter into the sector that can bring competition so that improve efficiency. Such private investment to develop the bio-ethanol production and use requires an incentive or assured market in a certain form. Only when government policy is introduced that private investment will then attempt to secure feedstock production and commission the plant to enter into the market. While some of the preliminary works could be done before the formulation of the policy like being exhibited now, the real production may take several years even after the policy.

Companies wishing to make investment in bio-ethanol production decide to invest based on the comparison of costs of production with the expected revenue over the life of a plant. Hence, investment in domestic production requires market certainty. The lower production cost of bio-ethanol in Ethiopia compared to the price of gasoline can be an indicative of the provision of certainty in revenues. There could be, however, other uncertainties, for instance future costs and benefits as a result of changes in the sector that increase the risks and are thus barriers to the development. Therefore, government regulation that requires the use of bio-ethanol would provide the market certainty in terms of creating demand for bio-ethanol.

[35] EC means Ethiopian calender, which lags behind 7 years from the European Calender between September to December and by 8 years from January to September.

Government regulation in this case provides assurance for developers entering into the sector by giving certainty that there would be a demand for bio-ethanol for the foreseeable future.

Absence of such regulation has blocked potential investors to enter into the sector and to play an important role in the development. Not only has blocked private investors to develop bio-ethanol, even the state factories which have the potential to produce bio-ethanol have not considered the option in the past due to failure to create local market (Shimeles, 2008, June 30, personal interview). As a result of interest by the government in recent days and visible move to introduce a blending mandate, the factories are in the process of expanding the farm and constructing bio-ethanol plant. But for private investors, still assurance is needed and thus its absence limit proponents wishing to develop bio-ethanol

5.1.4 Knowledge and information

Many of the members in the national bio-fuel forum, which is entrusted to implement the strategic document into action, state that both the members in the forum and the institutes the members represent lack knowledge and skill about the bio-ethanol (Aklilu, Alemu, Kifelu, Aregahegne, 2008 and etal, personal interview). They are in the process of learning mainly from information in the web and hence the forum is not delivering to the expectation of higher government bodies. Absence of educational system that teaches students on bio-energy and therefore absence of experts in the field is the main factor contributed for the lack of knowledge and skill. Moreover, lack of focus on the area in the past limited the development of in-house skill.

The bio-fuel energy development in general and bio-ethanol for transport fuel use in particular is coordinated at national level by the Ministry of Mines and Energy. At the development stage, assigning the ministry as the owner of the bio-ethanol development program may be appropriate since bio-ethanol is one form of renewable energy and the ministry is responsible in energy related matters. However, it lacks professionals who have expertise in the bio-fuel energy system to guide and lead the program. This is one of the main obstacles even the ministry itself declares for the slow progress towards the bio-ethanol use (Melis, 2008, May 26, personal interview). As a result the ministry at times refrains to ask actors what it should and at times delays in responding to enquiries from actors. At times it becomes a point of misunderstanding, especially when some concerns about sustainability and environmental concerns raised (Mulugeta, 2008, July 6, personal interview).

In connection to this, despite the existence of research centers in the different sector that could support the development of bio-ethanol, none of them are involved in the current bio-ethanol production and use development as bio-energy has not been in their priority. This lack of research and development link creates inability to answer questions raised in connection to the bio-ethanol use program. Many of the views that reflect skepticism in the use of bio-ethanol could have been easily nullified and the resistance would have been minimized that block the progress if some research and study work could have been conducted. Even information needed as in put for drafting a policy is absent as a result of lack of prior study thereby creates delay in preparation of guidelines and incentives mechanisms to foster the implementation of the strategic document (Bazezew, 2008, July 6, personal interview).

5.2 Implications

The use of bio-ethanol as transport fuel has become an important issue due to perceived economic, social and environmental benefits. In many cases, bio-ethanol from sugarcane considered offer better benefits taking the experience of Brazil compared to other countries where their feedstocks are different. Economically, production cost of bio-ethanol from sugarcane is said to be the most efficient compared to other feedstock's (Duffy, 2006). Perceived social benefits stated in many instances are the opportunity of employment creation and rural infrastructural development especially for developing countries. Due to higher value of energy balance of bio-ethanol from sugarcane (IAE, 2004) its contribution in reducing emission of greenhouse gasses is believed to be the main environmental benefit.

As environmental and social concerns grow however, different groups require to ensuring the production system and its perceived benefit of bio-ethanol addresses sustainability issues. The concerns essentially come from the fact that production of bio-ethanol feedstock could result deforestation, water pollution, food security problem, poor labour condition and so on. This is also important to avoid long term social and environmental negative impacts at the expense of short term economic benefits. This requires planned and integrated development programs to assure the environmental and social concerns to be addressed adequately so that the perceived benefit should not be short-lived.

In this part then, the economic, social and environmental implications (benefits and concerns) of the bio-ethanol production and use in Ethiopia are identified and discussed. The identification is by no means exhaustive, rather tries to highlight the important issues in the Ethiopian context guided by implications outlined in the background chapter from international experience. Due to lack of knowledge and prior study and research on the Ethiopian context, an in-depth discussion with the stakeholders was not possible. Also sufficient data and information could not be obtained from actors in the value chain on the implications.

As has been mentioned, bio-ethanol is currently produced only by Fincha Sugar Factory though there are projects being undertaken by others. As a result most of the topics covered here reflect the production chain of the Fincha bio-ethanol. The issues, however, can equally apply to the others in the future.

5.2.1 Economic

This sub section focuses on the economic implications of the production and use of bio-ethanol from molasses in Ethiopia. It starts with the brief indication of the main economic factors influencing the pricing of bio-ethanol market.

5.2.1.1 Influence of bio-ethanol market price

As any market is influenced by supply and demand, so does market price of bio-ethanol. On the supply side the price of bio-ethanol production heavily depends on the feedstock. Under Ethiopian current condition, bio-ethanol is being produced and intended to be produced only from molasses. The price of molasses is influenced by either fluctuation on the production cost of sugarcane or price of molasses for substitute products which can be made from molasses. Molasses uses for other purposes in Ethiopia include feeds for cattle and production of bio-ethanol for beverages. Thus, only when the price of molasses for cattle feed and beverage industries rises that the opportunity cost of molasses for anhydrous bio-ethanol increases which leads to lower profit potential to the anhydrous bio-ethanol production. If the production of bio-ethanol were like the Brazilian system where bio-ethanol could also be allowed to be produced from sugarcane that could have been used to produce sugar, then the price of bio-ethanol production would also be influenced by sugar price. But in the Ethiopian case, sugarcane that can be extracted to produce sugar will not be used for the production of bio-ethanol and hence the influence of sugar price on the production of bio-ethanol is not straightforward. One possible risk may be when the price of sugar goes down production of sugar might be reduced and thus shortage of molasses could lead to influence the supply. But this scenario is very unlikely given Ethiopia is one of the countries which produces sugar at cheap price and the potential to export at world competitive market price (DSD, 2005).

The demand side is influenced by the demand of bio-ethanol for fuel for vehicles. Here the government direction is to start using a blend of 5% bio-ethanol with 95% gasoline which can thus be sold at fuel stations. The 5% blend is chosen due to the shortage of bio-ethanol product in the country to make higher percentage. As the production is increased and experience is gained, the intention is to increase the blend ratio in the subsequent years. One important aspect which should be considered here is the difference in energy density between ethanol (21.17MJ/liter) and gasoline (32.4MJ/liter) (IAE, 2004). Taking this fact into account, the IEA cost comparison is corrected by a factor of 1.46 to arrive at cost for ethanol in terms of litre of gasoline equivalent (DSD, 2005).It is also indicated, however, the advantage of greater volumetric efficiency and octane number improvement equalize the lower calorific value of ethanol (26.8 MJ/kg bio-ethanol versus gasoline 42.7 MJ/kg). Appropriate engine brings pure alcohol to deliver 18% more power per litre than gasoline, but will be consumed 15-20% more (DSD, 2005). This means that the two factors offset, leading neither fuel with a clear benefit from an energy point of view (DSD, 2005). Since engine is not adapted in Ethiopia to make bio-ethanol deliver the 18% more performance, it is reasonable to assume as recommended by IEA (DSD, 2005) that 1 litre of gasoline is equivalent to 1.2 litres of bio-ethanol. This possible substitution means that the price relationship between bio-ethanol and gasoline will have an influence on the demand, especially if there will be no incentive from the part of the government to the oil distributors.

After looking the market price influencing factor on the demand and supply side, the following part reviews the potential economic benefits from the production and use of bio-ethanol in Ethiopia.

5.2.1.2 Potential benefits

Supply side

As indicated in 5.2.1.1, the key factor for determining the economical benefits for Ethiopia for production of bio-ethanol from molasses is the price of molasses for substitute use or products. Ethiopia generates molasses from the sugar factories in significant amount and this quantity is in excess for the local requirement for cattle feed and feedstock for beverage alcohol production. Even the selling price is not attractive; as a result considerable amount of molasses is spoiled during storage or sold at dumping cost (Azemera, 2008). Until the Fincha factory entered a supply contract for hydrous bio-ethanol, even the existing bio-ethanol plant was operating at low capacity. Thus, from supply side production of bio-ethanol for transport fuel use is an opportunity for utilizing the excess molasses. For indication, the following table shows the quantity of molasses and bio-ethanol (both hydrous and anhydrous) expected to be produced in the respective years. It is important to note here that 1 ton of molasses yield about 250 litres of bio-ethanol.

Table 5-2 Molasses and bio-ethanol production trend

Description	Years						
	2007/8	2008/9	2009/10	2010/11	2011/12	2012/13	2013/14
Molasses (Tons)	103,249	107,460	165,963	256,534	373,850	466,852	542,559
Bio-ethanol (m^3)	8,000	8,482	20,690	55,962	83,452	112,815	132,886

Source: ESDA, 2008

Demand side

Currently generally the energy demand of Ethiopia is very low compared to even other least developed countries, consumption stands at 28KWH per capita. This is mainly due to limited access of clean energy by the majority of the population living in the rural areas and underdevelopment of industry as well as infrastructure. However, in order to reduce the poverty level and register steady growth, undoubtedly the demand will increase significantly in the upcoming years. With the expansion of existing and new roads and the annual 10 % vehicle importation increment shown last year (Bazezew, 2008,July 6, personal interview), the demand for transport fuel will also rise. The trend in gasoline requirement as projected by the MME is shown in the table below.

Table 5-3 Gasoline consumption trend

	Years						
	2007/8	2008/9	2009/10	2010/11	2011/12	2012/13	2013/14
Gasoline (m^3)	210077	220581	231610	243190	255350	268,118	281,524

Source: MME, 2007

Current gasoline demand is entirely met by imports. If this trend continues to be met, Ethiopia needs to gain access to the heavily swarmed global demand of gasoline and ensure steady supply to facilitate its growth. In other words, Ethiopia needs to spend substantial amount of foreign currency to fulfil its gasoline requirement as the trading of petroleum products requires USD or Euro. But this foreign currency payment for petroleum products has already become a heavy burden to the economy of the country, recent report states that around 80% of the foreign earning is consumed by petroleum product imports (Reporter, 2008). Thus, with the increasing energy demand, the option to have local source of renewable energy is much attractive.

5.2.1.3 Bio-ethanol cost versus gasoline

As indicated in the paragraph on 5.2.1.1 above, oil distributors could be interested to distribute bio-ethanol if equivalency is adjusted based on 1 litre gasoline equals 1.2 litre to achieve the same performance as gasoline fuel in non adapted engines. This would mean that the value of bio-ethanol have to be equal to or lower than 80% of the price of unleaded gasoline. Taking this factor into account, it is necessary to have an insight to the production cost of bio-ethanol to see the economic benefit.

The production cost of bio-ethanol using full costing is shown in table 5-4 below, which is taken from budget document of Fincha Sugar Factory for the 1997 period during the site visit. It is important to note that some cost variation might occur since 1997, though assumption is taken as the cost inflation in some part of the cost element could be compensated by raising the productivity. This is generally true that as more experience is gained, production methods improve so that productivity would increase thereby cost inflation in some cost element could be compensated.

Table 5-4: Production cost of Bio-ethanol

S/No	Cost element	Annual Value (Birr)
1	Raw materials	971,040
2	Maintenance	461,538.48
3	Labour	382,142.82
4	Overhead cost	95,535.71
5	Consumables	1,484,796.37
6	Utilities	248,944.84
	Total, materials, labour and overheads	3,643,998.22
8	Fixed cost including depreciation	6,263,358.35
	Total operating cost	9,907,356.57
	Quantity of Bio-ethanol to be produced (Litres)	8,092,000
	Production cost/litre (Birr/litre)	1.224

Source: Fincha Sugar Factory

Since it has been said that 1.2 litres is needed to get equal performance with 1 litre gasoline, a mark up of 20% is added to this production cost to bring to gasoline equivalent. Adding the transportation cost to bring the bio-ethanol from the place where it is produced to the blending location near Addis Ababa, and the service cost for blending as well as some margin for fuel distributing companies to compensate their additional expense to upgrade the fuel stations, will bring to an equivalent cost of bio-ethanol with gasoline at Addis Ababa.

During the author's interview with the oil distributing companies, additional margin of birr 0.01/liter will be enough to recover the cost they incur for upgrading the fuel stations within 5 years (Getahun, 2008, June 30, personal interview). Estimating the transportation cost of bio-ethanol from Fincha Sugar factory to Addis Ababa as birr 0.01 per liter (EIA, 2007) and taking the service cost for blending which is set now as birr 0.04/liter (Babkir, 2008, June 8, personal interview), price equivalency for bio-ethanol is built.

As has been indicated in table 2-11 in part 2.2.3, the retail price of gasoline at Addis Ababa is Birr 9.4. In order to bring the bio-ethanol price to the equivalent retail price, the following cost build up estimate is made.

Table 5-5: Price comparison of gasoline and bio-ethanol

Gasoline retail price build up at A.A			**Bio-ethanol cost build up (Assumption)**		
S/No	Description	Value (Birr/liter)	S/N	Cost element	Value (Birr)
1	Ex-Djibouti price	6.5657	1	Factory production cost	1.224
2	Djibouti/Dewele/ Galafi Transport	0.0804	2	Assumed factory margin (50%)	0.612
3	Total Border Price (1+2)	6.6461	3	Correction to the equivalent of 1 liter gasoline 20%(1+2)	0.3672
4	EPE's Margin	0.0598	4	EPE's margin	0.0598
5	Product Cost(1+4)	6.6255	5	Product cost (1+2+3+4)	2.2630
6	Excise Tax [30% on(1+2)	1.9939	6	Excise tax	-
7	VAT [15% on 1+2+6]	1.2960	7	VAT [15% on 1+2+3]	0.33048
8	Road Fund	0.0950	8	Road fund	0.0950
9	Municipality Tax	0.0200	9	Municipal Tax	0.0200
10	Stabilization Fund	(0.8866)	10	Stabilization Fund	-
11	Total Duty (6 to 10)	2.5183	11	Total Duty (6-10)	0.44548
12	Invoice Price(5+11)	9.1438	12	Invoice price (5+11)	2.70848
13	Distributors Margin (including transportation)[36]	0.2562		Distributors margin (including additional 0.01 Birr/ liter additional margin)[37]	0.120
14	A.A Retail price (12+13)	9.4000		A.A Retail price estimate (12+13)	2.82848

Based on this assumption, for every liter of gasoline substituted, the country saves birr 6.5715. But there could be other costs associated with the development of bio-ethanol which could be difficult to convert into monetary terms. These may include financial cost to support the bio-ethanol industries and costs on impacting food price. Since there are no studies conducted on the area, such indirect costs could not be established.

[36] In the case of gasoline distributors margin, the transportation cost from Djibouti to Addis Ababa is included, which is estimated as birr 0.2262/liter (EIA, 2007)

[37] Transportation cost for bio-ethanol is less than that of gasoline, which would come birr 0.08/liter based on the distance difference (925 Km for gasoline and 327 for bio-ethanol).

5.2.1.4 Improved trade balance

Development of bio-ethanol-gasoline blend into the Ethiopian market seems provide foreign currency saving by reducing an equivalent quantity of gasoline importation. Stated below is an estimate of the country's saving potential coming from the bio-ethanol substitution, excluding the indirect costs mentioned above. For the estimation, the country gasoline requirement as determined by the Ministry of Mining and Energy (MME, 2007) and the bio-ethanol production forecast as determined by the Ethiopian Sugar Development Agency (ESDA, 2008) are taken. Out of the total bio-ethanol forecasted for production (see table 5-4), which include both hydrous and anhydrous, only the share of the anhydrous type is taken here.

Table 5-6: Saving potential from reducing gasoline imports

Year	Forecast national Gasoline consumption (M^3)	Share of Forecasted Bio-ethanol Production for fuel (M^3)	% of Bio-ethanol (%)	Estimated saving (in '000' Birr)
2007/8	210077	7000	3.3	46 000
2008/9	220581	7332	3.3	48 182
2009/10	231610	20690	8.9	135 965
2010/11	243190	55962	23.1	367 755
2011/12	255350	83452	32.68	548 406
2012/13	268,118	112,815	42.08	741 366
2013/14	281,524	118,121	41.96	776 234

The estimation is done with the current price structure of gasoline and bio-ethanol assumption (see table 5-5). Any price fluctuation will equally affect the saving positively or negatively depending up on how the changes occur. Increasing in price for gasoline maximizes the saving amount which also is the case if the production cost of bio-ethanol goes down. On the contrary, the saving amount decreases if the gasoline price declines or the gap between the price of gasoline and bio-ethanol narrows down.

The above table (table 5-6) shows the saving potential of the country when it starts using bio-ethanol-gasoline blend. The saving potential in value by substituting the equivalent amount of gasoline is tremendous. As a matter of fact unless vehicles with modified engine are introduced to operate with higher blend ratio, the entire bio-ethanol amount envisaged to be produced will not be consumed in the domestic market. Hence vehicles like those in Brazil where they can use higher blend ratio including the flexible fuel type needs to be imported in order to create domestic market to accommodate the large amount of bio-ethanol production potential.

Other potential options are utilizing bio-ethanol for cooking fuel.

Utilization of bio-ethanol for cooking fuel: household cooking fuel is one of the critical problems in the country. Estimates show that household accounts about 90 of the country's energy consumption. The existing households' energy sources are mostly comes from the uncontrolled use of wood fuels, and animal dung and agricultural residues. In many rural areas deforestation and soil impoverishment is mainly happened due to lack of alternative energy sources. In addition to these problems huge amount of kerosene is imported each year (15%

0f imported fuels come as kerosene)[38] with a lot of foreign currency as a household cooking fuel with government subsidies. As kerosene price is increasing, it is very essential that different source of energy have to be experienced at optimum condition (looking for another option).

To minimize the problems associated with household energy mentioned here-above, using bio-ethanol domestically as cooking fuel is another feasible option. In fact efforts are underway by different groups as a pilot study to use bio-ethanol as a cooking fuel and the early finding indicates as it has met with broad consumer acceptance and replaced kerosene, charcoal and firewood (MME, 2007). As long as affordable stove is introduced, it is going to be a good option.

5.2.1.5 Energy diversification and security

Local production of bio-ethanol renders a range of other attached benefits in addition to the benefits already mentioned above. Such benefits include: energy security and electrical power production by co-generation.

Energy Security: Using bio-ethanol as a blend means that the same quantity doesn't have to be imported thereby reducing the need for foreign currency to be spent. This has direct impact on the balance of payments. Saved funds can be used to focus on the same or other energy saving projects. In addition, having own energy supply means reducing the dependency of international supply thereby facilitates to secure the increasing transport energy demand of the country.

Electrical power production: production of sugar and bio-ethanol has a potential to produce electricity by co-generation to be connected to the national grid so that increases the country's electrical generating capacity. Particularly this is important to reduce the dependency of rain water hydropower system of the country. Due to recent water shortage for instance electrical power supply has been in *ration*[39]. In the coming years for instance, by improving the operational efficiencies and installing appropriate co-generating equipment, the sector plans to generate the following electricity amount for the national grid.

Table 5-7 Power production for the national grid

Description	**years**						
	2007/8	2008/9	2009/10	2010/11	2011/12	2012/13	2013/14
Power generation for the national grid (MWH)	-	-	53,072	166,667	363,908	521,658	583,117

Source: MME, 2007

In addition to the pure economic benefit to produce bio-ethanol and use, there are potential environmental benefits as well. As has been stated elsewhere, the use of bio-ethanol as transport fuel instead of fossil fuel based gasoline could provide reduction in greenhouse gasses and dependency of energy supply.

[38] Capital, Ethiopian weekly English news paper, Volume 10, No 503, August 03, 2008

[39] Due to low water volume in the dams, power production became less than the requirement of the country. As a result, from March to July, 2008, a ration system was introduced. Two to three days in a week were off from getting electrical power in the country.

Since the impact of greenhouse gasses is not limited to local condition, not only benefit this emission reduction to Ethiopia but also the developed countries. Developed countries have obligation by Kyoto protocol to reduce their greenhouse gases emission amount on average by 8% till 2012 from the base year of 1990. Thus these countries can reduce their emission level by investing in Ethiopia under the Clean Development Mechanism (CDM)[40], which in turn presents an interesting opportunity for Ethiopia to gain funds that will be invested again to expand the bio-ethanol program.

Moreover it can open up an international market for bio-ethanol transport fuel and earn foreign currency since a lot of developed nations are examining bio-ethanol blend as a means of reducing their greenhouse gasses.

It should be noted that all these benefits are difficult to convert into monetary terms. A simple illustration is given below to indicate the economic value of the environmental benefit.

As indicated by UNICA (UNICA, 2007), the Brazilian ethanol program has made a reduction of 2-2.8 kg of CO_2 per liter of anhydrous bio-ethanol. Taking the average value for this example to hold true for the Ethiopian situation which of course needs verification on local condition, 2.4 kg of CO_2 could be reduced by using 1 liter of bio-ethanol instead of gasoline. Point Carbon[41] estimated the current market price (July 24, 2008) of reduction of 1ton of CO_2 as Euro 25. This would lead an additional benefit of (Euro 25/1000kg of CO_2 X 2.4 kg of CO_2/ liter of bio-ethanol), which is equal to Euro 0.06 (birr 0.9) per liter of anhydrous bio-ethanol use. Besides, there are benefits for cleaner and less polluted air in the country using the bio-ethanol, which is not easily translated to economic value.

5.2.2 Environmental

Bio-ethanol production is attached with many environmental concerns. The main concerns from the international context are outlined in the background section. On the basis of this background information, the following are the status with respect to the Ethiopian bio-ethanol production and use context.

5.2.2.1 Water consumption

In general there seems to be sufficient water available for the foreseeable long term sugarcane as well as food crop cultivation, as Ethiopia is endowed with plenty of water resource, one of the largest fresh surface water in the Sub-Saharan Africa. Surface and ground water potentials estimated as 110 billion cubic meter and 2.6 billion cubic meters respectively. However, only 2% of this potential is annually utilized, 86% of this goes to irrigated agriculture (Agricultural and Rural Development Department, 2002).

However, the cultivation of Sugarcane and production of sugar and bio-ethanol require water, which could lead to the depletion of the resource. According to the experts working in the bio-ethanol plant (Azemera, 2008 June 20, personal interview), the current water usage both at the farm level as well as in the bio-ethanol plant is very high. There is no proper accounting of water despite the availability of provision and mechanisms to do that. The following are

[40] Under CDM, Annex I countries can implement projects in non Annex I countries (e.g in Ethiopia) to reduce greenhouse gas emissons and use the resulting certified emission reduction (CER) to meet their target

[41] http://www.pointcarbon.com/news/1.951064 [last visited on 25/07/08]

estimates of water usage at the farm, sugar and bio-ethanol production level which are collected during the site visit from Fincha Factory.

Table 5-8: Fincha sugarcane cultivation water consumption estimate at the farm

S/N	Description	Years		
		2004/5	2005/6	2006/7
1	Hectares of land cultivated (ha)	5439.52	5913.66	5668.41
2	Cane Production (Ton)	758,474.4	815,028	780,763.9
3	Water consumption (M^3)	86,223,420	96,135,000	75,587,280

Source: Azemera and Afework, 2008

As can be seen from the table, the water consumption level that comes from irrigated system is high, especially compared to the Brazilian way of farming which is mainly rain fed (UNICA, 2007). The average consumption per hectare of land and per ton of cane produced for the three years at the farm level becomes 15,154 m^3 and 109.56 m^3 respectively.

Minimum estimates of water consumption at the sugar extraction stage indicates at 11.22m^3 per ton of cane crushed and that of the bio-ethanol plant as at 0.12m^3 per liter of bio-ethanol.

Allocating the share of the water consumption at the farm and at the sugar extraction to the bio-ethanol product would give the total water consumption as 0.13m^3 per liter of bio-ethanol. The computation and the assumptions are as follows:

- 3.8% of the cane entering the sugar extraction step will be out as molasses, which is the raw material for bio-ethanol production. Hence, the 3.8% of the water consumption at the farm and at the sugar extraction level should be allocated to bio-ethanol production. This gives as 3.8% (109.56 + 11.22) or 4.59 m^3 per ton of molasses.
- Taking the conversion rate of molasses as 250 liters of bio-ethanol per ton of molasses, the water consumption per liter of bio-ethanol can be computed as (4.59/250 +0.12), which is equal to 0.13 m^3.

5.2.2.2 Water Pollution

No information is available on the level of water pollution due to the sugarcane and the sugar factories operation in the different regions where the sugar factories and their sugar plantations are located. From the visit at Fincha Sugar and bio-ethanol production factory however there is a danger of water pollution from the sugar and bio-ethanol production process as a result of discharging effluents containing organic pollutants to the near-by river. The effluent treatment system is equipped with proper facility composed of pre-treatment, collection system and final treatment system before it releases to the river. Because of failing to maintain the facility, effluents from the sugar and bio-ethanol plants are collected and then diluted with water before it is released to the river. As a result the water consumption has been tremendous in addition to risking the aquatic life in the river. Particularly the release of spent wash that is generated from the bio-ethanol plant during distillation has potential threat to the river. Spent wash has high organic load and its pH is in the range of 4-5 (Azemera, 2008, June 20, personal interview). Therefore, prompt action from the management is required to make the effluent treatment plant operational in order to ensure the factory operation will not pollute the water bodies.

The risk of water pollution from agrochemical at the sugarcane plantation farm has been minimized by applying the sprinkler water spray system. Due to the topography of the area, furrow type of irrigation system was not considered which otherwise would have facilitated erosion thereby residue of agrochemicals would enter the water bodies and contribute for pollution.

Figure 5-1: Sugarcane plantation Sprikler water system

5.2.2.3 Land use and biodiversity

The production of bio-ethanol could have a negative impact on diversity in many ways, either directly or indirectly. Land clearing practices such as deforestation, conversion of biodiversity rich area to sugarcane, construction of infrastructure for bio-ethanol production, use of chemical pesticides and fertilizers could be a cause for the negative impact on biodiversity.

In Ethiopia the sugar factories current land occupation for sugarcane cultivation is stated as 23657 hectares. With in eight years the land area that will be covered by sugarcane by the state sugar factories alone is going to reach at 118,135 hectares, which is almost five fold. Out of the 94,478 additional land required, 48,755 hectares is planned to come from the area which was used to grow cotton by state farm, and the rest is from areas close to the existing sugarcane plantation, some part is occupied by settlers and the other is free land, in some cases empty land and in some cases covered by forests (Shimeles, 2008, June 8, personal interview). This expansion scheme, even if considered as less, will have the potential to contribute habitat loss and impact on biodiversity. The expansion of sugarcane cultivation causes deforestation and displacement of settlers though the exact magnitude is not known (Shimeles and Tesfaye, 2008, personal interview). On the other hand, the net effect could also be positive as the use of bio-ethanol reduces the green house gas emission and thus reduces biodiversity loss from the impact of greenhouse gas emission. Hence, extensive study will require evaluating and identifying the net impact. To date no study on this issue has been conducted.

It is important however to take precautionary action in order to minimize the negative impact. In this regard policies that aim to protect forests and preserve biodiversity have been put in place in Ethiopia (see part 2.2.3). But due to weak enforcement capability, these protection tools have not been yet instrumental.

The other indirect contributor for negative impact on bio-diversity is pollution from the use of chemical pesticides (Insecticides, herbicides, fungicides) and fertilizers. The following table shows an overview of the pesticides and fertilizers use at Fincha sugar cane cultivation.

Table 5-9: Fertilizer and pesticide use at Fincha sugarcane plantation

S/N	Description	Years			
		2003/4	2004/5	2005/6	2006/7
1	Hectares of land cultivated (ha)	5017.01	5439.52	5913.66	5668.41
2	Cane produced (ton)	694,271.2	758,474.4	815,027.9	780,763.9
2	Fertilizers use (ton)				
	DAP	1286.3	1666.1	1544.43	1601.2
	UREA	1289.8	1987.8	1703.79	1928.85
	Average fertilizer use (kg/ha)	513.5	671.7	549.3	622.8
	Average fertilizer use(kg/ ton)	3.71	4.82	3.99	4.52
3	Herbicides use (lit)				
	Gesapax Conbi	-	60	-	-
	Gesapax H500 EC	-	-	-	10662
	Gramaxon (Parqat)	-	-	1251.5	1399
	Atramet Combi	8008	12965	18214.13	7012
	2-4D Amine	3475	3593	2991.2	29
	Velpar	828	173	770.5	448.5
	Glyphosate	1216	573	1251.5	925.5
	Teepol	388	75	-	-
	Activator-90	457	399	709.72	137.52
	Average herbicide use (l/ha)	2.86	3.28	4.26	3.64
	Average herbicide use(l/ ton)	0.02	0.024	0.031	0.026
4	Insecticides use (lit)				
	Malathion	96	9	205	28.5
	Dursban (pyrinex)	1746	2454	1424.38	3420
	Diazinon	11	-	-	-
	Average insecticide use (l/ha)	0.37	0.45	0.28	0.61
	Average insecticide use(l/ ton)	0.0027	0.0032	0.002	0.0044
5	Fungicide use (lit)				
	Lysol	245	143	-	5
	Benomyl	263	105	0.5	-
	Total average pesticide use (l/ha)	3.33	3.78	4.53	4.25
	Total average pesticide use (l/ton)	0.024	0.027	0.033	0.031

Source: Tekalegne (FSF), 2008

The general use trend of fertilizers and pesticides are on the rise. Table 5-9 for instance shows that average fertilizer use in the year 2003/4 was 513.5 kg per hectare or 3.71 kg per ton of cane produced. These figures have gone up to 622.8kg/ha and 4.52 kg/ton respectively in the year 2006/7. Likewise the average pesticide use in 2003/2004 was 3.33 liters per hectare or 0.024 liter per ton of cane produced, which have gone up in the year 2006/2007 to 4.25 liter/ha and 0.031litre/ton respectively.

Compared to other crops cultivated in Ethiopia, the sugarcane plantation consumption rate of these fertilizer and pesticides is higher, except for *teff*[42]. In the 2006/2007 main crop season for

[42] Teff is one of food crops grown in Ethiopia

example the use of fertilizers (DAP and UREA) in kilogram per hectare by private farmers for Teff, Wheat, Maize, Barely and Sorghum respectively were 740 112,130,91and 119 (CSA, 2008). Actual pesticide consumption data for the main crops is not available and hence comparison with sugarcane consumption rate could not be made. However, given the low level of pesticide application in the country, the consumption rate of the sugarcane plantation is still to the higher side. Particularly, when compared to the average pesticide consumption of the smallholder farms, which remains lower than 0.1kg/ha/yr (EEA, 2004). Therefore the increasing trend per ton of cane of fertilizer and pesticide use need to be discouraged to minimize the impact of these agrochemicals.

The exact level of their impact can not be determined as there is no prior study done to address the issue although it is apparent that use of agrochemical has always been associated with undesirable consequences. As a result priority should be given to other means to increase the soil fertility and prevent pest so that use of such chemicals needs to be as a last option as part of integrated farm management.

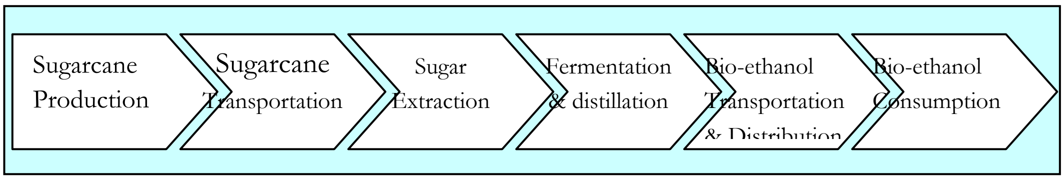
5.2.2.4 Energy Balance and Greenhouse gas emission

The energy balance refers to the ratio of energy contained in the bio-ethanol to the fossil fuel used along the lifecycle to produce it. There exists a debate about whether bio-ethanol has a better energy balance ratio than the conventional fuels.

Determining the energy balance is certainly a complex process that needs to consider the entire fuel cycle, from feedstock production to final use , which is referred to as well-to-wheel approach. And energy balance as stated, varies depending on, among other things, the type of feedstock, cultivation methods and conversion technologies

The basic components of the lifecycle stages to produce bio-ethanol in Ethiopia are depicted in fig 5-3 below.

Figure 5-1: Main life cycle stages of the Bio-ethanol production in Ethiopia



As shown in the figure, Sugarcane production and transportation, sugar extraction to get molasses, conversion of molasses to bio-ethanol through fermentation and distillation, bio-ethanol transportation to the place where it is blended and distribution to fuel stations, and finally consumption of bio-ethanol are the major life cycle stages where energy consumption and emission of greenhouse gases occur. In addition, the industrial steps when fertilizers and pesticides are produced must be considered to take full account of the greenhouse gas emission.

In Ethiopia, however there is no study available that assesses the energy balance and the greenhouse gas emissions from lifecycle stages of bio-ethanol production. Generally energy balance from sugarcane is considered to be in the range of 8-10 based on Brazilian experience. Although the feedstock is the same and closely related result could be assumed, energy balance is also dependant on other factors such as agricultural practices, sugarcane productivity, and process technology employed along the lifecycle as well as driving efficiency (IEA, 2004, WWI, 2006 and etal). Therefore, the validity of the assumption about the energy balance needs to be carefully checked and verified based on site specific data.

The energy balance is also useful for tracking the fossil fuel consumption trend and helps to take measures in order to reduce the amount. Not only useful for environmental reason, it has also social and economic benefits when its use becomes less and less. For this reason also, it is commendable the factory itself to conduct the energy balance study under its site specific condition by limiting the boundary.

The only current available data with respect to energy in the factory is the furnace oil consumption of the boiler that generates steam for sugar extraction and bio-ethanol production, and shows that in 2003/4 the consumption was 1.19 lit/ton of sugarcane. In the year 2006/7 this figure went up to 3.2 lit/ton. But this figure alone doesn't provide the full picture as to what seems the energy balance. It is clear however the consumption of fossil fuel in the conversion stage is on the rise. There is a plan put in place in that to maximize generation of electricity and sell the excess to the national grid starting from 2009/10. It is planned to sell 32,740 MWH in 2009/10 and reach to 50,223MWH in 20012/13. This undertaking clearly improves the energy efficiency of the production system.

5.2.3 Social

5.2.3.1 Implication for food security

There is a concern that production of bio-ethanol may lead to food security problems especially in poor countries like Ethiopia. The argument being the expansion of bio-ethanol feedstock leads land to be drawn away from food crops thereby could create food shortage and higher food prices for consumers.

The strategic document for the development of bio-fuel in Ethiopia emphasized the need to implement the program in a way that ensures the key objective of food security. However, there is no guideline yet to ensure how this strategic direction will be fulfilled. As it has been mentioned, the feedstock currently in use for the production of bio-ethanol is sugarcane. While sugarcane is not a principal food crop, and its price is relatively uncorrelated with other food crops bio-ethanol feedstocks like corn and wheat, any of the respondents did not consider risky on the direct implication of the Ethiopian bio-ethanol development to aggravate food insecurity.

The agricultural production in Ethiopia is dominated by smallholder producer that are characterized by low market network and infrastructure, low technical skill to apply modern farm practice and high prevalence of illiteracy (Birehanu, 2006). The sector mainly relies on rain fed farming thereby exposed to high level of climatic uncertainties. As the country irrigation farming stands very low, the sector is highly vulnerable to climate changes particularly for rainfall instability and draught. As a result the current agricultural products are not sufficient to make the country food self sufficient.

Assuming the land structure mentioned in the agricultural sector part (2.2.1)[43] holds true, the current cultivated sugarcane area of 23,657 hectare is very small compared with the total land area, which is only 0.02%, these shows that land competition for food crop is very small. This

[43] Out of the total land area, 66% is suitable for cultivation, and out of this only 15% is cultivated.

area also when compared with the potential arable land of the country, the share is still very small, only 0.032 %. In addition, as stated in part 2.2.1, out of the potential suitable arable land the country is endowed with, only 15% of this land area have been cultivated. With this low cultivation area, rain dependant farming system and low yield per hectare (as shown in table 2-5), the country food sufficiency rate is 70% (Birehanu, 2006).

Looking only at the size of available land, it seems that there may be available land to expand both crop and sugar cane cultivation. But the claim that 66% of the total land, of which 85% is available for cultivation, is something which needs an in-depth study. The trustworthiness of the claim becomes critical when one recognizes the absence of recent study made on the classification of land and land use planning. There are indications that the land which was once considered as suitable for farming found as unsuitable due to degradation (Negussu, 2008, July 23, personal interview). Under this situation, it is hard to determine the influence of sugarcane cultivation and its land occupation on food security. .

In terms of water competition, the sugarcane cultivation in all the farms is done using irrigation. There is no doubt that these farms consume some part of the country's water resource. In Ethiopia, the area that can be irrigated by surface water is estimated at 3.7 million hectares. Despite this potential the overall area cultivated by irrigation is less than 5 %(See part 2.2.1). Considering only the current area cultivated by sugarcane, the percentage is 0.64%. If all the potential suitable irrigation land identified for the sugarcane (700 000 ha) is utilized, which needs to expand the current size almost 30 times- that will certainly takes many years to reach this level, it will be 19% out of the total potential surface water irrigable land. This is again should be verified by revised study. The water resources may be accumulated in a certain area where they can not be utilized as computed.

The absences of recent and sufficient study make the development of bio-ethanol and its implication on aggravating food security uncertain. With soaring of gasoline price, bio-ethanol may become more and more attractive for fuel and create more demand. Accordingly, many investors tend to invest on cultivating feedstocks for which they need large area of land thereby change the *current situation*[44]; as a matter of fact the number of investors wishing to engage in the area is increasing. Hence, with the absence of clear guideline to realize the strategy and land use planning and demarcation (zoning) to prevent the crop land being issued to other purposes ,as well as weak level of policy implementation experience, there exist potentially a danger on sugarcane plantation to compete with land and water thereby influence the effort to food security

5.2.3.2 Land right

Land right has a factor for protecting the poor farmers from being displaced under the bio-fuel development. It is one of the social concerns raised in connection to bio-ethanol development in poor countries.

Land ownership in Ethiopia belongs to the state. This ownership structure is arranged in an attempt to give tenure security to the farmers. The arrangement doesn't allow land to be sold and such arrangement according to the policy makers would guarantee farmers to stay on their plot of land without the danger of being displaced.

[44] In the current set-up, the bio-ethanol development is monopolized by state owned Sugar factories.

Loosing the landholding can occur only when the government may require that land. This happens by providing compensation for relocation. However, the compensation amount is determined by the government itself and settlers who do not want or agree to accept the compensation don't have the means to reject it. In connection to this the proclamation on rural land administration and land use (proclamation no 456/2005,7.3) states as holder of rural land who is evicted for purposes of public use shall be given compensation proportional to the development he has made on the land and the property acquired or shall be given substitute land.

Given the availability of large land that can be cultivated by irrigation where in most sugarcane growing places people are sparsely settled or no settlement exists, the incidence of relocating dwellers for sugarcane plantation could be assumed less. But, though the magnitude is less, dwellers settled around the Sugar factories plantation area may face relocation to undertake expansions on surrounding areas of their respective sugarcane plantation (Shimeles, 2008, personal interview)

This policy protection to prohibit land from being sold may prevent farmers from selling their holdings to private investors and being dispossessed. However, the arrangement disallows farmers to use the full economic benefits of their land holdings by selling though they are free to lease for a period of time determined by rural land administration laws of regions based on particular local condition. Landholder can also, using his land use right, undertake development activity jointly with an investor in accordance with a contract he concludes under the approval of responsible authority.

5.2.3.3 Employment creation

One of the social benefits that could be obtained from the expansion of bio-ethanol production is the opportunity of creating jobs. The sugar factories in Ethiopia for instance created job opportunity for around 30,000 employees today both temporary and permanent. This number will increase to more than 102,000 in the year 2011/12 (ESDA, 2008). Most of these employees will be low skilled and poor workers in the rural areas. Women are also part of the beneficiaries by engaging themselves in sugarcane cutting. There are also other indirect job creation like employment in the infrastructure development and blending operation.

In connection to employment, the sugarcane plantation is located in malaria's area and hence employees are prone to malaria. In addition, sugarcane burning during harvesting is a common practice that can pose environmental and health risk. Due to absence of data with regard to working condition however, more information could not be given. In the opinion of the author, such things are one of the social issues which need to be studied well and improved.

6 Lessons for Ethiopia

This section outlines recommendations that are considered to be supportive for the Ethiopian bio-ethanol development endeavor to overcome the barriers and the negative implications in order to stimulate progress while also addressing sustainability. The recommendations are mainly from the lessons learnt from Brazil, which is a successful world leader in bio-ethanol production. Today, the bio-ethanol industry in Brazil is recognized as an efficient sector that brings substantial benefits to the Brazilian economy (IFRI, 2006). Thus the experience and the measures taken to reach to this level are important lessons to Ethiopia, which is in the process of developing bio-ethanol production and use.

The following discussion presents what lessons Ethiopia can take out of this successful experience, which was elaborated in chapter three.

6.1 State intervention

During the beginning of the bio-ethanol development in Brazil, government took a number of activities to back and shape the ways the sugarcane agribusiness headed. The intervention dominated all of the sector's structure; both production and marketing that include pricing and quota (UNICA, 2007). But later, the production and marketing of sugarcane, sugar and bio-ethanol was not subject to state control. Prices are determined by market, and import and export are at the risk of business deals.

Ethiopia is now at the early stage of developing bio-ethanol. Like the state of Brazil, the government of Ethiopia is making interventions for the development of the sector. A strategic document for bio-fuel development has been prepared, necessary resources (land and capital) for expanding the production of sugarcane and bio-ethanol have been given to state owned sugar factories, pricing is being set and a blending quota is expected to be formally proclaimed. Petroleum products are purchased and imported only through monopolized state owned Ethiopian Petroleum Enterprise. All the activities, in the Ethiopian case as well, are being dominated by the state. Such dominancy at this stage as was seen in Brazil could be healthy to support and make the industry successful.

What needs to be learnt here and applied to the Ethiopian bio-ethanol development is that such intervention should not continue forever. It should be for short period of time until the market develops since such activities of state monopolistic production and market control will be inefficient without the force of competition. For medium and long term, level playing field should be facilitated for competition and market to decide. Thus, any intervention at this stage needs to aim to bring a system that is determined by market force and business deals at a later stage.

What the role of the government would be and the type of intervention it would take at different stages to bring that system is beyond the scope of this paper. It should be answered by careful study considering the various factors interacting, which may include technical, market and socio-economic situation of the country. What is highlighted here is to follow the course of Brazil's government intervention. First there was strong intervention to develop the market and once the market was developed the intervention became less and less. The government role in the long run will be to create conducive environment by installing and regulating appropriate policies that create a competitive and sustainable local bio-ethanol market.

6.2 Establishing appropriate institutional framework

The first national alcohol program of Brazil (Proalcool I) was created by a decree with the aim of meeting the domestic and international market. In order to implement the Proalcool I program, it was determined to be implemented by an executive power. In addition different institutions like: IAA, CENAL, CNP, and a financing agent were created with specific task to accomplish (see part 3). The establishment of these institutions and the defined tasks they had to accomplish were one of the factors making the program successful.

In Ethiopia, it is said that there is strong government commitment and bio-ethanol production is given a priority development agenda to expand production and use of bio-ethanol (Melis, 2008, personal interview). As part of this commitment, a strategic document on bio-fuel development has been approved by council of minstrels in September 2007 and a forum, which is composed of different stakeholders' linked directly and indirectly and chaired by ministry of mines and energy, is created to implement the strategy. Compared with early development stage of Brazil, there is no decree, no executive power, and no specific task given to the forum and members of the forum in the Ethiopian bio-ethanol current initial stage.

The absence of assigning specific task to member organization to the forum and to the forum itself was especially mentioned as one of the barriers blocking the progress. Members do not know what they are supposed to accomplish and to deliver to the forum. Even the forum did not embrace all the important actors (for instance ministry of transport and communication was not a part) and thus could not progress as originally planned. Two deadlines that were set to be the starting date for using bio-ethanol were already missed. There is no guarantee a third one would be successful.

Therefore, establishing appropriate framework is one of the important lessons Ethiopia should learn. A target and defined tasks that can help to achieve the target needs to be identified. On the basis of these pre-defined tasks, appropriate institutions could be created. At the initial stage, it may be adequate to assign the existing structure in a productive way without the need to create a new one which can only be responsible for bio-ethanol. What is to be stressed are the specific tasks required to be accomplished, and the determinination of actors involved directly or indirectly with the program to participate, with a view to support the development program.

6.3 Providing Supportive Policies

The government of Brazil provided various policy supports to lift the bi-ethanol industry off the ground. Support mechanisms included a blending mandate, tax incentives, low interest borrowing option, and investment on research and development. Such institutional support offers some policy lessons to Ethiopia.

The policies that should be required to be enacted to bring rapid expansion of bio-ethanol and use need to be based on Ethiopia's condition, which means they should be according to its natural and economic context. These policies should also be focused on creating a predictable market, thereby attractring private developers which in turn draws capital, brings entrepreneurial creativity and competitiveness. Such conditions support the building of production and distribution infrastructure, advance technologies and enables learning experience to drive the cost down. Taking these facts into account, the following policy lessons (experience of Brazil) are important to consider for Ethiopia.

6.3.1 Blending quota (mandate)

One of the success factors of the Brazilian bio-ethanol development was the decision that the state owned oil company had to purchase a guaranteed amount of ethanol (see part 3.2) to blend with gasoline. This decision clearly had the ability to create a consistent and growing market for bio-ethanol and thus can be an important lesson to take to Ethiopia.

Ethiopia is now in the process of enacting a blending mandate, which is expected to mandate all fuel stations in Addis Ababa to sell 5% blend and subsequently to expand to other regions and to increase the percentage in the years to come (Melis, 2008, personal interview). If this proves true and proper enforcement mechanism is established, it will have equally (like the Brazilian case) the capacity to create long term market and to attract private sector investment in technology and infrastructure advancement. An enforcement mechanism is crucial to ensure the blending mandate is uniformly implemented throughout the fuel stations. Also the steady increase of the blending percentage encourages more developers to be attracted to the industry.

But the focus should not only be at increasing the production and use of bio-ethanol. As the production of bio-ethanol is associated with environmental and social aspects, the blending mandate should also be tied to address these aspects. It should also foresee to include the use of some percentage of bio-ethanol from second generation feedstocks in the long term.

6.3.2 Enacting incentive mechanisms

The different incentives provided by the Brazilian alcohol program were also among the factors for the success of the program. Provision of economic incentives for agro industrial enterprises of bio-ethanol producers by offering loans with low interest rate, making bio-ethanol attractive to consumers by selling with reduced price than gasoline, and the tax rate reduction for vehicles running by bio-ethanol blend were the important incentives mentioned in many places (Moreira and Goldemberg, 1999, UNICA, 2007, Goldemberg and etal, 2003 and Dufey, 2006 and etal). What is learnt here is that providing incentives encouraged the development of bio-ethanol and thus can be applied in Ethiopia on the basis of the country's unique situation.

There is no doubt that providing an incentive mechanism is a proven tool to support the development. It can also be a tool for Ethiopia to put in place incentives that stimulate the bio-ethanol production and use. Though the provision of appropriate incentives need to be enacted based on an in-depth study to reduce net cost or avoid an unfair market structure, providing soft loans to private investors and tax incentives for imported vehicles could be worthy of consideration.

Provision of low interest loans solves somehow the capital shortage of private investors wishing to enter into the industry. In addition it will help the oil distributing companies to implement the technical change of their fuel stations and trucks thereby reduce their systematic hindrance of the bio-ethanol development.

Provision of tax incentives for vehicles that can use more percentage of bio-ethanol blends will enable higher consumption of bio-ethanol. As has been shown, the forecast of the bio-ethanol production from the state owned sugar factories would reach around 40% of the gasoline requirement with in 5 years. Unless vehicles of modified engines that can utilize higher blends of bio-ethanol are imported, the bio-ethanol product quantity can not be consumed with vehicles of conventional engine. It may also be worth revising the current vehicle importation tax system that discourages new cars as the tax system is built on value. The current system encourages the importation of old cars, as a result huge amount of foreign currency is being spent for spare parts (Bazezew, 2008, personal interview). In addition, comparative to new vehicles, old cars consume more fuel per kilometer, hence attribute more to the foreign currency requirement required for gasoline and environmental pollution from the exhaust. Therefore, tax system that addresses these two issues could be important to look into. It is important to introduce an integrated policy packages not only serve to develop the production and use of bio-ethanol but also other means to reduce the consumption of fuel and increase efficiency.

6.3.3 Strategic guidance on research and development

One notable success factor for the Brazilian bio-ethanol development was the commitment and strategic guidance of the government on research and development (Elena, 2007).There was long term guidance on research and the knowledge created and its diffusion were based on broad research guidance, including the agricultural, energy and transport sector (Elena, 2007). This strategic guidance created strong public and private investment on research and development that enabled decisions to be taken based on the results of research and at the same time brought about improvements in production and infrastructure.

The strong research and development commitment exhibited in the Brazilian bio-ethanol development is one of the important lessons Ethiopia should replicate. There is virtually weak research and development work on bio-ethanol system and at the same time the development endeavor has weak link with universities and research institutes in Ethiopia. As was mentioned (see part 5.1), this was also one of the barriers identified that failed to find solutions for many of the questions raised by some actors in the supply chain. It also created a situation of delaines on preparing and putting in place some policies and guidance due to lack of information required as inputs, which had to come from research.

Therefore, government policy that encourages both public and private institutes to focus on the development of bio-ethanol needs to be formulated and implemented in Ethiopia. The government is best placed to address and guide long term research needs in the development. Long term research in turn needs continuous funding that support consistent research, development and demonstration in order to develop and diffuse the knowledge in system. It is also best suited to bring together the talents and resources in national research institutes and universities by coordinating public and private efforts. As the production and use of bio-ethanol involves multi sectors, the research and development needs to be worked in an integrated way from these cross sectors. For this, there have to be proper policies and guidance.

Research is the foundation to bring about sustainable feedstock management. It is the basis for improvement in harvesting, transportation, storing and processing of feedstocks, which are now being operated (in Fincha Sugar Factory for instance) in the same way as they were 8 years back when the plant started production, even in some cases the standard is declined (effluent treatment system). Had there been research and development work conducted, the methods and the performance would have been improved. Research is also a tool to better understand the potential barriers to the development and the environmental and societal impact of the production and use throughout the life cycle thereby develops improvement remedies, fills in the gaps in the existing data insufficiency, etc…

7 Conclusions

7.1 Key findings

This conclusion part summarizes the key findings of the research by responding to the research questions laid out in part 1 of the thesis.

What is the current status and future potential of bio-ethanol from molasses in Ethiopia?

Different firms and public bodies involve in the current bio-ethanol endeavour in Ethiopia. The production activity is entirely dominated by sugar factories. There are three sugar factories, Wonji-Shoa, Metehara and Fincha, engaged in sugar production, and the fourth, Tendaho, which will be the biggest in production capacity, is under construction. All the factories cultivate sugarcane for extraction of sugar and they produce or intend to produce bio-ethanol from molasses, the by-product obtained from the sugar extraction.

There is only one plant now, Fincha Sugar Factory, producing bio-ethanol in Ethiopia- the current production capacity stands at about 8 million litres per annum. The other factories are in the process of installing ethanol production units from molasses. In the next 5 years till 2013, they have planned to reach a production volume of 135 million litres.

Blending with gasoline is not yet started- it is expected to start soon in a percentage of 5% in the capital, and will be expanded subsequently to other regions. As the production is increased, the intention is to increase the percentage. Six oil distributing companies operate in distributing petroleum by receiving from the government enterprise (EPE), which is the only legally responsible body to purchase and import petroleum products in the country. The oil distributing companies, though unhappy mainly for economic reason, will be the ones which are expected to distribute blended gasoline.

Sugarcane is cultivated entirely for the production of sugar and only the by-product (molasses) is used for bio-ethanol production. There are around 4 million hectares of irrigable land available for multipurpose use. Of these, the area identified as suitable for sugarcane plantation are 700 000 ha and this can yield more than 1 billion litres of bio-ethanol per annum.

What are the barriers to and implications of the production and use of bio-ethanol?

a) Key barriers

A host of barriers are hindering the development of a local market for bio-ethanol as a transport fuel. The key barriers lie within economic and technical spheres, and some relate to public policies and regulations as well as knowledge and information.

Lack of economic incentives to the oil distributing companies is one notable blocking factor for the progress of bio-ethanol. Oil distributors incur additional expenses for upgrading fuel stations to deal with blending of gasoline. Absence of a low interest loan system or setting better margins to compensate and motivate the distributors holds back any significant progress.

Technical barriers relate to the uncertainties and higher technical risks involved in expanding into bio-ethanol rather than focusing only on conventional gasoline. Particularly the absence of clear direction on the product quality control system along the supply chain and the lack of sufficient local testing on the performance of the product (the blend) refrain the oil distributors to align themselves and cooperate fully towards bio-ethanol blending.

Policies and regulations are important tools to support bio-ethanol development by creating markets and future certainties. Their absence on the other hand, is a major hindrance to market development. Policies and regulation create demand and future predictability of the sector so that they are a pre-requisite for investors and developers. The absence of policies and regulation in the area of bio-ethanol in Ethiopia stagnates with the progress towards the use of bio-ethanol and expansion of production.

Lack of knowledge and adequate information on bio-ethanol in the country also contributes to the slow progress. In addition weak link with research institute and lack of research work means there is little information to support the formulation of bio-ethanol policies and regulations.

b) Key implications

The production and use of bio-ethanol from molasses in Ethiopia will have implications (both positive and negative). It is associated with economic, social and environmental benefits as well as social and environmental concerns.

Economical benefits from bio-ethanol production and use include: a) it creates a market for excess molasses generated as a by-product from sugar factories and b) it improves trade balance by providing foreign currency savings. Since the production cost of bio-ethanol is much less than the gasoline price, the savings potential by using bio-ethanol is high. In addition, it provides energy diversification and security benefits.

The main environmental implications of bio-ethanol production include water consumption, water pollution, land use and biodiversity, and energy balance and greenhouse gas emission. Bio-ethanol production consumes considerable water during feedstock cultivation and bio-ethanol distillation. The current water usage level both at the farm and industrial stage is high. It stands at the farm as about $109m^3$ of water per tone of sugar cane, during sugar extraction about $11.2m^3$ per tone of sugarcane and at bio-ethanol production about $0.13m^3$ per liter. In addition to high consumption of water, there is a high risk of water pollution due to high BOD and low pH content of the effluent. Due to the maintenance problem, effluents are released to the near by river only by dilution, the additional water being used for dilution exacerbates the water consumption level.

Another environmental concern is land use and biodiversity. Expansion of bio-ethanol requires the occupation of new land. Some areas will be obtained by displacing settlers and some by deforestation. As a result the expansion will have the potential to contribute to habitat loss and impact on biodiversity. Further study, however, can identify the exact magnitude of the consequence as it may have also a net positive impact as use of bio-ethanol reduces greenhouse gas emissions and thus reduces biodiversity loss. The use of agrochemicals also has an indirect negative impact on biodiversity. Particularly the rising trend exhibited in the use of such chemicals poses a risk to biodiversity.

Another environmental implication of production and use of bio-ethanol is the energy balance and emission of greenhouse gases in the entire life cycle. Due to the absence of prior research on the Ethiopian bio-ethanol development and lack of knowledge, information on these issues does not exist to accurately evaluate energy balance and greenhouse gas emissions.

Social implications related to bio-ethanol production and uses in Ethiopia include impact on food security, land rights to minimize displacement and employment creation. With respect to the impact on food security, theoretically the land and water requirement for bio-ethanol production does not appear to threaten or aggravate the food insecurity in Ethiopia, given the huge land and water availability. But in practice, this involves complex issues. Assumptions are made on data that may not be accurate, such as the suitability of the available land, and the location of the water to cultivate 4 million hectares of land. Therefore, here again further research is required to determine the real impact on food security.

The land tenure system in Ethiopia is tight in order to protect the poor from being displaced by investors for land requirement for new development-feedstock production for bio-ethanol also requires new land. The land ownership remains with the state and unless the land occupied by the rural landholders is required by the state itself for development purposes, no other force can displace the holders. The land holders can rent their holdings to investors without being threatened to be displaced. Thus, feedstock production expansion doesn't appear to threaten the poor with regard to loosing their land holdings.

The other social implication is employment creation. Bio-ethanol production can create direct and indirect employment. For example, the state owned sugar factories alone will create direct job opportunities for more than 102 000 workers (ESDA, 2008), most of them unskilled including rural women. In connection to job creation, the working conditions and health of the workers remains an issue that requires extensive study.

What lessons can be taken from Brazil to stimulate bio-ethanol development in Ethiopia?

Exploring the Brazilian experience is chosen due to its success in bio-ethanol production and use. Moreover, both Ethiopia and Brazil use sugarcane as feedstocks and they are suitably situated geographically for growing sugarcane. Thus, there are lots of experiences that are valuable to Ethiopia. The key ones which are found relevant are the state intervention, establishing appropriate institutional frameworks and enacting supportive policies.

Dominant state interventions at the beginning of the development stage were important to bio-ethanol production in Brazil. What needs to be learnt here and applied to the Ethiopian bio-ethanol development is that intervention should not continue forever. It should be for a short period of time since such activities of state monopolistic production and market control will be inefficient without the force of competition. For the medium and long term, a level playing field should be facilitated for competition. Thus, any intervention at this stage needs to aim to bring a system that is determined by market force and business deals at a later stage

Establishing appropriate institutional frameworks with defined tasks was one of the ingredients in the Brazilian success. Likewise, establishing appropriate frameworks is one of the important lessons for Ethiopia. A target and defined tasks that can help to achieve the target needs to be identified. On the basis of these pre-defined tasks, appropriate implementing institution needs to be created.

Supportive policies played a crucial role in the bio-ethanol development of Brazil. Likewise, Ethiopia needs to enact policies that can help develop bio-ethanol production and use sustainably on the basis of its unique context. Overarching policies needs to be enacted based on thorough studies that include blending mandate, economic incentives, and strategic direction on research and development.

Enacting a blending mandate will have the capacity to create long term markets and to attract private sector investments in technology and infrastructure advancement. Particularly if a blending mandate is attached with social and environmental concerns. It can therefore promote sustainable bio-ethanol development.

Enacting incentive mechanisms will have the tendency to stimulate the bio-ethanol development. Providing soft loans to private investors and tax incentives for imported vehicles are two incentive mechanisms suggested. Provision of low interest loans solves the capital shortage of private investors wishing to enter into the industry. In addition it will help the oil distributing companies to implement the technical change of their fuel stations and trucks thereby reduce their systematic hindrance of bio-ethanol development.

Provision of tax incentives for vehicles that can use higher percentages of bio-ethanol blends will enable higher consumption of bio-ethanol. Unless vehicles of modified engines that can utilize higher blends of bio-ethanol are imported, the bio-ethanol product quantity the country envisaged to produce would not be consumed with vehicles with conventional engines.

Another important lesson that Ethiopia should learn and apply is the strategic guidance on the state level on long term research and development. Policy that directs both public and private institutes to focus on long term research needs to be enacted. Continuous research and development are important to develop and diffuse knowledge. At the same time, they are the basis for finding answers to questions raised and information needed as input for policy formulation. Research and development is the key to investigate the many social and environmental issues that are not yet answered, like energy balances, net greenhouse gasses emissions, impact on food security etc…

7.2 Main recommendations

In part 4, 5 and 6 of this thesis an attempt was made to answer the research questions. This being the main task, the author would also like to supplement some issues that are of significance to the case under study.

The first one is the need to increase awareness among local developers. Though bio-ethanol demand and the involvement of developers are globally increasing, the interest of local private investors in Ethiopia is minimal. One reason for this is the low level of market awareness. Thus, creation of awareness is one tool to promote bio-ethanol development in Ethiopia.

The second one is capacity building. There are deficiencies both in financial capacity and technical capability in bio-energy in general. Therefore, experience sharing with foreign countries that have the necessary know-how needs to be facilitated. Finding foreign partners to engage in the sector as joint ventures is also one solution to overcome the capital shortage.

The third one is to ensure enforcement and implementation of policies. In some cases, policies that are in place are simply by-passed. For example, the pollution prevention and control law stipulates an EIA is a pre-requisite for every prospective project. But, this has not always been performed. Such instances undermine the impacts associated with bio-ethanol development.

The fourth one is the need to land demarcation and zoning for bio-ethanol feedstock growing sites. Ethiopia has a total land mass of 1.1 million square kilometres, of which 66% is said to be suitable for agricultural cultivation -most of that area is located in the lowlands where the temperature is high. As a result these areas are sparsely populated. Using these parts of the land for feedstock cultivation reduces the land competition with food crops. But absence of inventories of land and classification risks real crop growing areas to be issued for feedstock production. The current allocation of land without guidelines may adversely affect capacity of Ethiopia for growing food crops. Hence, an inventory of land including zoning of feedstock growing areas should be undertaken.

The fifth one is the need to exert more pressure on oil companies. Though they are generally supportive in their stance, they find issues that delay the introduction of bio-ethanol. Thus, in order to diffuse bio-ethanol into the market, mechanisms are needed to make them realistically cooperate and truly act towards diffusion of biofuels.

7.3 Future research

In the opinion of the author, there are a number of areas this study could not investigate sufficiently due to lack of data. These areas require further research.

The first one is the direct and indirect impact of bio-ethanol development on food security. As this involves complex issues to consider, this research could not come up with clear cut answer. Is the available land suitable to cultivating crop? Can the surface water resource really cultivate 3.7 million hectares? What is the impact of taking 700,000 hectares for sugarcane? What is the potential of sugarcane cultivation to attract individual farmers? Questions of these kind need to be explored sufficiently to determine the impact of bio-ethanol development on food security.

The second is the energy balance and the net greenhouse gas emissions of bio-ethanol. There has not been any attempt to determine these aspects due to virtually no reliable data. Hence, no information is available to judge the Ethiopian bio-ethanol energy balance and net greenhouse gas emissions. This is an area of research that requires immediate attention to ensure that any development of biofuels is done in a sustainable way.

The third area is the health impact of sugarcane cultivation. The plantations are located in malarias area and people working there are prone to malaria. In addition sugarcane burning is the normal practice during sugarcane harvest. Such working conditions would not be free from incidents that threaten the health of the workers. Due to the absence of prior studies on the issue, more information could not be provided here. Thus, the author finds the topic an important sustainability aspect from a social point of view.

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Abbreviations

ADLI	Agricultural Development Led Industrialization
BIRR	Ethiopian Currency
CDM	Clean Development Mechanism
CENAL	National Alcohol Executive Commission
CNP	National Oil Council
CSA	Central Statistics Authority
DAP	Di -Ammonium Sulphate
DSD	Deutch Sustainable Development
EARO	Ethiopian Agricultural Research Organization
EC	Ethiopian Calendar
EEA	Ethiopian Economics Association
EEPCO	Ethiopian Electric and Power Corporation
EIA	Ethiopian Investment Authority /Environmental Impact Assessment
EPAE	Environmental Authority of Ethiopia
EPE	Ethiopian Petroleum Enterprise
ESDA	Ethiopian Sugar Development Agency
ETB	Ethiopian Birr
ETCA	Ethiopian Transport and Communication Authority
EU	European Union
FFV	Flexible Fuel Vehicles
IAA	Sugar and Alcohol Institute
IEA	International Energy Agency
MME	Ministry of Mines and Energy
MOARD	Ministry of Agriculture and Rural Development
MOTI	Ministry of Trade and Industry
MSW	Municipal Solid Waste
NBE	National Bank of Ethiopia
NGO	Non Governmental Organization
NOC	National Petroleum Company
QSAE	Quality and Standard Authority of Ethiopia
RTA	Road and Transport Authority
UN	United Nation
UNICA	Sugarcane Industry Union
USD	United States Dollar
WWI	World Watch Institute

Appendixes

Appendix I –Quality standard for bio-ethanol, gasoline and 10% blend

Table 0-1: Requirement for fuel bio-ethanol

No	Characteristics	Requirements	
		Minimum	Maximum
1	Water content (%)	-	1.25
2	Solvent-washed content (mg/100ml)	-	5
3	Chloride ion content, mass ppm (mg/l)	-	40 (32)
4	Copper content, mg/kg	-	0.1
5	Acidity (as acetic acid CH_3COOH), mass % (mg/100ml)	-	0.0075 (5.53
6	Appearance	Visibility free of suspended or precipitated contaminants (clear and bright)	
7	Density in g/ml at 15.56^{0}c	0.7937-0.7977	
8	Ethanol purity of fuel ethanol excluding water, ethanol (C_2H_5OH), V/V %	99.5	-
9	Methanol or total aldehydes or both, V %	-	0.5

Source: QSAE, 2008

Table 0-2: Requirement for gasoline

No	Characteristics	Requirements	
		Premium	Regular
1	Octane rating a) Research octane number (RON), min	95	91
	b) Motor Octane number (MON), min	85	81
2	colour	red	Orange/yellow
3	Density at 20 ^{0}C, g/ml	0.705-0.740	
4	Distillation Temperature, ^{0}C 10% (by Volume) evaporated, max 50% (by Volume) evaporated, max 90% (by Volume) evaporated, max Final boiling points, ^{o}C, max Residues, % (by volume), max.	 70 77-121 190 225 2.0	
5	Reid Vapor Pressure (RVP),Kpa, max	69	
6	Lead Content, pb/l	0.013	
7	Oxidation stability induction period, minutes, min.	240	
8	Existent gum contents, mg/100ml, max	4	
9	Sulphur content, % (by mass), max	0.10	
10	Copper strip corrosion (3h at 50 ^{0}C), max	1	

Source: QSAE, 2008

Table 0-3: Requirement for gasoline-bio-ethanol blend

No	Characteristics	Requirements	
		Premium	Regular
1	Octane rating a) Research octane number (RON), min	95	91
	b) Motor Octane number (MON), min	87	83
2	colour	red	Orange/yellow
3	Density at 20 ^{0}C, g/ml	0.710-0.785	
4	Distillation Temperature, ^{0}C for 10% (by Volume) evaporated, max 50% (by Volume) evaporated, max 90% (by Volume) evaporated, max Final boiling points, ^{c}o, max Residues, % (by volume), max.	 70 77-121 190 225 2.0	
5	Reid Vapor Pressure (RVP),Kpa, max	70	
6	Lead Content, pub/l	0.013	
7	Oxidation stability induction period, minutes, min.	240	
8	Existent gué contents, mg/100ml, max	4	
9	Sulphur content, % (by mass), max	0.10	
10	Copper strip corrosion (3h at 50 ^{0}C), max	1	
11	Total acidity, mg KOH/g, max	0.03	

Source: QSAE, 2008

Appendix II: Private vehicle owners responses on the use of Blend

Question: What is your opinion on the use of ethanol-gasoline blend use[45] ? Very soon the fuel stations will start distributing only 5% blend, first in Addis then in other regions.	
Respondents	Short form of the Responses
1	As long as possible, I will try to get from regions, when it becomes impossible, I will sell my petrol vehicle and buy diesel driven. I am not happy to use blend of gasoline since no one will be responsible if my car gets stacked
2	As long as the decision is going to be obligatory, I will not have other choice. I must use it, but I will not be the first one.
3	I know such fuel type is available in different countries. I will use it. But price discount should be given since ethanol is local product, which I think is produced cheaper than gasoline and being local product avoids transport and import taxes. Also commented on local test to be made and make the supply sustainable once started
4	I will use only when I will not have other choices
5	My expectation was to start ration system like we had earlier. If there is local substitute, it should be encouraged. But test should be conducted first.

[45] More explanations were given to respondents as most of them didn't know the government direction, and what blend of bio-ethanol and gasoline is.

6	The existence of local substitute should be promoted. I am happy if it starts now. Due to petrol price, the prices of all items are going up. Why it has been delayed if there were such alternative. Local test and advertisement should be needed.
7	I was very exhausted about fuel price. Every time we are told the price goes up by this amount. I was questioning myself when are we going to explore our reserves[46] and utilize it to relief from this bad news of petrol price hike. If there is this option, why not. I will use it. But once started, the supply should be sustainable.
8	I will decide when the issue become real. All talking points will not be realistic. I may say no and start using later though from the question there will be no choice or vice versa. But it is good to know first the local test result
9	This will not happen in Ethiopia. But if it happens and I confirm the blend will not bring any problem I may use. If people talk about something, either it will not realize at all, or takes years to realize or it will be realized and then it diminishes like K-50[47].
10	If it is obligatory, what option would I have except using? But I need local demonstration first
11	I will decide when it is real.

Appendix III- Tariff rate and service charge for power consumption in Ethiopia

Table 0-4: Tariff rate and service charge for power consumption in Ethiopia

No	**Sales price**			**Service charge**		
	Tariff category & Block ID	Monthly Consumption (KWH)	Rate (Birr/Kwh)	Tariff Name	Monthly Consumption (KWH)	Rate (Birr/ Month)
1	Domestic					
	First Block	01-50	0.2730	Single Phase (220 V)	0-25	
	Second Block	51-100	0.3564		26-50	
	Third Block	101-200	0.4993		51-105	
	Fourth Block	201-300	0.5500		106-300	
	Fifth Block	301-400	0.5666		> 300	
	Sixth Block	401-500	0.5880	Three Phase (380 V)	Monthly	17.056
	Seventh Block	Above 500	0.6943			
2	General Sector (Commercial)					
	First Block	01-50	0.6088	Single Phase	Monthly	14.494
	Second Block	> 50	0.6943	Three Phase	Monthly	22.558
				Active/Reactive (380 V)	Monthly	35.258

Source http//: www.eepco.gov.et [2008, July 2]

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[46] Though not confirmed, people in Ethiopia talk about the availability of petroleum reserve in the country

[47] K-50 was 50% kerosene and 50% bio-ethanol. In the past it was started to be distributed for coking fuel. But later it has been stopped.

Appendix IV: Literature findings on technical barriers

Effect of altitude on the use of blended gasoline:

The initial start up to use blend of gasoline will be expected to take place in Addis Ababa, which is situated at 2500 above sea level. The effect of this high altitude is mainly to decrease the oxygen content of air and to lessen the atmospheric pressure (SAFRECO, 1985). And at lower pressure, the blend will have a higher tendency to distillate (a phenomenon of more products to vaporize at the same temperature) [48] ; this distillation induces higher risk of a 'vapour lock' formation in the engine's piping. As this risk increases with the content of bio-ethanol in the blend, the best way of taking the effect of altitude into consideration is to start the blend with minimum blend ratio (SAFRECO, 1985). For this the direction to start the blend at 5% would be a good experience and arrest the concern of altitude on the use of blended gasoline.

Effect of use of blended gasoline on the age of car:

It is true that most of the vehicles in Ethiopia are old due to affordability and the *existing tax system which levies heavy custom duties on new cars* [49]thereby discourages importation of new vehicles. However, as far as the use of blended gasoline is concerned, the age of car by itself is not a problem. The problem could be, as many literatures indicate, (IAE, 2004, Dominik Rutz and Rainer Janssen, 2008 and etal) some old automobiles are equipped with rubber gaskets, pump rubbers or even rubber floats in fuel tanks (for the most ancient of them) and that rubber is attacked progressively by the bio-ethanol. Unless it is said that the replacement cost will be higher, the solution would be when the old rubber component are out of use, to replace them by plastic spares or other suitable materials like fibre spares , which can resolve the concern at stake.

Mileage concern

The concern of less mileage in case of usage of blended gasoline has been mentioned often for which the expectation of some compensation mechanism to bring to the equivalent mileage coverage of pure gasoline (unblended unleaded gasoline). Most actors don't even know the mileage test conducted locally though some raised the validity of the test in terms of adequacy and independency.

The theoretical explanation generally given for a possible shorter mileage when blended gasoline is used instead of gasoline alone is that ethanol contains less energy per litter than gasoline. The following table shows the important properties of bio-ethanol and gasoline.

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[48] http://www.nmma.org/lib/docs/nmma/gr/environmental/ethanol-report.pdf

[49] Custom duty 35% and Excise tax in the range of 30 to 100%. 30 % up to 1300c.c, 60% for 1301 to 1800 c.c and 100% above 1800c.c (EIA, 2007)

Table 0-5 Properties of gasoline and Bio-ethanol

	Flash-point (⁰c)	Calorific value(at 20⁰c in MJ/Kg)	Calorific value(MJ/l)	Heat content (kcal/l)	Heat content (kcal/kg)	Octane Number (RON)[50]	Fuel equivalence (L)
Gasoline	< 21	42.7	32.45	7,789	10,248	92	1
Bio-ethanol	< 21	26.8	21.17	5,059	6,364	100	0.65

Source: Adapted from Dominik Rutz & Rainer Janssen, 2008

The heat content of ethanol is about 5,059kcal/l (6,364 kcal/kg) and that of gasoline is about 7,789 kcal/l (10,248 kcal/kg); thus the calorific value per liter of pure bio-ethanol is roughly 35% lower than that of average gasoline, resulting in a liter of 10% blend for instance will contain about 3.8% less energy than a liter of gasoline. Therefore, if all other factors were equal, it is thought that this would result in 3.8 % lower mileage, or 1.9% less mileage for 5% blend. Nonetheless as the engines of vehicles using the bio-ethanol-gasoline blend are internal combustions, the real factor which should be taken into consideration is not only the heat content, but also a factor which is not well defined and which is bound to the explosive power of the fuel. In US for example, an experiment has been investigated and the result was as tabulated below.

Table 0-6 Mileage test result for gasoline and bio-ethanol blended gasoline

Type of fuel type	Type of Vehicle and miles travel per gallon			Average Mileage (Miles/gallon)	% of average reduction in mileage
	2005 –Chevrolet Impala 3.4L	2005- Toyota Camry 4 cyl	2005 Ford Taurus 3.0L		
Gasoline	27.714	31.455	24.810	27.993	
E10	27.426	31.464	23.851	27.580	1.5
E20	27.406	30.116	24.635	27.386	2.2
E30	27.894	28.275	23.527	26.565	5.1

Source: http://www.ethanol.org/pdf/contentmgmt/ACEFuelEconomyStudy_001.pdf [last visited on 21/07/08]

The table shows that E10 (10 % bio-ethanol-90% gasoline) resulted in lowering of 1.5% mileage on average compared to gasoline, which is less than the result from the use of considerations related only to the heat content. Thus the value of pure bio-ethanol actually is more than 65% of gasoline equivalent. The mileage to be obtained by using blended gasoline is almost the same as that obtained by using gasoline. This can also be verified in the local condition by setting a committee composed of relevant government and private organization representatives so that the result will determine how the compensation should be set out if the variation is considerable.

[50] Octane Number characterizes a fuel's resistance to knocking, which is described as the uncontrolled combustion which puts heavy mechanical and thermal loads on the engine.The product which is tested is compared to two pure hydrocarbons chosen as references: respectively isooctane, which is very resisting to self-firing and to which the Octane number 100 is attributed, and heptane, little resistance, which reserves the octane number 0. A fuel presents an Octane number X if it behaves like a mixure of X% isoocatane and (100-X)% heptane. Several Octane numbers exist depending on the experimental conditions. The most usual one is the RON (Research Octane Number), which gives a general valuation of the resistance to knocking (Dominik Rutz & Rainer Janssen, 2008, SOFRECO, 1985 and etal)