# PROJECT REPORT

On

# Prospects and Challenges of Bio Ethanol Production from Molasses in the Ethiopian Sugar Industry

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# CHAPTER ONE

## 2. INTRODUCTION

### 2.1. *Research Problem*

Production and use of bio-fuels for transport fuel has recently attracted significant attention worldwide. This ismainly due to the escalation of petroleum prices coupled with a shortage of foreign currency reserves andtheir reduced carbon emissions compared with fossil fuels. These factors and the increasingenergy demand for transportation to keep the pace of economic development are alertingmany countries, including Ethiopia, to find alternative energy sources for their security of energy supply.

In order to ensure Ethiopia's continued development program and the national fuel security, it is important to increase the production and utilization of renewable fuels. Substituting the demand for fossil fuel by locally produced fuels such as bio-ethanol and bio-diesel is paramount importance for the country's economic use of scarce energy resources. The Ethiopian bio-fuel development and utilization strategy has been designed based on this broad objective (Ministry of Water & Energy, 2010).

To realize the above strategic objective, the country is pursuing bio-ethanol development program. The Ethiopian Sugar Industry is responsible for the implementation of this strategic objective by producing bio-ethanol from molasses. In this regard, the gross available potential land for sugarcane plantation to be used as feedstock for sugar extraction andeventually for bio-ethanolproduction from molasses is about 700,000 hectares, which offers a potential to produce above 1 billionliters of bio ethanol (Ministry of Water & Energy, 2010).

The production and use of bio-fuels has been justified by high oil prices, geo-political instability in those countries that hold most of the proven oil reserves as well as environmental concerns such as climate change or the improvement of air quality in metropolitan areas (Hazell and Pachauri, 2006). Bio-fuels production and use also poses challenges and risks including potential land use conflicts, environmental degradation risks, heightened concerns about food security and water conservation.

According to the bio-fuel development strategic plan of the country, up to the end of the fiscal year 2014/2015, the total bio-ethanol production and supply will reach 181.6 million liters (Ministry of Water & Energy, 2010). This volume of production and supply will be by far over and above the volume of demand for transport fuel ethanol requirement. The strategic plan for bio-ethanol development stated that the current proportion of the blend (10% ethanol and 90% gasoline) will gradually increase up to 25% ethanol and 75% gasoline up to 2015. In addition, the strategy indicated that the excess supply of bio-ethanol would be used for household energy consumption in replacement of kerosene (Ibid).

However, given the current status of the composition of gasoline vehicles that consume this blend; technically the proportion of ethanol to gasoline cannot go beyond 10% (Manaye, July 13, 2011 personal interview). 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).In addition, IEA (International Energy Agency) restricted that beyond 10% bio-ethanol content on gasoline cannot be used in all models of gasoline vehicles across the board (IEA, 2009). On the other hand, although starting from the fiscal year just passed (2010/2011) the production of bio-ethanol is in excess of the demand and the efforts to use bio-ethanol for households' energy consumption is not likely to materialize in the near future.

Unless there are other alternative ways of use to optimize bio ethanol consumption, it will be a challenge for the sugar industry in particular and of the economy of the country in general. This project aims to assess the current status and future potential of bio-ethanol production; identify the composition of gasoline vehicles and what measures require from the government to increase bio-ethanol usage for transport fuel above 10% and recommend other alternative uses apart from transport.

## 2.2. **Objectives of the Project**

The general objective of this project is to encourage the development of bio ethanol in Ethiopia and increase its alternative usage to improve the energy security of the country.

Under the above broad objective, the specific research objectives of this project include:

a. To identify and analyze the status of the supply chain and the potential of fuel ethanol production from the Ethiopian Sugar Industry; examine the amount of bio-ethanol required for blending with gasoline for use as transport fuel and determine the excess supply and propose other ways of use for the country's energy requirement.
b. To analyze the current composition of gasoline vehicles and propose measures on policy changes that will support the increased use of bio ethanol blend with gasoline for transport fuel.
**c.** To examine and identify the potential contribution in terms of foreign exchange savings to the country.

## 2.3. Research Questions

In order to fulfill the aforementioned objectives, there are questions thisproject work poses. These include:

a. What is the current status and future potential of bio-ethanol production from molasses in the Ethiopian Sugar Industry? How much is the requirement for bio-ethanol to be blended with gasoline for transport fuel?

b. How the composition of gasoline vehiclesis and what policy measures are required that can help to increase the blend of ethanol with gasoline above 10%?

c. What are other possible uses of the bio-ethanol apart from transport fuel?

## 2.4. Research Methodology

The project work was conducted using a combination of descriptive and quantitative methods.The research utilized descriptive techniques in analyzing the issues and research questions that have been raised. The data collection methodology employed included both primary and secondary data sources.

### Primary data

Primary data was collected through interviews, as well as observations and discussion with informant groups.

### Sampling Technique

The sampling technique that was used to gather the data will be purposive sampling technique. It is particularly useful in identifying and contacting key stakeholders in the various organizations that directly or indirectly involve in the production and consumption of bio ethanol.

## Interviews

Primary data was collected through formal interviews of various actors and experts (50 selected people list attached in appendix I) whoinvolve directly or indirectly in bio-ethanol production and use. The interviewees were mainlyselected by contacting first the national bio-fuel forum coordinator, Ministry of Mines andEnergy and then from respondents. In order to get an opportunity to supplement questions, ifnecessary, and allow the author to adjust questions, semi-structured open ended interview wasconducted. This method allowed having a good interpersonal interaction, supplementaryquestions to be added in instances where the author needed more information. Moreover, itallowed clarifying confusing questions.

The interview with the various stakeholders allowed the author to obtain their viewpoints onthe study topics. At times different views were presented on the topic and thus the samequestions were discussed with various informants applying triangulation to reveal facts. Beforeeach interview, the author designed a goal and in most of the interviews asked the informantsto 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. Thenames of the 50 people, organizations they work for and the date interviewed are shown in thebibliography section.

a) Ministry of Water and Energy (MWE)

b) Ethiopian National Biofuel Coordination Office (NBCO)

c) Ministry of Agriculture and Rural Development (MOARD)

d) Ethiopian Sugar Corporation (ESC)

e) Metehara Sugar Factory

f) Fincha Sugar Factory

g) MonjiShewa Sugar Factory

h) Tendaho Sugar Factory

i) Ethiopian Environmental Protection Authority (EPA)

j) Ethiopian Quality and Standard Authority (EQSA)

k) Forum for Environment

l) Ethiopian Investment Authority (EIA)

m) Ethiopian Agricultural Research Organization (EARO)

n) Ethiopian Petroleum Enterprise (EPE)

o) Ethiopian Transport and Communication Authority (ETCA)

p) Nile Petroleum

q) Yetebaberut petroleum

r) National Oil Company (NOC)

### Observations

Data was also collected using direct observation. In order to get the real picture of sugarcaneplantation and sugar and bio-ethanol production, site visit was paid by the author and stayedtwo days at the Metehara Sugar Factory. The site visit was important to observe the farm as wellas 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 viewpoints of individual as well as to collect more information. Discussion with Metehara Sugarfactory was held to know more about the effluent treatment practice. Informal discussion was also held with departments of Ministry of agriculture and ruraldevelopment to clarify the status of policies and their implications to bio-ethanol production.

### Secondary Data

Secondary data was also collected by consulting and reviewing different official documentations of government organizations that will directly and indirectly be influenced by the research project. In this regard, strategic plans, productionand consumption data, import forecasts, project documents, and literature review on world productiontrend of bio-ethanol was collected and used for analysis.

### Data Analysis and Interpretation

The data collected was summarized and analyzed using tables and graphs.  Based on the analysis interpretation of the results was described which became the basis for conclusions and recommendations. The findings were summarized in descriptive method.

## 2.5. Scope and Limitations

This project work covers a wide perspective on bio-ethanol that goes across several sectors andincludes many actors involved in the system. The author believes such coverage providesgreater understanding of the bio-ethanol development status and the connection with therelevant sectors and actors.

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 themain focus. As the goal of the project work is to help the country to develop a sustainable bioethanolmarket, the scope is narrowed down to identification, development analysis of bio-ethanol production and encourages its alternative uses.

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

This project is not without limitation that the author would like to acknowledge. The firstlimitation is the wide scope of the study. Analyzing the whole value chain of bio-ethanoldevelopment and analyzing its efficient alternative use. It needs multidisciplinary approach thatrequires inputs from different disciplines. As a result, the study may have limitations toencompass some important issues at depth and to satisfy experts in the specific discipline.

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

## 2.6. Structure of the Project Work

The structure of this project work begins with an introduction where among other things the researchproblem, the objective, the research questions, the methodology and the framework foranalysis are addressed. Then chapter 2 deals with the theoretical background. It serves themain basis for discussion of the key prospects and challengesassociated with the Ethiopianbio-ethanol development. In order to facilitate the identification, analysis and discussion in theprocess of the research, this second chapter provides background information consisting oftwo sections.

The first section indicates general description about bio-ethanol that includes why it has beenchosen to be used for transport fuel, what feedstocks are available for it, how it can beproduced 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 thebarriers and sustainability issues at global level as well as policies enacted by different countriesto promote bio-ethanol. This section is believed to give background information to the project workdescribing what are known in the field. It shares the known facts of other studies that areclosely related to this study. Moreover, local production and use of bio-ethanol isstrongly linked with what is happening at the global level and indicating the trend in the globallevel would give what direction and requirement should the local development take and fulfillrespectively.

The second section of the background chapter will describe about three sectors in Ethiopia onthe basis of the first section. They are main sectors that would have influence or be influencedby the bio-ethanol program that include: agriculture, energy and transport. There are of courseother sectors that could be influenced as sectors are interlinked. But these three sectors aredirectly linked to the bio-ethanol development and are important examining them in thecountry in order to determine to what extent the bio-ethanol development would affect(positively or negatively) the present configuration.

For the analysis of the Ethiopian bio-ethanol setting, which is presented in chapter 3, the twosections of the background information are jointly used as input. For the analysis, aninnovation system approach framework for technology development and diffusion is utilized. The framework is used to identify the structural component(actors, networks and institutions) of the bio-ethanol development in Ethiopia and to assessthe current status and future potential of actors.

Following the analysis, key findings and main recommendations are discussed in Chapter 4. They arederived from the analysis. The identification of prospects and challenges are done in twosteps. First the theoretical explanations are formulated in the background part. Then they arechecked through interview and observation. The discussion is followed by key findings and recommendations for overcoming the challenges and redevelops sustainable alternative uses in the domestic market.

## 2.7. Relevance of the Project Work

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

*For policy makers*: it provides a clue on policy options that could be considered toadopt in Ethiopia context to support the bio-ethanol development. The challenges and themeans to overcome them and the social and environmental concerns highlighted in the studycould also provide important inputs for policy makers to make interventions for sustainabledomestic bio-ethanol market.

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

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

*For industry actors*: The implication of bio-ethanol is not well understood in Ethiopia. Thisstudy tries to indicate implications associated with bio-ethanol expanded production. Knowingthese issues would enable industry actors to consider them in their action and when they setup new facilities thereby available data could be captured, analyzed and improvementachieved.

# CHAPTER TWO

## 3. BACKGROUND ON BIO-ETHANOL AND ETHIOPIA

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

### 3.1. Bio-Ethanol Main Issues

Biofuels have attracted global attention due to concerns on climate change, energy securityand dependency and import burden of petroleum products. They are increasingly consideredby many countries as much as feasible to substitute the fossil fuel source in the transportsector.

Currently bio-ethanol and biodiesel, sometimes referred them as first generationbiofuels, are the most important ones as both can be used blended or in neat form althoughneat usage requires engine modification (IAE, 2004). Biodiesel is blended with petroleumbased diesel whereas bio-ethanol is blended with gasoline. Biodiesel is derived from oil cropslike rapeseed, palm-oil, jatropha, sunflower, and soy while bio-ethanol is based on starch cropslike sugarcane, sugar-beats, corn, wheat and sorghum (Dufey, 2006). Since the focus of thestudy is on bio-ethanol the following section presents background information exclusively onbio-ethanol.

## 3.2. Bio Ethanol Background

There is semantic confusion with regard to the term bio-ethanol. Very often the term is used as a synonym for alcoholic beverages. This is misleading, even though ethanol may be used as a raw material for the production of spirits. Bio-ethanol is a clear, colorless, flammable oxygenated hydrocarbon, with the chemical formula $C_2 H_5 OH$(Berg, 2004). Even though the definition is fairly straightforward, there are various categories for describing a particular type of ethyl alcohol which are not mutually exclusive:

- by feedstock
- by composition
- by end use

The feedstock and therefore the processes by which bio-ethanol can be produced are diverse. Synthetic alcohol may be derived from crude oil or gas and coal. Agricultural alcohol may be distilled from grains, molasses, fruit, sugar cane juice, cellulose and numerous other sources. Products, fermentation and synthetic alcohol are chemically identical(Breg, 2004).

Synthetic alcohol is concentrated in the hands of a couple of mostly multi-national companies such as Sasol with operations in South Africa and Germany, SADAF of Saudi Arabia, a 50:50 joint venture between Shell of the UK and Netherlands and the Saudi Arabian Basic Industries Corporation, and BP of the UK as well as Equistar in the US (Berg, 2004).

Another distinction which is of importance in the field of ethanol is the one between anhydrous and hydrous alcohol. Anhydrous alcohol is free of water and at least 99% pure. This ethanol may be used in fuel blends. Hydrous alcohol on the other hand contains some water and usually has a purity of 96%. In Brazil, this ethanol is being used as a 100% gasoline substitute in cars with dedicated engines. The distinction between anhydrous and hydrous alcohol is of relevance not only in the fuel sector but may be regarded as the basic quality distinction in the bio-ethanol market share (Berg, 2004).

The final distinction which is necessary in order to understand the dynamics of the world ethanol market is by end-use. Certainly the oldest form of use of alcohol is that of a beverage. The most important market for bio-ethanol as an industrial application is solvents. Solvents are primarily utilized in the production of paints and coatings, pharmaceuticals, adhesives inks and other products. Bio-ethanol represents one of the most important oxygenated solvents in this category. Production and consumption is concentrated in the industrialized countries in Northern America, Europe and Asia. It is the only market where synthetic ethanol producers hold a significant market share (Berg, 2004).

The last usage category is fuel alcohol. As mentioned before, fuel alcohol is either used in blends, for example in gasohol or diesohol, or in its pure form. However, at present Brazil is the only country that uses ethanol as a 100% substitute for gasoline (IEA, 2010).

## 3.3. Why Bio-ethanol use for Transport

Bio-ethanol is a liquid obtained by distillation of fermented sugar. It has become preferentialbecause 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 andherbaceous crops and dedicated starchy crops (Rutz D. and JansseR..2008). It offers anumber of benefits that includes: high *octane*and high heat of vaporization that allow it toachieve higher engine efficiency. Its use reduces ozone and smog formation compared withthe conventional gasoline due to its low volatility and photochemical reactivity (Dufey, 2006).

Its blended use reduce fossil fuel consumption and provide oxygen to promote morecomplete combustion that results less exhaust emission of carbon monoxide and unburnedhydrocarbon (Wyman, 1996). In addition to using the existing petroleum infrastructure, bioethanolcan be blended with gasoline in any proportion up to 10 per cent without the need forengine modification (IAE, 2004). Blends of 5 percent or 10 percent of bio-ethanol in gasolineare denominated as B5 and B10, respectively (Dufey, 2006). In some cases they aredenominated as E5 for 5% bio-ethanol blend (5% Bio-ethanol and 95% gasoline) and E10 for10% (10% bio-ethanol and 90% gasoline) (Dufey, 2006).

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

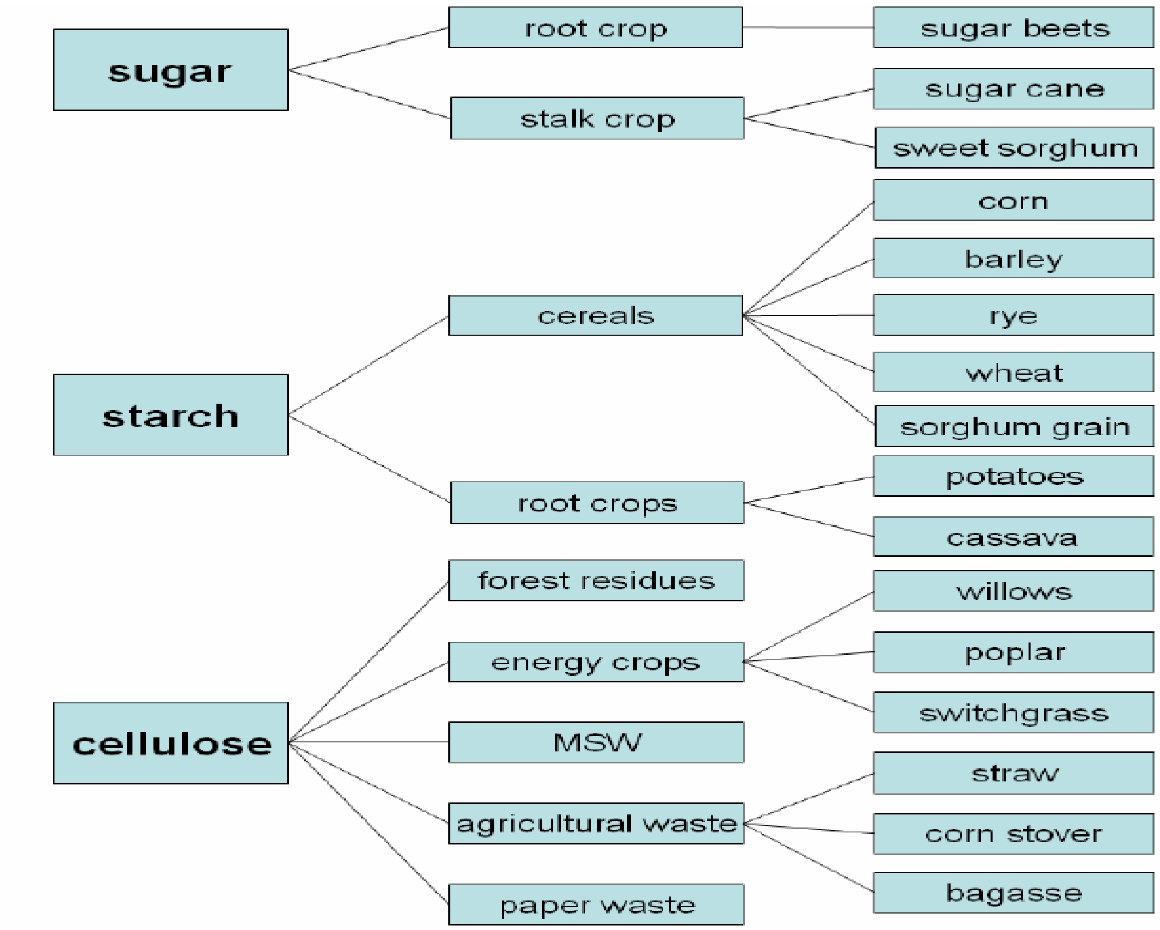
Other considerations behind bio-ethanol market development include the promotion ofgreater energy security, rural development, and poverty reduction (Dufey, 2007).

## 3.4. **Feed Stock Production**

Different feedstock are available for producing bio-ethanol as it can be derived from anybiological raw-materials that contain sugar or materials that can be converted into sugar fromstarch or cellulose(Dufey, 2006). For instance, sugarcane and beats are feedstock types thatcontain sugar whereas corn, wheat, and other cereals contain starch (Rutz D. and Jansse R.2008).

On the next page figure 2-1 shows the different feed stocks that can be used to produce bio-ethanol.

*Figure 2-1 Types of feedstocks for bio-ethanol production*




*Source: Rutz D. and Jansse, R. 2008*

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

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

Generally, the feedstock's are converted to bio-ethanol by acid or enzyme based approach. 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 bioethanolby adding yeasts, bacteria or other suitable organisms and then the bio-ethanol isseparated by distillation.

The next generation feedstocks comprise cellulose rich organic materialsthat include biomasssuch as wood, tall grasses and crop residues (IEA, 2004), which are harvested for their totalbiomass. 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 feedstocks under thenext generation.

*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*

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

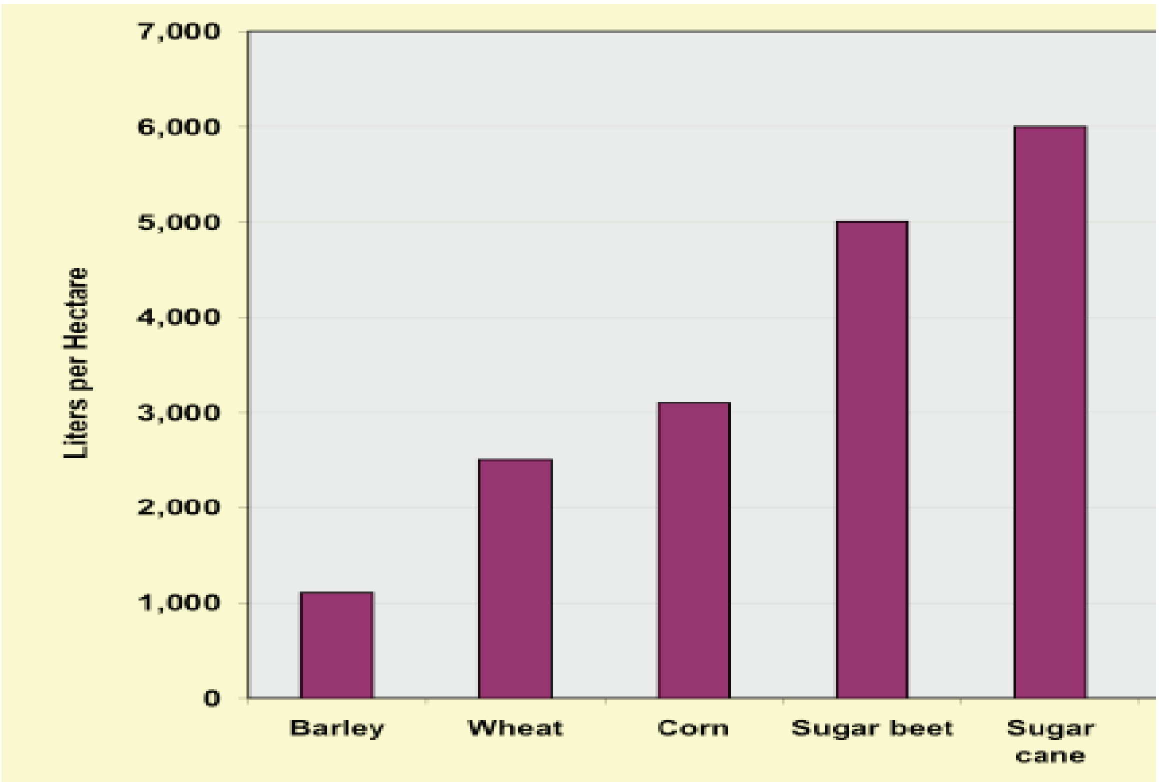



*Figure 2-2 Bio-ethanol yield from first generation feedstock*

*Source: World Watch Institute, 2006*

## 3.5. Current Status and future trends of bio-ethanol

The production and use of bio-ethanolis rising worldwide as aresult of various driving factors asdescribed in fig. 2.3 below.The production in 2000 was around20 billion liters and the quantitydoubled to around 40 billion litersin 2005 (WWI, 2006). Predictionsindicate that the production wouldreach 120 billion liters by theyear 2020 (Bio-Fuel Market, 2007 and Dufey,2006).

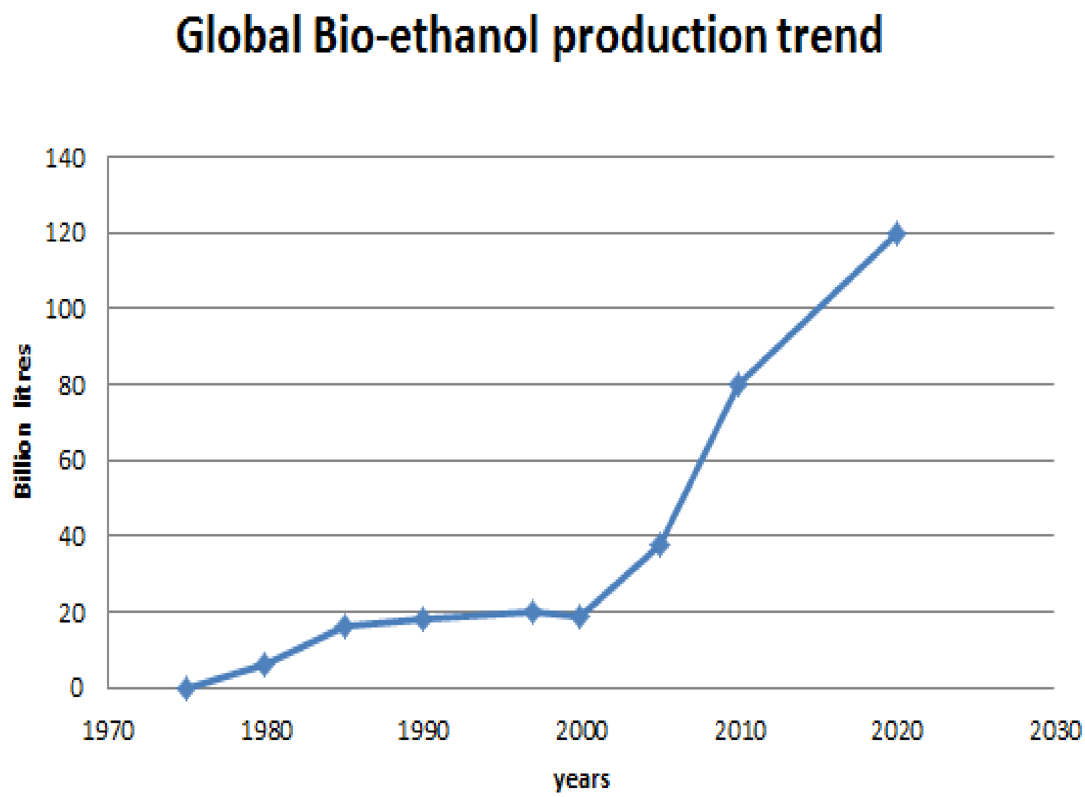



*Fig. 2.3. Current Status and future trend of bioethanol production*

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

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

## 3.6. Bio-ethanol as a Transport Fuel

Bio-ethanol and bio-ethanol/gasoline blends havea long history as alternative transportation fuels. It has been usedin Germany and France as early as 1894 by the then incipientindustry of internal combustion (IC) engines. Brazil has utilizedbio-ethanol as a transportation fuel since 1925. The use ofbio-ethanol for fuel was widespread in Europe and the UnitedStates until the early 1900s. Because it became more expensiveto produce than petroleum-based fuel, especially after WorldWar II, bio-ethanol's potential was largely ignored until the oil crisisof the 1970s.

Since the 1980s, there has been an increasedinterest in the use of bio-ethanol as an alternative transportationfuel. Countries including Brazil and the United States have longpromoted domestic bio-ethanol production. In addition to the energyrationale, bio-ethanol/gasoline blends in the United Stateswere promoted as an environmentally driven practice, initially asan octane enhancer to replace lead. Bio-ethanol also has value asoxygenate in clean-burning gasoline to reduce vehicle exhaustemissions (Dufey, 2006)

Bio-ethanol has a higher octane number (108), broader flammabilitylimits, higher flame speeds and higher heats of vaporization.These properties allow for a higher compression ratio and shorterburn time, which lead to theoretical efficiency advantages overgasoline in an IC engine. Octane number is a measure ofthe gasoline quality for prevention of early ignition, which leadsto cylinder knocking.

The fuels with higher octane numbers arepreferred in spark-ignition internal combustion engines. An oxygenatefuel such as bio-ethanol is provided a reasonable antiknockvalue (IAE, 2004).

Disadvantages of bio-ethanol include its lower energy densitythan gasoline (bio-ethanol has 66% of the energy that gasolinehas), its corrosiveness, low flame luminosity, lower vapor pressure(making cold starts difficult), miscibility with water, toxicity toecosystems, increase in exhaust emissions of acetaldehyde,and increase in vapor pressure (and evaporative emissions) whenblending with gasoline.

Bio-ethanol can be used in various methods as a transportationfuel. It can be directly used as a transportation fuel or it can beblended with gasoline. Bio-ethanol can be mixed with gasoline itis substituting for and can be burned in traditional combustion engineswith virtually no modifications needed. Bio-ethanol is mostcommonly blended with gasoline in concentrations of 10% bio-ethanolto 90% gasoline, known as E10 and nicknamed ‟gasohol”. InBrazil, bio-ethanol fuel is used pure or blended with gasoline in amixture called gasohol (24% bio-ethanol and 76% gasoline) (IAE, 2004).

Bio-ethanol can be used as a 5% blend with petrol under the EUquality standard EN 228. This blend requires no engine modificationand is covered by vehicle warranties. With engine modification,bio-ethanol can be used at higher levels, for example, E85(85% bio-ethanol).Bio-ethanol is an oxygenated fuel that contains 35% oxygen,which reduces particulate and nitrogen oxides (NOx) emissionsfrom combustion. Using bio-ethanol blended fuel for automobilescan significantly reduce petroleum use and exhaust greenhousegas emission. Adding bio-ethanol to gasoline increases theoxygen content of the fuel, improving the combustion of gasolineand reducing the exhaust emissions normally attributed to imperfectcombustion in motor vehicles, such as $C_O$ and unburnedhydrocarbons.

## 3.7. Background on Ethiopia- Main Sectors

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

## 3.8. The Agricultural Sector

Ethiopia is an agrarian economy based country. Its total area is 1,127,127 square kilometers, ofwhich 7444 square kilometers is covered by water. About 66% of the total land area isconsidered to be potentially suitable for agriculture, whereas only 15% of this land area iscultivated (ONAR 1, 2002). In terms of the area that can be developed by surface waterirrigation, it is estimated at about 3-4 million hectares, of which not more than 5% or 200,000hectares of land developed. Only about 10-15% of the total land is presently covered by forestas a result of rapid deforestation during the last 30 years (Country profile, 2005). The maincauses for this rapid deforestation are extensive farming activities, overgrazing anduncontrolled exploitation for fuel wood (ONAR 1, 2002). Of the remainder, the majority partof the land is utilized by pastoralists. Some land is dry and infertile for agriculture or any otheruse (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 arethe 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 arethe leading one. The smallholder agriculture accounts for over 95% of the cultivated land andproduction (Birehanu, 2011). Production system is largely characterized by subsistencefarming, low levels of external inputs, dependency in rainfall and limited integration into the market (Birehanu, 2011). The highlands (above 1500m above sea level) which amount to beabout 44% of the highland mass are the greatest economic asset of the country. They shelterabout 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).

## 3.9. Land ownership

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

- Land is a common property of the Nations, Nationalities and Peoples of Ethiopia and itshall not be subject to sale or to other means of exchange.
- Regions shall administer rural land in accordance with the general provision of thisproclamation and each Regional Council shall enact a law on land administration of itsregion. Experts rather recommend theownership to be decided based on the socio-economic situation of the country, preferablysubstantiated by research (EEA, 2002). However, to close any policy dialogue on the issue, thegovernment inserted the key feature of the existing land tenure system (public ownership ofland) as one of the articles of the constitution (EEA, 2002). In connection to land tenure, astudy

made by the Ethiopian Economic Policy Research Institute indicates that the nationalaverage holding is 1.02 ha per household where 37.6% of the households have less than 0.5hectare per household and 63% of the households own less than or equal to 1 hectare perhousehold. The average landholding per active farm labor force (land-labor ratio) is only 0.38hectare and about 11% of the households are landless (EEA, 2002). The land-holding sizesignificantly determines the level of farm income; and the low level of income of farmhouseholds in Ethiopia is largely a result of both the small size of holding and the low level ofproductivity (EEA, 2002).

## 3.10. **Crop production**

About 744 000 square kilometer of the land area (66% of the total land) is considered to bepotentially suitable for agricultural production while only close to 15% (112 000 squarekilometers) is actually cultivated; almost all are dependent on rainfall. Farming in Ethiopia ismostly in the hands of peasants, who cultivate individual small size plots-all land belongs tothe state. Given the suitability of the climate, Ethiopia cultivates a variety of crops. In thehighlands, grains (barley, corn, teff, and wheat) as well as pulses and oilseeds are the majorcrops; whereas at lower elevations, sorghum and sugarcane are favored.According to the 2007 Ethiopian Statistics Authority report, of the private holding cultivatedarea, which accounts 95 % of the total cultivated land, cereals occupied 8 471 920 ha, oilseedsoccupied 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 areshown in table 2-2 below.

*Table 2-2 Area under cultivation, production and yield of major crops for 2005/06 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 | 1019314 | 1352140 | 1.33 |
| 1.2 | Maize | 1694522 | 3776440 | 2.23 |
| 1.3 | Sorghum | 1464318 | 2316041 | 1.58 |
| 1.4 | Finger millet | 374072 | 484409 | 1.30 |
| 1.5 | Teff | 2404674 | 2437749 | 1.01 |
| 1.6 | Wheat | 1473917 | 2463064 | 1.67 |
| 1.7 | Oats | 32798 | 36243 | 1.10 |
| **2** | **Oil Seeds** | **741791** | | |
| 2.1 | Linseed (Flax) | 174108 | 108224 | 0.62 |
| 2.2 | Neug (sunflower) | 274720 | 147759 | 0.54 |
| 2.3 | Sesame | 211312 | 149387 | 0.71 |
| 2.4 | Ground nuts | 37126 | 51080 | 1.38 |
| 2.5 | Sunflower | 13019 | 11176 | 0.86 |
| 2.6 | Rapeseed | 30637 | 29206 | 0.95 |
| **3** | **Pulses** | **1379046** | | |
| 3.1 | Chick-peas | 200066 | 253871 | 1.27 |

| | | | | |
|---|---|---|---|---|
| 3.2 | Field peas | 221715 | 210095 | 0.95 |
| 3.3 | Haricot beans | 223357 | 222701 | 1.00 |
| 3.4 | Faba beans | 459202 | 576156 | 1.26 |
| 3.5 | Lentils | 97110 | 81049 | 0.84 |
| 3.6 | Grass pea | 124954 | 183784 | 1.47 |
| 3.7 | Soya Beans | 6352 | 5849 | 0.92 |
| 3.8 | Fenugreek | 20762 | 16398 | 0.79 |
| 3.9 | Gibto | 25526 | 28717 | 1.13 |
| **4** | **Other crop** | | | |
| 4.1 | Sugarcane | 42995 | 1374712 | 31.97 |

*Source: Central Statistics Authority of Ethiopia*

## 3.11. **Energy sector**

Ethiopia's Energy consumption is predominantly based on biomass energy sources. The lionproportion (95.1%) of the country's energy demand is met by traditional energy sources suchas 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). The most important issue inthe energy sector is the supply of household fuels, which is associated with massivedeforestation and the resultant land degradation (EEA, 2004). The increasing scarcity of fuelwood is compounded by Ethiopia's high population growth rate.The energy sector in Ethiopia remains heavily dependent on biomass despite the country'shuge potential of various energy production resources.

However, the exploitation rate is verysmall, except for biomass. Table 2-3 below indicates the resource potential and the exploitedstatus of the various energy sources.

Even though per capita energy consumption of Ethiopia is among the lowest in the world,which is 28KW, the gap between sustainable biomass supplies and demand is constantlywidening. The demand of households for forest products in many areas exceeds by far theannual incremental yield from the existing forest. As a result, the price of fuel wood has roaredto a record high that people living in cities are forced to switch to fossil fuel use. The currentprice for one metric ton of fuel wood reaches as high as Birr 200.

*Table 2-3 Energy resource potential and exploited rate in Ethiopia*

| Overview of energy status | | | |
|---|---|---|---|
| Resource | Unit | Potential | Exploited (%) |
| Hydropower | MW | >45000 | <5 |
| Solar/day | $KWh/m^2$ | 4-6 | 0 |
| Wind Speed | m/s | 3.5-8 | 0 |
| Geothermal | MW | 1070 | 0 |
| Wood | Millions 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 thehouseholds. 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 attributedto the remaining 2.3% (EEPCO, 2005). The consumption of energy is directly related to theavailability of energy source, the size of the population and the price (Meskir, 2007).

Table 2.4 shows thesector-wise percentage usage distribution of energy source type in Ethiopia.

*Table 2-4 Sector wise energy source utilization percentage distribution*

| Sector | Energy source | | |
|---|---|---|---|
| | **Biomass (%)** | **Petroleum (%)** | **Electricity (%)** |
| Households | 98.6 | 1.1 | 0.3 |
| Industry | 75.7 | 17.3 | 7 |
| Services | 94.7 | 1.3 | 4.4 |
| Transport | - | 100 | - |
| Agriculture | - | 100 | - |

*Source: Meskir, 2007*

Transport and agriculture sectors are entirely dependent on imported fossil fuel as Ethiopiadoesn’t have at the moment vehicles run by electricity and biofuel. Petroleum import quantityis shown in part 2.3.3.

With regard to electricity use, currently the country is able to generate831MW of electricity per hour from hydro dams, which accounts 98% of all electricproduction, the rest comes from fossil fuel and only about 14% of the population has accessto 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). 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.

### 3.12. **Transport sector**

The transport sector contributes only about 6% of the total GDP in Ethiopia albeit it's crucialrole in supporting agricultural development, facilitation of trade and domestic competitiveness(NMSA, 2001). Road transport, single railway, airline and ships are the conventionaltransport 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 densityis 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 widetopographical variations, extremely rugged terrain; sever climatic conditions, and a widelydispersed population (NMSA, 2001). These factors make construction of transportinfrastructure not only physically difficult but also extremely costly.

As mentioned, the road transport plays important role in the movement of goods andpassengers as compared to other modes of transport. According to the Ethiopian RoadAuthority of the Ministry of Transport and Communications, totally 354,107 vehicles foundregistered up to the year 2010 (RTA, 2011). These vehicles consume either gasoline or gas oil fuel type. Of this total number of vehicles, 178,618 are vehicles that consume petrol or gasoline.

The transport sector consumes more than 50% of the total petroleum products the country isimporting every year (MME, 2007). The volume of the fuel consumed by road transportvehicles has the greater share and currently become a challenge due to increasing quantity andprice escalation of the products. Stated below in table2-5 is the country's petroleumconsumption, excluding kerosene which is used for household cooking fuel, in quantity andvalue respectively for the last 6 years.

The share of gasoline of the total consumption declined from 9.3 % in 2005/06 to 7.7% in2009/10. This is due to the fact that vehicle importers have been inclined more to diesel drivenvehicles as a result of gasoline cost (Esayas, 2011). In terms ofquantity, gasoline showed 13.6 % increment from 2005/06 to 2009/10.

As a result of the increment and huge expenditure of money for petroleum products, thegovernment regularly adjusts the local selling price of the products including the subsidies totransfer some of the increment happening in the world market to consumers.

*Table 2-5: Petroleum import data (in quantity)*

| | Importation quantity in metric tons (MT) | | | | | |
|---|---|---|---|---|---|---|
| | Gasoline | Jet/kerosene | Diesel oil | LFO | HFO | Total |
| 2005/06 | 137193 | 370401 | 811689 | 41521 | 117198 | 1478002 |
| 2006/07 | 143743 | 402311 | 905478 | 42255 | 116429 | 1610216 |
| 2007/08 | 139093 | 482173 | 1073148 | 49692 | 138059 | 1882165 |
| 2008/09 | 150099 | 506497 | 1203567 | 36421 | 116506 | 2013089 |
| 2009/10 | 155805 | 529857 | 1237922 | 10714 | 100967 | 2035265 |
| 2010/2011 | 167340 | 551148 | 1395377 | 48478 | 117940 | 2280283 |

*Source: EPE, 2011*

*Table 2-6: Petroleum Import Data in Value*

| | Importation in value inUSD | | | | | |
|---|---|---|---|---|---|---|
| | Gasoline | Jet/kerosene | Diesel oil | LFO | HFO | Total |
| 2005/06 | 78146971 | 217222639 | 403308005 | 13996405 | 35273178 | 747947198 |
| 2006/07 | 84245805 | 246366769 | 519146279 | 14291536 | 38139482 | 902189871 |
| 2007/08 | 116129645 | 449776779 | 938033763 | 25450125 | 70654000 | 1600044312 |
| 2008/09 | 85926963 | 357984568 | 750960862 | 17939958 | 47844701 | 1260057054 |
| 2009/10 | 106316446 | 343931636 | 794090551 | 5732120 | 51626457 | 1301697210 |
| 2010/11 | 1951503816 | 3596562939 | 15702946006 | 458050391 | 1073780838 | 25893456007 |

*Source: EPE, 2011*

# CHAPTER THREE

## 4. ANALYSIS

### 4.1. Background Analysis

This part analyses the situation currently prevailing in Ethiopia on production and use of bio-ethanol.The background informationpresented in part 2 is used to address important issues on the development of bio-ethanol.Using the background information as input and the framework as guidance, thestatus, potential and challenges in the production and consumption of bio-ethanol are identified.

#### 4.1.1. Main firms in the production level of bio-ethanol

The production level of the value chain consists of feedstock production, sugar extraction andfermentation/distillation. This production stage of the value chain is dominated by the stateowned sugar factories that are engaged mainly in sugar cane plantation, sugar extraction and bio-ethanol distillation.Currently there are three sugar factories, Wonji-Shoa, Metehara and Fincha, which have beenin operation at least for decades and the fourth, Tendaho, which will be the biggest in capacityis under the project phase (Shimeles and Aklilu, 2012, January 8, personal interview). All thefactories cultivate sugarcane for extraction of sugar and they produce or intend to producebio-ethanol from the by-product obtained from the sugar extraction. Their role and currentstatus as well as their future intention are elaborated below.

### 4.1.2. Feedstock production

The three factories cultivate feedstock for the production of sugar. The feedstock used forproduction of sugar by the sugar factories is solely sugar cane. Sugar cane plant is generallygrown between the latitudes of 300 North and South mainly because it requires a warm climatecoupled with adequate natural or artificial water (Shimeles, 2011).

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

From the interviews (Shimeles, Azemera and Afework, 2011) and observation from site visitthe following information is obtained. Sugarcane cultivation in Ethiopia follows a systemsimilar to that of the Brazilian. Before planting at the first time, the soil is intensively preparedand necessary fertilizers are applied. During plantation the plants are treated with artificialfertilizers including filter cake from the bio-ethanol plant. After 12-18 months, the cane isready to be cut.

*Table 3-1: Description of Sugar Factories sugarcane plantation areas*

| S/N | Description | Name of the Sugar Factories | | | |
|---|---|---|---|---|---|
| | | Wonji-Shia | Metehara | Fincha | Tendaho |
| 1 | Distance from the capital | 110km to the east | 210km to the east | 340km 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 | 26.9.9$^0$c | 32.6$^0$c | 31$^0$c | 39.7$^0$c |
| 5 | Altitude | 1540 ma.s.l | 950m a.s.l | 1650m a.s.l | 340m 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 Corporation (ESC)*

For cutting andharvesting, it is a common practice to burn down the cane inorder to simplify manual harvesting and avoid possible attack by insects and animals with inthe 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 declinesanother cycle will start.The current status and future expansion scheme of the plantation the sugar factories are able tocultivate and envisage to cultivate respectively are summarized in table 3-2 on the next page.

*Table 3-2 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* | *50000* |
| *4* | *Sugar cane production from the expansion area (tone cane per day)* | *9400* | *5000* | *8100* | *26000* |

*Source: ESC, 2011*

The table shows the current areas cultivated and the production quantity of sugarcane fromthese areas as well as the future expansion plan both from the existing sugar factories and theproject being constructed. The cultivation is mainly done by the factories themselves on theland they are allocated. Insignificant quantity is planted by out-growers living in thesurrounding in the case of Metehara. The factory gives seeds and proper advice and later itbuys the cane the out-growers cultivated. The price is based on the sugar content the canewould deliver during extraction. Otherwise, the practice of cultivation and harvesting are doneentirely by the factories themselves by employing seasonal labourers. Since cultivation and harvesting jobs are seasonal, the factories do not employ permanentworkers for the labour works of plantation cutting and loading to trailers and hence do notretain the workers in the entire year. Cultivation is done from the beginning of December tothe end of May of the year while harvesting is done from the beginning of November to theend of May (Yersaw, 2011, Sept. 20, Personal interview).

Such classification of periods is donedue to mainly rain, which facilitates erosion if the cultivation is not covered by plants when itstarts 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 rainyseason that extends from June to September.

All factories cultivate sugar-cane by irrigation. Wonji- Shoa and Metehara sugar factoriesemploy furrow type irrigation as the topography is flat whereas Fincha, surrounded by hillylandscape, utilize sprinkler type to reduce erosion. These irrigation systems practiced by thefactories waste considerable amount of water due to poor management and low level ofawareness (Shimeles, 2011, Sept. 20, personal interview). Proper account of water lacks as towhat 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 haveto pay to the Ethiopian Water Works Authority, a government body which constructed andowns the irrigation facility (Shimeles, 2011). However, there is no explicit amount that goesonly 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 farmsdiffer, so does the type of pests on the farm. As a result, the type and quantities of pesticidesthe plantations apply differ. Generally, insecticides like Malathion and Dursban, herbicides likeGlyphosate, Velpar, Paraqat, 2-4D Amine and fungicides like Benomyl, Lysol are being usedby the farms. Urea and DAP are also the main fertilizers of the plantations (Shimeles, 2011 and Yersaw, 2011, personal interview).

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

Realizing this potential and the investment opportunities in the sector, many private investorshave shown interest and received investment license. According to the Ethiopian InvestmentOffice (Aklilu, 2011, Oct.

2, personal interview), 20 private (mainly foreign ones) investorshave been licensed to develop sugar cane cultivation with a total land area of about 400hectares. Most of these private actors are at the pre-implementation stage; only 4 of them havereceived the land they have requested. The exact status and future potential of all the privatefirms could not be fully captured as they are scattered in the different region and unable toreach them through phones. But at the current position, they don't seem influential anddominant firms in the value chain- though the interest of these private firms and theirinvolvement indicate the bright prospects of the feedstock production and of bio-ethanoldevelopment in the country.

### 4.1.3. Sugar extraction

The main firms that play a role in the sugar extraction operation today are the existing threesugar factories which are already in operation. Others are in the process of entering into thefield. 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 beconsumed for production of sugar. At the moment, no sugar cane is cultivated solely to theproduction of bio-ethanol. All sugar cane produced goes to sugar production and the byproductfrom the sugar factories, molasses, is utilized for bio-ethanol production. This isbecause sugar is a high value product in Ethiopia and still there exists a gap between locallyproduced supply and demand. The general process flow how the sugar factories convert sugarcane into sugar is shown in fig 3-1 on the next page.

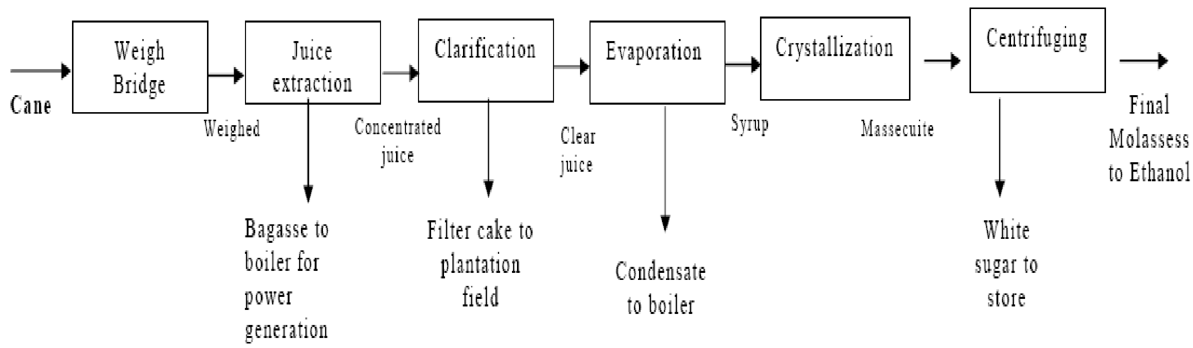



*Figure 3-1- General process flow of Sugar production in Ethiopia*

*Source: Fincha Sugar factory*

Sugar cane coming from the field is weighed first and passed to the juice extraction stagewhere separation of juice from bagasse is made. Bagasse is the fibrous residue of the cane stalkafter crushing and extraction of the juice. This bagasse goes to boiler for steam generation tobe used for the sugar factories own consumption. The steam generated is enough to cover thesugar factories thermal energy requirement. They however take additional energy from thenational grid (generated 100% from hydro) to fulfill the electricity requirement except Fincha,which is self-sufficient that require additional electricity only in the winter season formaintenance work as it doesn't have production in the winter and thus doesn't generate energyas the rain makes virtually impossible to cut and transport sugarcane.

All factories have shortterm plan to generate electricity and sell the excess power to the national grid, which was notthat attractive in the past due to low electricity rate.

Then the production process continues with clarification step wherein impurities (scums) areseparated 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 alsocontain nitrogen and a great part of proteins existing in cane juice. They havetherefore fertilizing properties and are used on the sugarcane plantation field (Muleta, Yiersawand etal, 2011, personal interview).The clear juice obtained at this stage is further concentratedby evaporation where the condensate is returned to boiler to increase thermal energyefficiency.

Then crystallization (formation of sugar crystals) followed by centrifugation(separation of sugar and molasses) complete the process. The molasses obtained at this finalstage then goes to the production of bio-ethanol. It is residual syrup from which no crystallinesucrose can be obtained following evaporation, crystallization and centrifuging of themassecuite (mixture of sugar crystal and molasses). It is a by-product of sugar manufacturingand the cheapest source of feedstock for ethanol production.

The existing three sugar factories employ the same kind of production step as depicted here-aboveand together currently produce 295,063 tons of sugar annually (Shimeles, 2011, Sept. 30, Personal interview). The new project which has been launched already with an investmentcapital of $600 million is expected to boost the production by 600,000 tonnes, which isexpected to start in 2013 (ESC, 2011). With the expansion work being undertaken by theother three factories together, the four state owned factories alone are expected to produce 1,560,981 tons of sugar by the year 2013/14 (ESC, 2011).

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

### 4.1.4. Fermentation and distillation processes of bio-ethanol

There are only two plants, Fincha Sugar Factory and Metehara Sugar Factory, engaged in fermentation and distillation for theproduction of bio-ethanol to date in Ethiopia. The other state owned factories are in theprocess of installing an ethanol production unit from molasses following the governmentdirection 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 andbe a means to convert into useful products easily.

The Fincha bio-ethanol plant and Metehara are the only plants now producing bio-ethanol, both technical(hydrous) and anhydrous which can be used for power alcohol. The current annual productioncapacity of the two factories is 55,962$m^3$ liters per year (Bekele, 2011, Oct. 8, personalinterview).

Wonji-Shoa sugar factory has completed the feasibility study and is now in the bid preparationphase to invite companies to participate in the supply of equipment and erection as well ascommissioning of a bio-ethanol plant (ESC, 2011). It isexpected as the envisaged plant would start producing bio-ethanol around end the last quarter of 2012.

Likewise, Tendaho sugar Factory project (the biggest in capacity) has awarded a contract topossess a turnkey plant comprised of sugar extraction and bio-ethanol producing plant to anIndian company. The project is in the civil construction and equipment manufacturing phaseand the plants are expected to be operational in 2012 (Bekele and Shimeles, 2011).

The potential ethanol productionfrom the 700,000 hectares of suitable irrigable land for sugar cane plantation is estimated as 1billion liters. The assumptions taken to arrive to this figure are: (1) total net irrigable areasidentified 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) Ethanolproduction per ton of molasses as 250 liters (MME, 2007).

In the next 5 years till 2015, the state owned four sugar factories have planned to reach aproduction volume of 181 million litres ( ESC, 2011).

Though additional quantities are also expected from privatefirms, reaching those who requested an investment license to enter into the sector was notpossible. But it can be assumed as the quantity will be more than the number shown if notreached 1 billion in the short and medium term.

The existing bio-ethanol production plant employs a combination of biological and physicalprocesses in the production. It is produced by fermentation of sugars with yeast and thenconcentrated to fuel grade by distillation. The flow chart, shown in Fig 3-2 below, is aschematic representation of the principal steps in fuel bio-ethanol production in Ethiopia.

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

The first process step in fuel bio-ethanol production is molasses treatment. This stageenvisages a reduction in the level of impurities, notably Calcium salts to facilitate the nextoperations, i.e., fermentation and distillation. This guarantees better performance with regardto distillation where the reduction in scaling will be significant, thus permitting better yieldsand lower steam consumption (Azemera, 2011, Oct 20, personal interview).

Molasses at a concentration of 860 Brix30 comes from the sugar factory, undergoes heating to atemperature of 95-100 0c and dilution to 500 Brix using process water and steam condensate inorder to reduce molasses viscosity. While heating, acidification is undertaken using sulphuricacid 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 20-220 Brixand cooled to a temperature of 55-600c, which is now called as *Mash*31. This Mash is now freeof large part of the impurities and suitable for obtaining a good fermentation.

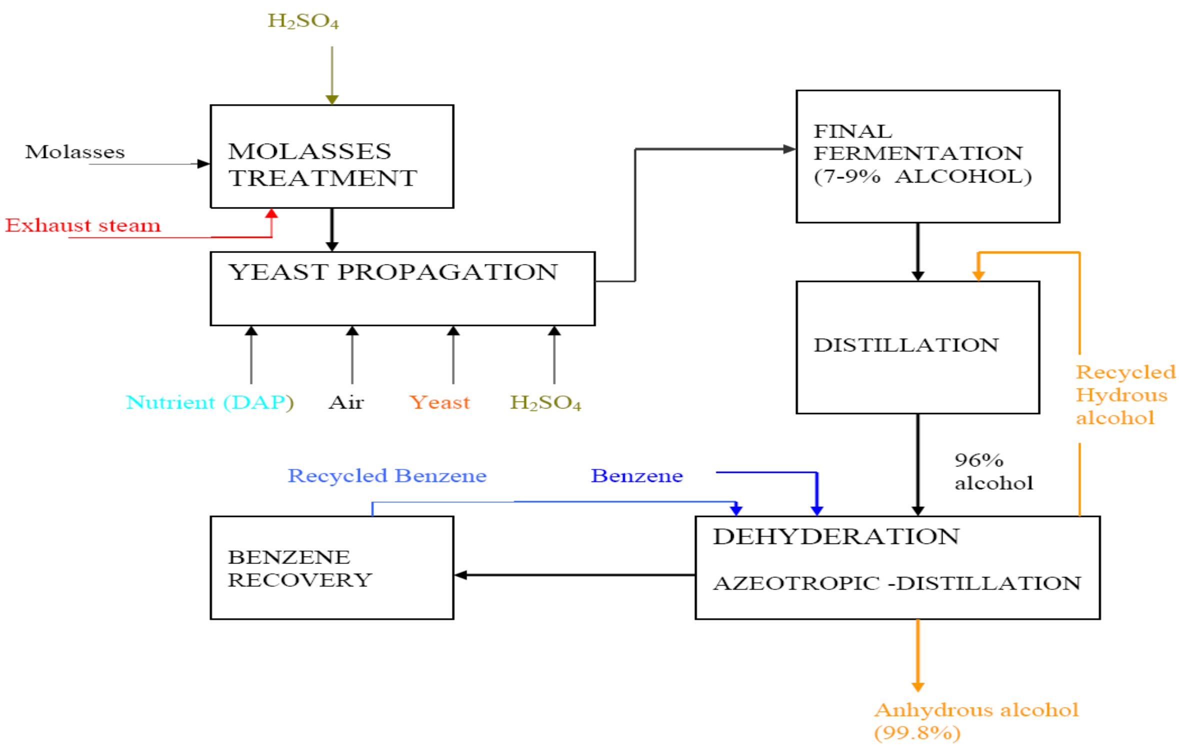



*Figure 3-2 Bio-ethanol production process*

*Source: From Site visit at Fincha Sugar Factory, 2011*

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

The third step is distillation, in which the fermented beer is distilled to draw off ethanol. Byconventional distillation processes ethanol can be concentrated to about 96% ethanol byvolume, which is called hydrous ethanol or technical ethanol that is utilized bypharmaceuticals, beverage industries and others. The anhydrous bio-ethanol or bio-ethanol tobe used for fuel with gasoline blend should be concentrated and further distillation cannotincrease this percentage, as the composition form a zoetrope, or a constant boiling. Theremaining 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 stepso that anhydrous bio-ethanol is obtained. Benzene is chosen due to its less cost compared toother solvents and its consumption is about 1-2 liter per 1000 liter of bio-ethanol. Since thebio-ethanol that has been produced in the past was the hydrous type, benzene consumptionwas almost none.

The bio-ethanol production of the past shows as the plant was operating at low capacity. Asthere was no market for anhydrous bio-ethanol both at local and export level, the entireproduction has been the hydrous type. This figure together with background data is detailed intable 4-3 below. As the conversion of molasses is estimated as 250 liters of bio-ethanol couldbe obtained from a ton of molasses, there has been excess of it in the past, which the factorywas selling for beverage industries and for private cattle farmers to be used as feeds (Azemera,2011, Oct. 20 personal interview).

## 4.2. Analysis -status and potential

### 4.2.1. Supply side

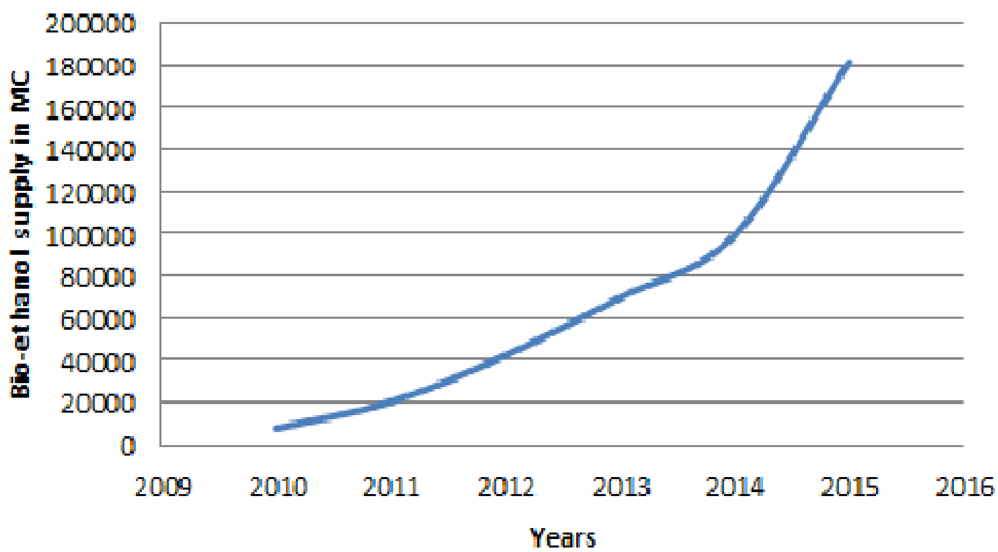
The key factor for determining the economic benefits for Ethiopia forproduction of bio-ethanol from molasses is the price of molasses for substitute use orproducts. Ethiopia generates molasses from the sugar factories in significant amount and thisquantity is in excess for the local requirement for cattle feed and feedstock for beveragealcohol production. Even the selling price is not attractive; as a result considerable amount ofmolasses is spoiled during storage or sold at dumping cost (Azemera, 2011). Thus, from supply side production of bio-ethanol for transportfuel use is an opportunity for utilizing the excess molasses. For indication, the following tableshows the quantity of molasses and bio-ethanol (both hydrous and anhydrous) expected to beproduced in the respective years. It is important to note here that 1 ton of molasses yieldabout 250 litres of bio-ethanol.

*Table 3-6: Molasses and bio-ethanol production trend*

| Description | Years | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 20112/13 | 2013/14 | 2014/15 |
| Molasses (tons) | 107,460 | 165,963 | 256,534 | 373,850 | 466,852 | 542,559 | 945,578 |
| Bio-ethanol ($m^3$) | 8,482 | 20690 | 55,962 | 83,452 | 112,815 | 132,886 | 181,604 |

*Source: ESC, 2011*

**Fig. 3-1: Planned bio-ethanol production**



### 4.2.2. Demand side

Currently generally the energy demand of Ethiopia is very low compared to even other leastdeveloped countries, consumption stands at 28KWH per capita. This is mainly due to limitedaccess of clean energy by the majority of the population living in the rural areas andunderdevelopment of industry as well as infrastructure. However, in order to reduce thepoverty level and register steady growth, undoubtedly the demand will increase significantly inthe upcoming years. With the expansion of existing and new roads and the on average annual 10%vehicle importation increment (Bazezew, 2011,July 6, personal interview), thedemand for transport fuel will also rise. The trend in gasoline requirement as projected by theEPE is shown in the table below.

*Table 3-7: Gasoline Consumption trend*

| Description | Years | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 20112/13 | 2013/14 | 2014/15 |
| Gasoline ($M^3$) | 220581 | 231610 | 243190 | 255350 | 268118 | 281524 | 295268 |
| Bio-ethanol demand ($M^3$) | 11029 | 11,580 | 11,836 | 25,801 | 28,123 | 30,654 | 33,413 |

*Source: EPE, 2011*

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 ensuresteady supply to facilitate its growth.

In other words, Ethiopia needs to spend substantialamount of foreign currency to fulfill its gasoline requirement as the trading of petroleumproducts requires USD or Euro. But this foreign currency payment for petroleum productshas already become a heavy burden to the economy of the country, recent report states thataround 80% of the foreign earning is consumed by petroleum product imports (Reporter,2011).

*Table 3-8: Kerosene consumption trend*

| Description | Years | | | | | |
|---|---|---|---|---|---|---|
| | 2010/2011 | 2011/2012 | 2012/2013 | 2013/2014 | 2014/2015 | 2015/2016 |
| Kerosene in $M^3$Qty | 295,540 | 322,139 | 351,131 | 382,732 | 417,178 | 454,725 |
| Kerosene import cost in billions of Birr | 3.6 | 4.37 | 4.78 | 5.21 | 5.681 | 5.677 |
| Total cost of petroleum import in billions of Birr | 25.89 | 28.14 | 30.68 | 33.46 | 36.47 | 39.75 |
| Kerosene import cost %age | 13.9% | 15.5% | 15.58% | 15.57% | 15.57% | 14.26% |

Source: EPE, 2011

Thus, with the increasing energy demand, the option to have local source of renewableenergy is much attractive.

From the above table, we can see that the cost of kerosene import is on average 15% of the total cost of petroleum import. If Ethiopia starts using bio-ethanol for household energy consumption, there is a potential of replacing kerosene with gasoline which would result in contributing for the saving of about 15% of total cost of foreign currency being used to import petroleum products.

### 3.2.3 Combined View of Bio-ethanol Supply and Demand

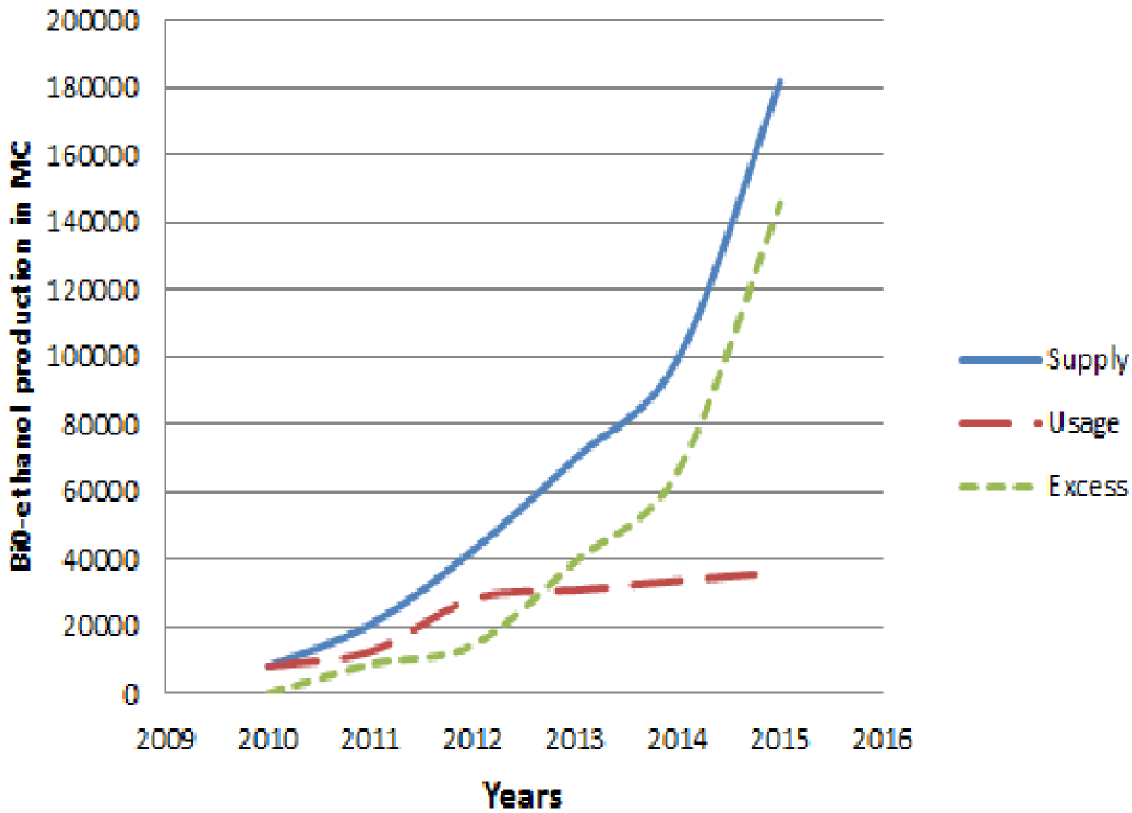
*Table 3-9: Supply and demand of bio-ethanol in $M^3$*

| Description | Year | | | | | |
|---|---|---|---|---|---|---|
| | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 | 2014/15 |
| Public owned | 8482 | 20,690 | 55962 | 83452 | 112,815 | 111,204 |
| Private factories | - | - | - | - | - | 17,600 |
| New projects | - | - | - | - | - | 52,800 |
| Total Supply | 8482 | 20690 | 55962 | 83452 | 112815 | 181,604 |
| Planned Gasoline sales | - | 236,706 | 258,009 | 281,231 | 306,541 | 334,130 |
| Bio-ethanol demand | - | 11,836 | 25,801 | 28,123 | 30,654 | 33,413 |
| Excess Supply (demand) | | 8,664 | 30,161 | 55,329 | 82,161 | 148,191 |

*Source: ESC, 2011*

As postulated in fig. 3-2 below, up to the end of the fiscal year 2014/2015, the total bio-ethanol production and supply will reach 181.6 million liters. This volume of production and supply will be by far over and above the volume of demand for transport fuel ethanol requirement.

Fig. 3-4: Excess supply of bio-ethanol




### 3.2.4 Composition of Gasoline Vehicles

The strategic plan for bio-ethanol development stated that the current proportion of the blend (10% ethanol and 90% gasoline) will gradually increase up to 25% ethanol and 75% gasoline up to 2015. In addition, the strategy indicated that the excess supply of bio-ethanol would be used for household energy consumption in replacement of kerosene (Ibid).

*Table 3-10: Composition of Gasoline Vehicles by year of manufacture*

| **Year of Manufacture** | **Number of Gasoline Vehicles** | **Number of Diesel Vehicles** | **Total No. of Vehicles in Ethiopia** |
|---|---|---|---|
| Upto 1990 | 48191 | N/A | N/A |
| 1991-2000 | 62606 | N/A | N/A |
| 2001-2010 | 67821 | N/A | N/A |
| **Total** | **178,618** | **175,489** | **354,107** |

*Source: TAE, 2011*

However, given the current status of the composition (shown in table 3-9) of gasoline vehicles that consume this blend; technically the proportion of ethanol to gasoline cannot go beyond 10% (Manaye, July 13, 2011 personal interview). This is because of the fact that if the percentage of bio-ethanol is to increase beyond 10%, 110,797 gasoline vehicles,which are above 62% of the total gasoline vehicles, should go first through engine modification to make them compatible for a blend above 10%.

Though not that much extensive compared to vehicles made in the years 2000 and before, the recent model vehicles also require some sort of change to adopt them to a blend of bio-ethanol which is more than 10%.

However, the idea of going through engine modification is not yet in the plan of the Transport Authority of Ethiopia. The non-existence of plan to make gasoline vehicles compatible with a blend of above 10% would defeat the strategic plan set-out by the National Biofuel Coordinating Unit to gradually increase the blend up to 25% up to the end of the 5 year GTP period.

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).In addition, IEA (International Energy Agency) restricted that beyond 10% bio-ethanol content on gasoline cannot be used in all models of gasoline vehicles across the board (IEA, 2009). On the other hand, although starting from the fiscal year just passed (2010/2011) the production of bio-ethanol is in excess of the demand and the efforts to use bio-ethanol for household energy consumption is not likely to materialize in the near future.

This clearly shows thatgiven the excess production and supply of bio-ethanol, it will be a challenge for the sugar industry in particular and of the economy of the country in general. There should be alternative ways to efficiently consume the excess supply for other uses other than transport fuel.

### 3.2.5 Bio-ethanol and Vehicle Compatibility

It has been stated that 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, 2009). 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, 2009). 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 maydegrade 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…'*

# CHAPTER FOUR

## 4. CONCLUSION AND RECOMMENDATION

### 4.1. Conclusion

Bio-ethanol is a fuel derived from biomass sources of feedstock;typically plants such as wheat, sugar beet, corn, straw, and wood.Bio-ethanol is currently made by large-scale yeast fermentationof sugars that are extracted or prepared from crops followed byseparation of the bio-ethanol by distillation. One major problemwith bio-ethanol production is the availability of raw materialsfor the production.

The availability of feedstocks for bio-ethanolcan vary considerably from season to season and depend on geographiclocations. The price of the raw materials is also highly volatile, which can highly affect the production costs of the bioethanol. However, in Ethiopia there is no problem with regards to feedstock for the production of bio-ethanol in the foreseeable future as molasses is being secured in the required quantity from the sugar factories.

Bio-fuels are being promoted in the transportation sector. Manyresearch programs recently focus on the development of conceptssuch as renewable resources, sustainable development, green energy,eco-friendly process, etc., in the transportation sector.Increasing the use of bio-fuels for energy generation purposes isof particular interest nowadays because they allow mitigation ofgreenhouse gases, provide means of energy independence andmay even offer new employment possibilities.

Bio-ethanol is byfar the most widely used bio-fuel for transportation worldwide.It will continue to be developed as a transport fuel produced intropical latitudes and traded internationally, for use primarily asa gasoline additive.

From the literature review in chapter 2 and the analysis in chapter 3, we have seen that global production of bio-ethanol increased from 17.25 billion litersin 2000 to over 46 billion liters in 2007. With all of the newgovernment programs in America, Asia, and Europe in place, totalglobal fuel bio-ethanol demand could grow to exceed 125 billionliters by 2020. In 2007, bio-ethanol production represented about4% of the 1300 billion liters of gasoline consumed globally.

In Ethiopia, bio-ethanol is being produced and used for transport fuel with gasoline at blending mandate of 10%. The country has the potential to increase its production up to 1billion liters of bio-ethanol in the medium term (5-10years). It has been identified and portrayed that the production trend of bio-ethanol in Ethiopia has also been increasing. By end of 2015, total supply will hit a record height of 181million. This would be over and above the projected demand considered for transport fuel.

The country's import requirement of petroleum products is consuming the huge percentage of its foreign currency reserve. Hence substituting the demand for fossil fuel by locally produced fuels such as bio-ethanol and bio-diesel is paramount importance for the country's economic use of scarce energy resources.

In view of the above summary, the following key findings would answer the questions and address the objectives that have been laid down in this project work in chapter one.

### 4.1.1. Findings

This part summarizes the key findings of the research by responding to the research questions laid out in chapter 1 of this project work.

*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 endeavor 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 produceBio-ethanol from molasses, the by-product obtained from the sugar extraction.

It has been pointed out that Ethiopia has 700,000 ha of land suitable for sugarcane cultivation which avails the capacity to produce over 1 billion liters of bio-ethanol.In Ethiopia- the current production capacity stands at about 55,962 million litres. The other factories are in the process of installing ethanol production units from molasses. In the next 5 years till 2016, they would have the capacity to reach a production volume of 181.6 million litres.

The bio-ethanol production and the requirements for blending with gasoline have been demonstrated and the excess supply has been identified in chapter three.

*How the composition of gasoline vehicles is and what policy measures are required that can help to increase the blend of ethanol with gasoline above 10%?*

Blending with gasoline was started in May 2008 with 5%, and subsequently increased to 10% in March 2011. As the production increases, the intention is to increase the percentage. However, given the current composition of gasoline vehicles, the blend cannot be increased above 10% due to technical restrictions. For the blend to increase above 10%, more than 60% of the vehicles should go through engine modification to make them compatible. It was confirmed that the Transport Authority of Ethiopia has no plan for engine modification in the near future. On the other hand there is no restriction for vehicle import from the point of view of fuel conservation and bio-ethanol usage. There is no incentive either to stimulate the import of new model vehicles.

*What are other possible uses of the bio-ethanol apart from transport fuel?*

Given the Ethiopian context, the other possible use of bio-ethanol is for household energy consumption. The country is using kerosene for household energy consumptionespecially in the urban areas. This product is supplied 100% from outside through import constituting 15% of the total petroleum import. If the government and other stakeholders expedite the provision for the use of the already excess bio-ethanol supply for household energy consumption, the country would be able to save a huge amount of foreign currency enabling it to reduce the cost of petroleum import at least by 15% in addition to the 10% saving from gasoline import that is being substituted for gasoline.

The usage of bio-ethanol for household consumption has already been envisaged in the strategic plan of bio-fuel development of the country. What it lacks is the identification of appropriate institutional framework and enacting supportive polices.

### 4.1.2. Recommendations

In Chapter three parts3.1 and 3.2 as well as under the key finding of this project work an attempt was made to answer the research questions and address the objectives. Thisbeing the main task, the author would also like to supplement some issues that are ofsignificance to the case under study.

Dominant state interventions at the beginning of the development stage of bio-ethanol are important. What needs to be learnt here is that the dominancy should not continue forever. It should be for a short period of time since such activities of the 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.

Provision of tax incentives for vehicle importers to import vehicles that can use higher percentages of bio-ethanol blendswill enable higher consumption of bio-ethanol. In addition, there should be a thorough study to come up with a strategic plan that would help to modify the engines of the existing old vehicles in a cost effective means so that they canutilize higher blends of bio-ethanol.

The final and the key recommendation of this project work is for the government to intervene and promote the use of bio-ethanol for household energy consumption in replacement of kerosene by establishing appropriate institutional frameworks and enacting supportive policies. Overarching policies needs to be enacted based on thorough studies.

### 4.1.3. Future Research

In the opinion of the author, there are a number of areas this study could not investigatesufficiently 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. Asthis involves complex issues to consider, this research could not come up with clear cutanswer. Is the available land suitable to cultivating crop? Can the surface water resource reallycultivate 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 thesekinds need to be explored sufficiently to determine the impact of bio-ethanol development onfood security.

The second is the energy balance and the net greenhouse gas emissions of bio-ethanol. Therehas 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 netgreenhouse gas emissions. This is an area of research that requires immediate attention toensure 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 inmalarias area and people working there are prone to malaria. In addition sugarcane burning isthe normal practice during sugarcane harvest. Such working conditions would not be freefrom incidents that threaten the health of the workers. Due to the absence of prior studies onthe issue, more information could not be provided here. Thus, the author finds the topic animportant sustainability aspect from a social point of view.

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# Appendix I

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